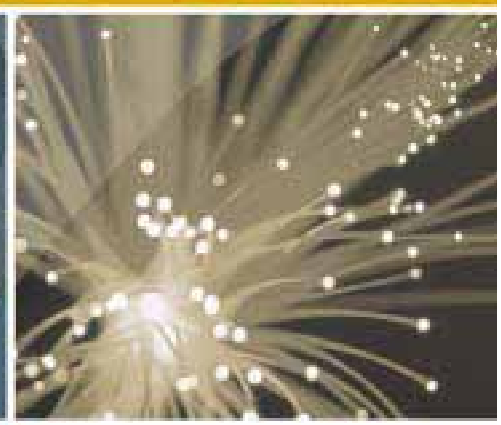
GROWTH & INNOVATION



Perspectives on
the interaction
between
economic growth,
science, technology
and human capital

NATIONAL ADVISORY COUNCIL ON INNOVATION

NATIONAL SCIENCE
AND TECHNOLOGY
FORUM

Growth and Innovation:

Perspective on the interaction between economic growth, science, technology and human capital

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Chapter 1

Growth, Employment and Human Development: an overview of the issues

1.0 Introduction

South Africa's democratic transition now lies close to a decade in the past. The transition carried with it much by way of hopes in terms of a greater access by its population not only to an improved rights environment. It was envisaged that the political self-realization of all South African citizens would bring with it access to improved economic well-being also. Employment as well as rising per-capita income are obvious indicators of progressive development for the population of a country. But the strong emphasis placed on a strong rights-culture in the negotiated transition leading to the first democratic elections of 1994, and the reflection of these values in the constitution accepted in 1996, makes it clear that the concern in South Africa lies not merely with the immediate and narrowly "economic" indicators of development, but that broader "human development" indicators of progress featured prominently in the transition South Africa embarked upon.

For these reasons South Africa constitutes an important case study in at least two senses. In the first South Africa is important to anybody interested in either the processes that govern democratic transitions, and whether such transitions lead to broader transformations of well-being also. But South Africa also constitutes a central case of an instance in which the *extent* to which "good things go together" across a broad range of developmental indicators beyond the narrowly economic.

Given the elapse of almost a decade since the political transition, it is perhaps time to take stock. In this document we will do so by reference to the growth performance of South Africa, as well as developments in its labour markets in terms of employment opportunities created. But we will also attempt to consider the wider dimension of the human development indicators that may give a more comprehensive view of the developmental successes and failures of the South African economy and society.

In developing such an assessment, it will be important to take cognizance of the fact that the new South Africa was not born of a vacuum in 1994. South Africa in 1994 carried with it the baggage of its prior developmental strategies and the structural characteristics this provided it with. That the prior developmental strategy of apartheid was fundamentally flawed and damaging to long-term economic development as been amply documented and established by now, and thus requires little by way of emphasis.[1] But a legacy of four decades of seriously misguided developmental strategy does not dissipate overnight. Putting South Africa onto a new and better growth path will take time, no matter how good the new policy initiatives may be. Understanding the growth trajectory that South Africa finds itself on will have to pay attention to longer-term trends in the key variables of interest.

In similar vein, the South African economy does not exist in isolation of the rest of the world. Trade linkages, international financial, physical and human capital flows, the exchange of information and the dissemination of technological advance all mean that our economy and society at large is in constant interplay with other economies and societies. Ignoring such forces would be to leave aside both significant enabling forces for development in the domestic context, as well as significant constraints on the policy options that are feasible for the South African economy.

This study therefore hopes to provide an understanding of the wider context within which the South African economy finds itself in its developmental path. In doing so we will consider both international trends in crucial variables, as well as the longer term historical context within which South African development has to be understood. Moreover, in developing our argument, we will consider key lessons that we can heed from the experiences of other countries around the world – countries chosen both for the sake of their similarity to the South African context, as well as for their difference.

1.1 A Brief Initial Overview

In order to assess where South Africa currently finds itself, we consider three fundamental indicators of both its rate of development as well as the level of development it has attained. The first indicator is given by the growth rate of output in the South African economy. The second is concerned with the level of employment generated in South Africa's labour markets. The third comprises of a range of indicators that give an indication of well-being in a broader sense than is captured by narrow economic measures such as output and employment levels.

The objective here is merely to provide a brief general overview of the performance of the South African economy in each of these dimensions. We will return to examine each point in greater detail in subsequent discussion.

At first sight it does not appear as if South Africa's performance in terms of these three key criteria contains much to be sanguine about. Or more positively, that much remains to be achieved.

This is evident from a brief consideration of some descriptive data.

[1] See for example the discussion in Moll (1992).

1.1.1 The Growth Performance

South Africa's growth performance has been on a steady downward trend since the early 1970's. This downward trend is present both when we consider the growth rate in real Gross Domestic Product (GDP), as well as when we consider the growth rate in real per capita GDP[2] – see **Figure 1.1**. What is alarming about the evidence of **Figure 1.1** is less the declining trend in the two growth rates depicted. Evidence of a declining growth rate in output is available for a number of countries, and was central to the debate surrounding the long term economic development of the USA for the last twenty years (until the upsurge in US growth during the course of the 1990's). Instead, what is alarming about the South African evidence is the *extent* of the decline in the two growth rates in GDP. By the 1990's the growth rates were frequently negative rather than positive, meaning that South Africa was producing less each year either in absolute terms, or on average per citizen of the country. Note further that the growth rate of real per capita GDP lies consistently below that of the level of real GDP, with average real resources available per individual resident of the country growing at an even slower rate than the absolute level of real GDP, and with the 1990's subject to a consistent decline.

The evidence on growth in real GDP is thus not reassuring. But the evidence must also be viewed in context. The declining growth performance of the South African economy mirrors a slow down of growth in the rest of the world [3]– and certainly the evidence is of a long term structural decline in growth rather than a sudden poor performance during the course of the 1990's.

On the other hand, middle income countries as a whole grew at 2.7% per annum on average over the 1980-90 period, and at 3.9% per annum on average over the 1990-98 period . In the case of East Asia the acceleration was from 8.0 to 8.1% per annum over the same period. Thus, while South Africa ranks as a middle income country, its performance while not out of line with the performance of the *world* economy, is out of line with the performance of its peers. The suggestion is that South Africa has missed out on important growth opportunities. Opportunities that countries with similar per capita levels of output to South Africa have been able to grasp, but that have passed South Africa by. In the light of this evidence, the South African experience of slow down is more ominous and anomalous for a country of its level of development. Certainly it raises the question of why South Africa has not done better than it has.

Two further factors might give us reason to pause before accepting the evidence we have seen at face value. The first is that in the mid-1990's **Figure 1.1** does show evidence of a recovery in growth performance. While the 1970 – 94 period may have been bad for growth, perhaps the democratic transition may be seen as a stimulus for growth also. The second is that one of the reasons that has been advanced for the sharp increase in the growth performance of the US economy is that GDP *measurement* has been improved in order to take better account of quality improvements in output in the economy, especially

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[2] Measured as the ratio of real GDP to population.

[3] The growth rate of real GDP in the world as a whole declined from 3.2% on average over the 1980-90 period, to 2.4% over the 1990-98 period. See World Development Report. (2000).

as concerns the contribution of information technology to production methods. The question that then arises is whether in the South African case a similar impact might not become evident if such revised GDP figures were to be considered.

The South African Reserve Bank (SARB) has made some attempts to correct its measures of GDP in order to bring the measure in line with revised international best practice. In **Figure 1.2** we report both the "old" and the "new" measure of nominal GDP – and it is evident that the revision of the GDP figures has indeed had an impact –though note that the revision has only been backdated to the early 1990's.

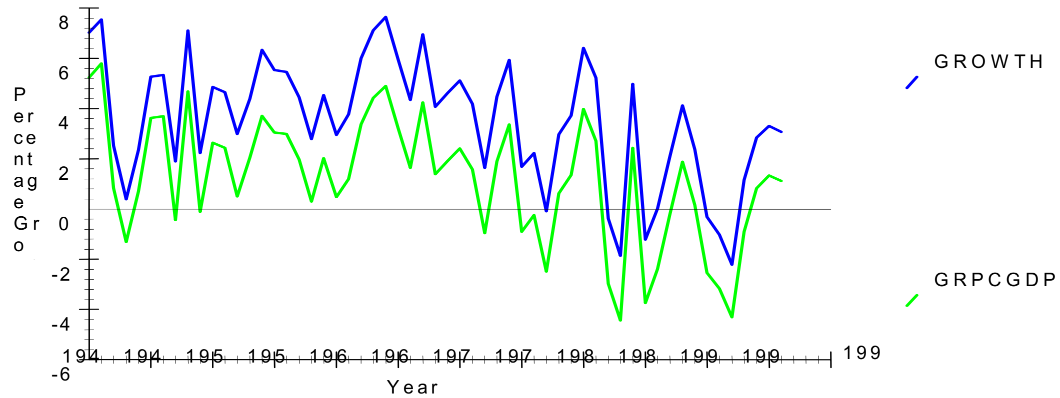

Figure 1.1: Growth Rates in Real Gross Domestic Product (GROWTH) and Per-Capita Real Gross Domestic Product (GRPCGDP)

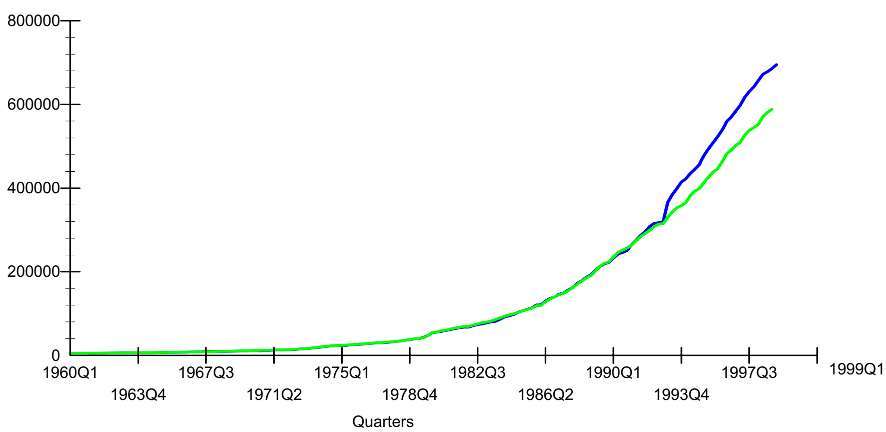

Figure 1.2: Nominal “old” (GDP) and “new” (GDP2) GDP measures.

Figure 1.3: Growth rate in real GDP over the full 1990’s – and in terms of both “old” (GROWTH1) and “new” (GROWTH2) GDP measures.

Unfortunately, what appears to hold promise for the level of GDP, does not translate into an improved growth performance of real GDP. **Figure 1.3** reports the growth rate in real GDP in terms of both the "old" and "new" measurements. Two features of the evidence stand out. The recovery in South Africa's growth rate did not prove to be sustainable, and after better performances during the mid 1990's, the growth rate has returned to the poor levels it reached at the beginning of the decade.[4] Rebasing the measurement of GDP in South Africa, while changing the absolute level of GDP reported, does not provide an improved picture of the growth performance of the economy. In this the experience of SA appears to be similar to countries such as the UK, rather than the experience of the USA.

The picture that emerges from the growth in output of the economy is thus not reassuring. What is more, the evidence suggests that the poor growth performance is of a long-standing structural nature rather than a sudden feature of the 1990's. It appears as if the evidence points to the long-term developmental strategy that South Africa had pursued in previous decades is the culprit for the poor growth performance of the economy. Unfortunately, the implication of this is likely to be that turning South Africa's growth performance around is likely to require fundamental and probably painful structural reforms of the economy.[5]

1.1.2. The Labour Market

In terms of employment in the economy, the evidence is both more reassuring, and more deeply disturbing than the evidence on economic growth. Consider employment in the formal sector of the South African economy, reported over the 1970-97 period in **Figure 1.4.**

What is evident in terms of aggregate employment, is that formal sector employment continued to expand through the 1970's and 1980's, despite the declining growth performance of the economy. But equally, what emerges is that the continued expansion of the labour market did not prove to be sustainable in the face of the ever decreasing growth in output, and finally, beginning in the early 1990's we have witnessed a very dramatic fall in the level of formal employment in the South African economy. Note that here we are not witnessing a fall in a growth rate, as in the case of output above. If it had merely been the growth rate of employment that had declined, we might still have experienced positive growth, and thus continued expansion of employment opportunities in the economy. Instead, in South Africa we are witnessing a contraction in the absolute level of employment in the economy.

What also emerges from the evidence of Figure 1.4 is that just as the growth rate in output in the economy as a whole has been on a long term downward trend, so the growth

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[4] One imponderable here is whether this will prove an aberration due to the impact of the East Asian crisis of 1997-8.

[5] Arguably these reforms are already under way – but have not yet been able to have their full impact. See for instance the GEAR policy intervention of 1996, which has substantially stabilized government finances.

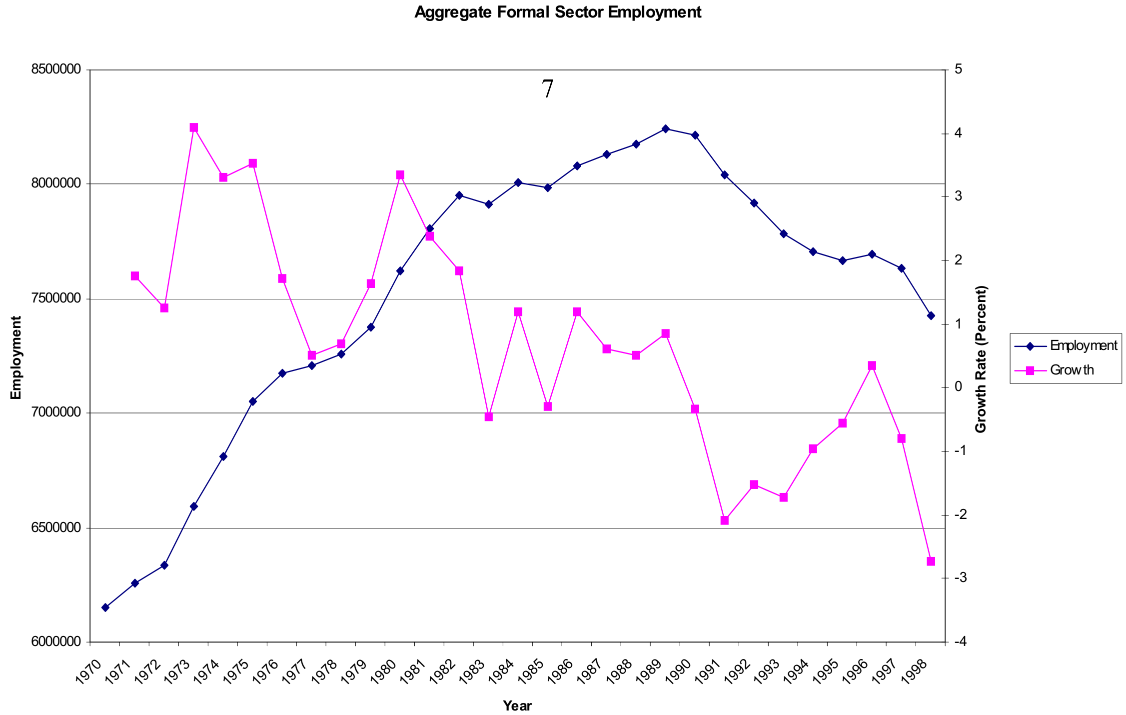

Figure 1.4: Total formal sector employment in South Africa, 1970-98: Growth in Total Formal Sector Employment in South Africa 1970-98

rate in employment has trended down. In both output and employment creation therefore the evidence suggests a structural constraint in the South African economy.

What is more, this poor performance in job creation during the course of the 1990's is almost universal in the South African economy if considered in terms of the employment growth of the principal sectors in the economy. Agriculture, Forestry & Fishing, Mining, and to a somewhat lesser extent Manufacturing and Services all show falling employment levels during the course of the 1990's. In the case of the Mining sector, the fall is particularly dramatic.[6] Only an ever expanding government sector has maintained a countervailing trend. This evidence is summarised in **Table 1.1**, which confirms the negative average growth rates in all but the government sector during the course of the 1990's. More detailed evidence of employment levels by economic sector is contained in **Figure 1.5.**

That the entire private sector has been forced to shed labour over the past ten years, has to raise serious concerns about the health of South Africa's labour markets. Much as for the growth performance of the South African economy, therefore, serious questions face us concerning the *reasons* for poor employment prospects of South Africa's work force. This is particularly so since *all* sectors that have faced competitive market pressures in any degree have shed labour during the 1990's. The implication must be that a serious and *general* structural problem is impacting on the performance of the labour market, preventing employment creation from taking place.

[6] See also the discussion in Fedderke & Pirouz (2000) for a more detailed analysis of the mining sector.

Table 1.1: Average annual growth rates in formal employment by major economic sector of the South African economy

	1970's	1980's	1990's
AFF	-0.46	-1.29	-1.00
Mining	1.35	0.89	-6.37
Manuf	2.67	1.33	-1.20
Service	4.37	1.54	-0.84
Govt	5.87	3.47	0.41
Total	2.05	1.12	-1.15

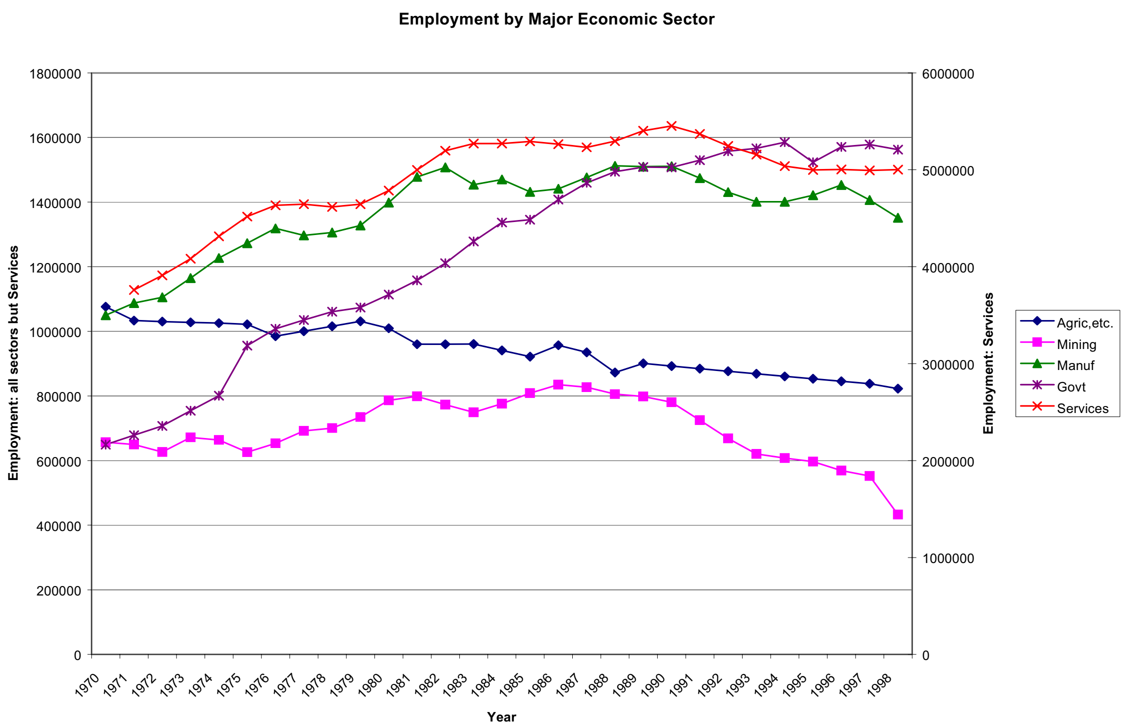

Figure 1.5: Formal employment by major economic sector

1.1.3 The Quality of Life of South African Citizens.

Finally, we consider South Africa's performance in terms of indicators of human development in wider terms than provided by simple output and employment dimensions.

The concern here is with indicators of the "quality of life" beyond that measurable in terms of income and employment. Of course "quality of life" embodies many factors, many of which may be intensely subjective, culturally coloured, perhaps very poorly accessible to measurement in such a manner as to allow for objective comparison over time and across countries.

Nevertheless, we consider a few indicators we believe to make a fundamental difference to the ability of human beings to realize the fullest possible self-actualization in whatever terms they may consider appropriate. They can perhaps be thought of as enabling conditions for "quality of life", if not as sufficient (or a guarantee) for its full realization. These indicators include:

- A measure of child mortality before 5 years of age, per 1000 population, measured in 1980 and 1997. The intention here is to obtain some indication of the level of health of the population, on the presumption that health is a significant determinant of the well-being of individuals.
- A measure of the proportion of the adult population, male and female, who are illiterate. The presumption here is that literacy is one of the crucial means human beings have at their disposal to engage in self-betterment. The latter should be understood not only in terms of gaining improved access to information about life-enhancing opportunities in work-related fields. Of course these feature. But improved literacy widens the opportunities humans have both in terms of their own self-expression and in terms of accessing and communicating with the self-expression of others. See Sen (1999).
- A measure of the degree of income inequality. Motivation for considering inequality as a component of individual's perceived well-being could be advanced on disparities in the basis of a Rawlsian argument that vast disparities in income, and the associated opportunity sets, is in itself an infringement of human dignity.[7]
- A measure of the percentage of the population living at less than $1 per day (measured in purchasing power parity terms). This is an indication of poverty. Again (Sen 1999) argues eloquently that poverty is a serious delimiter of human dignity and self-fulfillment, and we include the measure for this reason.

In **Table 1.2** we report child mortality before 5 years of age, per 1000 population for countries that rank lowest in the world, while in **Table 1.3** we report data on South Africa and a number of other countries that also fall into the emerging market or middle income country category.

What emerges from the evidence is that child mortality for South Africa has been improving – and certainly on this indicator South Africa does nowhere near as badly as some countries. In 1980 9.1% of children died before the age of five. By 1997 this proportion had declined to 6.5%. Contrast this with the 28.6% of children who died before age five in Sierra Leone in 1997. Moreover, this fall in mortality rates is not insubstantial – the decline is in the region of a third. However, when compared with countries that are arguably at a comparable level of development to South Africa, the latter's improved performance becomes somewhat less reassuring. In particular Latin American and East Asian countries often began with worse child mortality in 1980 than South Africa, and were able to report far greater improvements in lowering the mortality

[7] See Rawls (1970).

rate by 1997. In many cases by 1997 mortality rates in these countries were lower than in South Africa in 1997, despite having begun with worse mortality rates in 1980. See the evidence of **Table 1.3.**

Thus to the extent that health is an important component of quality of life, South Africa (at least on the indicator cited) certainly does less poorly than some. But equally, it has done less for its citizens than other countries that are similarly resourced in terms of average income per capita. Where other middle countries have used some of the resources generated by their accelerating growth performance to dramatically curtail ill-health in their populations, South Africa's improvements have been more modest. Nevertheless, in this instance of human development there has been improvement in South Africa's performance, and substantially so. Lowering child mortality by a third deserves acknowledgment, even when room for improvement can be detected.

Table 1.2: Child Mortality below 5, per 1000 population: 22 bottom-ranked countries

	1980	1997
Sierra Leone	336	286
Cambodia	330	147
Niger	320	..
Guinea	299	182
Malawi	265	224
Angola	261	209
Chad	235	182
Mozambique	223	201
Madagascar	216	158
Benin	214	149
Ethiopia	213	175
Bangladesh	211	104
Congo, Dem. Rep	210	148
Haiti	200	125
Lao PDR	200	..
Yemen. Rep.	198	137
Nigeria	196	122
Birimdo	193	200
Senegal	190	110
Nepal	180	117
Uganda	180	162
India	177	88

Source: World Development Report 2000

Table 1.3: Child Mortality below 5, per 1000 population: South Africa and related countries

	1980	1997
South Africa	91	65
Morocco	152	67
Turkey	133	50
Peru	126	52
Indonesia	125	60
El Salvador	120	39
Honduras	103	48
Ecuador	101	39
Philippines	81	41
Mexico	74	38
Dominican Republic	92	47
Paraguay	61	28
Colombia	58	30
Thailand	58	38
Sri Lanka	48	19
Malaysia	42	14
Uruguay	42	20
Venezuela	42	25
Jamaica	39	14
Argentina	38	24
Panama	36	26
Romania	36	26
Chile	35	13

Source: World Development Report 2000

Table 1.4: Adult Illiteracy Rates as a Percentage of the Population Aged Above 15 in 1997

	Adult illiteracy rate % Of people 15 and above 1997			Adult illiteracy rate % Of people 15 and above 1997	
	Males	Females		Males	Females
Latvia	0	1	South Africa	15	17
Slovenia	0	0	Congo, Rep	15	30
Poland	0	0	Brazil	16	16
Lithuania	0	1	Zambia	17	33
Belarus	0	2	Dominican Republic	17	18
Russian Federation	0	1	Kuwait	17	23
Croatia	1	4	Tanzania	18	38
Moldova	1	3	Iran. Islamic Rep.	19	34
Korea.Rep	1	4	Jamaica	19	10
Italy	1	2	Saudi Arabia	19	38
Bulgeria	1	2	Namibia	19	22
Tajikistan	1	2	El Salvador	20	26
Hungary	1	1	Cameroon	21	35
Romania	1	3	Tunisia	22	44
Israel	2	7	Ghana	23	43
Greece	2	5	Uganda	25	47
Spain	2	4	Guatemala	26	41
Uruguay	3	2	Malawi	27	57
Argentina	3	4	Algeria	27	52
Thailand	3	7	Botswana	28	23
Hong Kong China	4	12	Lesotho	29	7
Singapore	4	13	Honduras	29	30
Philippines	5	6	Rwanda	29	44
Chile	5	5	Togo	31	62
Costa Rica	5	5	Nigeria	31	49
Vietnam	5	11	India	33	61
Paraguay	6	9	Egypt.Arab Rep.	35	60
Peru	6	16	Yemen. Rep.	36	79
Sri Lanka	6	12	Nicaragua	37	37
Portugal	6	12	Morocco	41	67
Zimbabwe	6	12	Mozambique	43	75
Ecuador	7	11	Nepal	44	79
Venezuela	7	8	Central African Republic	44	70
Mexico	8	12	Pakistan	45	75
Panama	8	10	Burundi	46	64
Jordan	8	18	Cote d'Ivoire	49	66
Turkey	8	26	Bangladesh	50	73
China	9	25	Mauritania	51	72
Colombia	9	9	Haiti	52	57
Bolivia	9	23	Benin	52	79
Indonesia	9	20	Senegal	55	75
Lebanon	9	22	Mali	57	72
Malaysia	10	19	Ethiopia	59	71
Myanmar	11	21	Burkina Faso	70	89
Syrian Arab Republic	13	43	Niger	78	93
Kenya	13	28			

Source: World Development Report 2000.

In terms of illiteracy, South Africa again does better than many other countries both in terms of the average level of illiteracy across the entire population, and in terms of the differential between genders. Compare the 15% and 17% illiteracy rates for males and females in South Africa with Kenya's 13% and 28% respectively. **Table 1.4** reports the illiteracy rates for all recorded instances in the world for 1997. But again, comparing South Africa with countries that might be regarded to be at a similar level of development reveals a far less reassuring picture. Thus Latin American countries tend to report far lower illiteracy rates, and certainly Korea and Singapore have done considerably better than South Africa in eliminating illiteracy.

As in the case of child mortality, therefore, we find that while South Africa does not rank with the worst instances of illiteracy, and certainly does not show much gender inequality in terms of adult literacy, when compared with countries at a similar level of development considerable room for improvement becomes evident. The absolute level of illiteracy is (sometimes well) above that of other middle income countries. When compared with many Latin American or East Asian countries, the difference becomes marked.

It is by now well established that South Africa does not perform well relative to the rest of the world in terms of income inequality measures. In **Table 1.5** we report the Gini coefficient[8] for the countries with the 30 highest coefficients. The evidence confirms that South Africa continues to rank amongst the countries with the highest level of income inequality in the world.

This much is well known. But it is feasible to maintain a high level of income inequality with a relatively high average standard of living. Under these circumstances, while the population on average escapes poverty, inequality would be an expression of the very much higher standard of living maintained by a minority of the population. It would be at least arguable that under these circumstances the performance of a country would be more defensible than where citizens face both inequality and poverty. At least citizens would not face the indignity of struggling to establish command over the resources required for the most basic existence.

In **Table 1.6** we therefore consider the proportion of the population that faces real poverty in a sample of the world's countries, including South Africa. The measure reported is the percentage of the population that earns less than $1a day in purchasing power parity terms, or less than $2 a day in PPP terms[9]. Again, while South Africa's performance is much the same as that of Brazil (just as the two countries have very similar Gini coefficients), South Africa maintains a very much greater proportion of its population in poverty than other countries at a similar level of development such as Malaysia, Chile, Mexico. Indeed, even countries generally considered to be at a much

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[8] The higher the coefficient, the greater the degree of inequality.

[9] We adjust the purchasing power of output for the price level that is maintained in different economies. $1 buys much more housing in Johannesburg than it does in London and this should be reflected in the 'value' of measured output. PPP measures undertake such an adjustment.

lower level of development, such as Pakistan have been more successful in lowering poverty on the dollar-based standard than South Africa has.

Table 1.5: Income Inequality as Measured by the Gini Coefficient

Economy	Survey Year	Gini index
Sierra Leone	1989	62.9
Brazil	1995	60.1
Guatemala	1989	59.6
South Africa	1993/94	59.3
Paraguay	1995	59.1
Colombia	1995	57.2
Panama	1995	57.1
Zimbabwe	1990	56.8
Chile	1994	56.5
Lesotho	1986-87	56
Senegal	1991	53.8
Honduras	1996	53.7
Mexico	1995	53.7
Papua New Guinea	1996	50.9
Dominican Republic	1989	50.5
Mali	1994	50.5
Niger	1995	50.5
Nicaragua	1993	50.3
El Salvador	1995	49.9
Zambia	1996	49.8
Malaysia	1989	48.4
Burkina Faso	1994	48.2
Russian Federation	1996	48
Ukraine	1995	47.3
Costa Rica	1996	47
Venezuela	1995	46.8
Ecuador	1994	46.6
Peru	1996	46.2
Thailand	1992	46.2
Madagascar	1993	46
Nigeria	1992-93	45

Source: World Development Report 2000.

Table 1.6: Poverty Indicators

Economy	Survey Year	Population below $1 PPP a day %	Population below $2 PPP a day %
Zambia	1993	84.6	98.1
Madagascar	1993	72.3	93.2
Uganda	1989-90	69.3	92.2
Niger	1992	61.5	92
Senegal	1991-92	54	79.6
Guatemala	1989	53.3	76.8
Nepal	1995	50.3	86.7
Kenya	1992	50.2	78.1
Lesotho	1986-87	48.8	74.1
India	1994	47	87.5
Honduras	1992	46.9	75.7
Ethiopia	1981-82	46	89
Rwanda	1983-85	45.7	88.7
Nicaragua	1993	43.8	74.5
Zimbabwe	1990-91	41	68.2
Botswana	1985-86	33	61
Mauritania	1988	31.4	68.4
Nigeria	1992-93	31.1	59.9
Ecuador	1994	30.4	65.8
Philippines	1994	26.9	62.8
Guinea	1991	26.3	50.2
Panama	1989	25.6	46.2
South Africa	1993	23.7	50.2
Brazil	1995	23.6	43.5
China	1995	22.2	57.8
Dominican Republic	1989	19.9	47.7
Costa Rica	1989	18.9	43.8
Kyrgrz Republic	1993	18.9	55.3
Cote d'Ivoire	1988	17.7	54.8
Romania	1992	17.7	70.9
Chile	1992	15	38.5
Mexico	1992	14.9	40
Slovak Republic	1992	12.8	85.1
Venezuela	1991	11.8	32.2
Pakistan	1991	11.6	57
Indonesia	1996	7.7	50.4
Egypt.Arab Rep.	1990-91	7.6	51.9
Colombia	1991	7.4	21.7
Moldova	1992	6.8	30.6
Poland	1993	6.8	15.1
Estonia	1993	6	32.5
Turkmenistan	1993	4.9	25.8
Jamaica	1993	4.3	24.9
Malaysia	1995	4.3	22.4
Sri Lanka	1990	4	41.2
Tunisia	1990	3.9	22.7
Czech Republic		3.1	55.1
Bulgeria	1992	2.6	23.5
Jordan	1992	2.5	23.5

Source: World Development Report 2000.

Thus in South Africa (as in Brazil), inequality is married to the presence of poverty, and poverty at levels that exceeds that of countries at a lower level of development. Of course this is an expression of the inequitable growth path the country pursued in the past. But it also points to important tasks that lie ahead in the future.

We therefore conclude our overview of South Africa's quality of life performance on a mixed note. There is certainly evidence that South Africa has made progress in improving the quality of life of its citizens in a number of dimensions that might be considered important enabling mechanisms for enjoying a better life. Child mortality has been improving over the 1980's and 1990's, and illiteracy does not show some of the gender biases that are present in other countries. But the degree to which South Africa has been able to improve its performance in these human development indexes, and the level of income inequality as well as the absolute level of poverty that is still present in South Africa leaves considerable room for improvement. Particularly when South Africa is compared with countries in East Asia that might be considered instances of best practice, it is evident that South Africa has some way to travel before it can consider the task of improving the quality of life of its population accomplished.

1.2 Can we provide a framework to understand these developments?

The short answer is yes. But unfortunately the full answer will not necessarily be a simple one. The reason for this is that economists have been delving at the question of what drives economic development and growth for at least two centuries now. And what may add subtlety and insight to theory and data analysis often comes at the expense of accessibility to laity.

For this reason we propose to explore the basic structure of all growth theory as a preliminary to the more detailed analysis that will follow in subsequent chapters. We believe this to be useful above all since the basic structure that underlies all growth theory is the same – no matter what the subtle modification that is being proposed. It is useful to recall this throughout in the discussion that follows, in order to orient one's understanding of the precise point that is being advanced.

In growth theory we are interested in the *long-run* performance of the economy. That is, we are interested not in the problems of stabilization of the economy (the object of monetary and fiscal, and to a lesser extent supply side policy), nor in medium-term fluctuations of the economy over the business cycle, but in its long-run trend or potential growth path. The assumption is that aggregate demand is equal to potential output in the economy, that the economy is operating at full capacity and employment.

Of course, de facto real output is subject to both short term and medium term shocks, so that at any given time actual output is likely to differ from its long term trend value. But we will be concerned here not with what causes deviations from the underlying trend, but with what is likely to determine the magnitude of the underlying trend itself. For instance, for South Africa real GDP and trend GDP might be presented as in **Figure 1.6**. The concern of much of macroeconomics is to keep fluctuations of real GDP from trend to a minimum. Growth theory's concern is with an explanation of the determinants of the trend line itself.

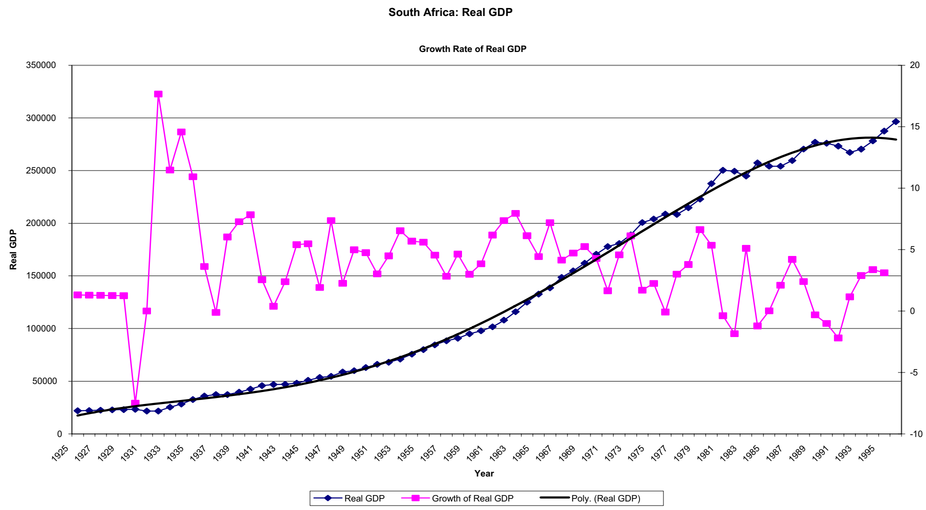

Figure 1.6: The distinction between actual (Real GDP) and trend real GDP (Poly)

In fact, for the most part in growth theory our concern is not with the growth rate in absolute real GDP. Instead, growth theory concerns the growth rate of real per capita GDP in order to place countries on a comparable footing for purposes of comparison. While the USA produces far greater GDP than Switzerland, the ordering of the two countries is reversed on a per capita basis. Hence the information provided by per capita GDP is more useful for the purposes of international comparison if our concern is with the average well-being of a country's citizens.

1.2.1 So why should we concerned about growth in the first place?

The reason for the importance of the growth path of an economy, and hence our interest in growth can be easily illustrated. In **Figure 1.7** below, we show South African and United Kingdom real per capita GDP in 1985, measured in purchasing power parity (PPP) terms. South African GDP was \$3885, UK GDP \$8665 in PPP terms. We then plot per capita GDP for SA under the assumption of three distinct growth rates, at 2%, 2.5% and 3% per annum. Differences in the three growth paths should be clear. For the 2% growth path it takes 42 years for SA per capita GDP to arrive at the UK's 1985 value. On the 2.5% growth path the time taken for SA to reach the UK's 1985 per capita GDP drops to 33 years, and yet further to 28 years for the 3% growth path. Clearly, even relatively small improvements in the growth performance of SA's economy can make a substantial difference to the welfare prospects of a population. Understanding of the determinants of growth, is thus of considerable importance to economic policy makers.

This interest is strengthened by the fact that over the past three decades the growth performance of economies throughout the world have shown very dramatic differences. An examination of the distribution of per capita GDP in 1960 and 1985 for a sample of 118 countries shows that the dispersion of countries' per capita GDP has been widening - indicating growing inequality on a world-wide scale. The distribution of real per capita PPP GDP from 1960 to 1985 has widened - as can be seen from a comparison of **Figures 1.8 and 1.9.** The reason for this lies in the wide dispersion of average growth rates over the period, and indeed the fact that some countries have maintained negative growth rates on average over the 1960-85 period - see **Figure 1.10**.[10]

There is an important qualification we need to introduce here though. The story is not one of unambiguous widening of the distribution. In 1960-4 the distance between the 15th and 25th percentiles was 0.13 times world per capita income - by 1985-89 the distance had fallen to 0.06; similarly the distance between the 85th and 95th percentiles fell from 0.98 to 0.59 times the world per capita income (see Durlauf and Quah 1998:3). This means that countries are coming to "cluster" together at the top end and the bottom end of the income scale. The implication is one of a widening of the overall spread of incomes over the post-1960 period, but of increased clustering amongst the relatively poor and relatively rich.

Put another way, the last quarter of the twentieth century has seen the emergence of distinct growth "clubs". Belonging to one or the other (rich or poor) carries vast implications in the command over resources that the citizens of a country will enjoy.

In this wider world-wide context therefore, the evidence we have already seen concerning the changing performance of the South African economy, above all the declining growth rate in real and per capita real GDP, carries serious implications. There is not much evidence to suggest that South Africa is on a growth path which is serving to improve the welfare of its citizens sufficiently to allow it to join the club of developed (rich) countries. If anything, South Africa is falling back in the race to reach levels of per capita output comparable to first world levels and is heading toward the "club of poor" countries.

We face the serious policy concern of how we can ensure that the economic environment in South Africa can be altered sufficiently to reverse this trend.

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[10] Durlauf and Quah (1998:2) point out that averaged over 1960-4, the poorest 10% of the world's economies each had per capita incomes less than 0.22 the world average (while containing 26% of the world's population); the richest 10% of the world's economies each had per capita incomes greater than 2.7 times the world average (while containing 12.5% of the world's population). By 1985-9 the 10th percentile had declined to 0.15 the world average, the 90th percentile had increase to 3.08 times the world average. The picture is again one of widening disparities.

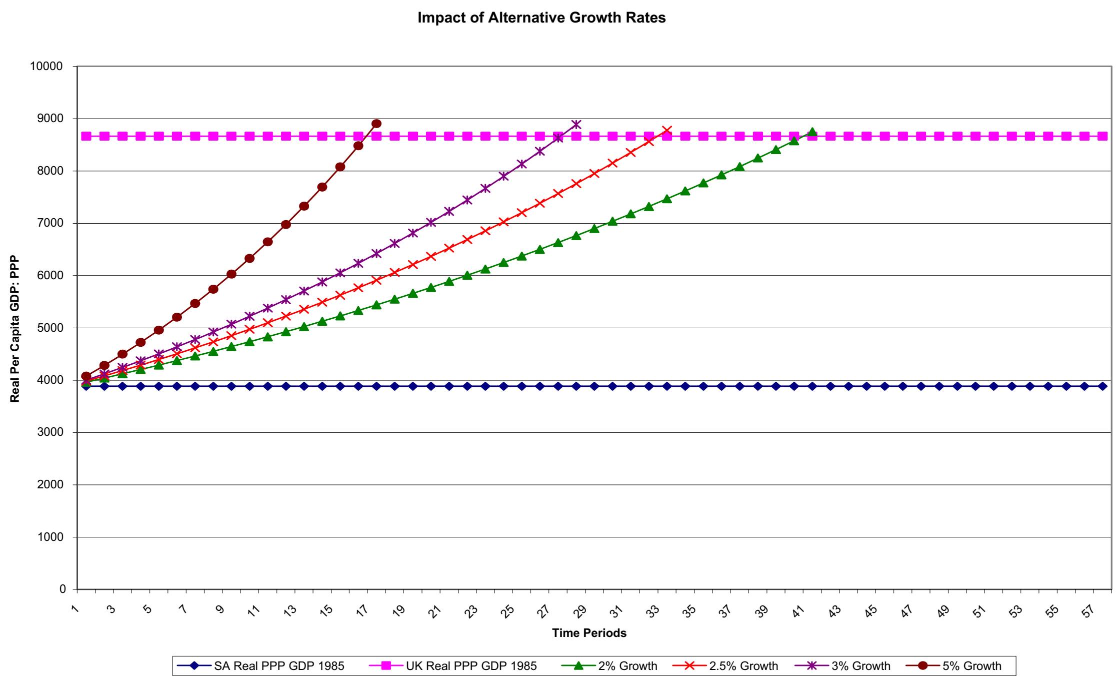

Figure 1.7: The impact of alternative growth rates on long run welfare.

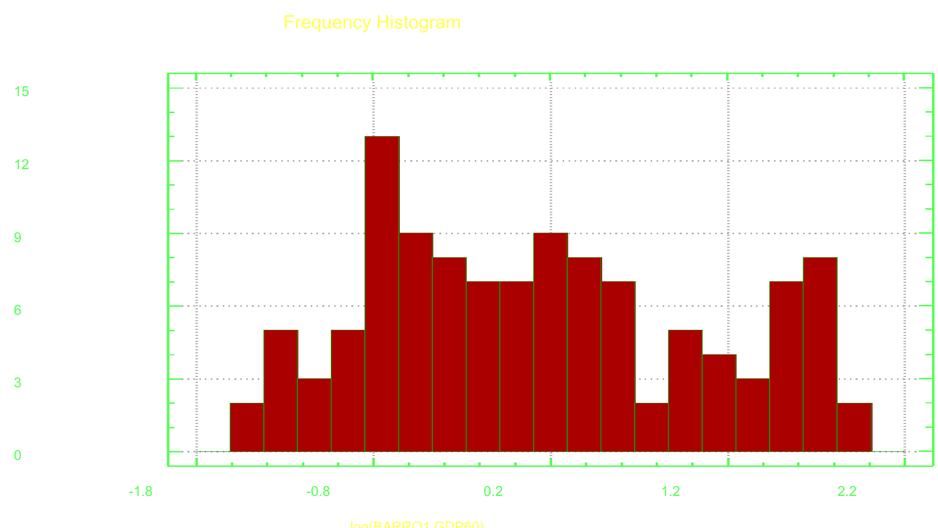

Figure 1.8: Frequency distribution of real per capita GDP internationally: 1960.

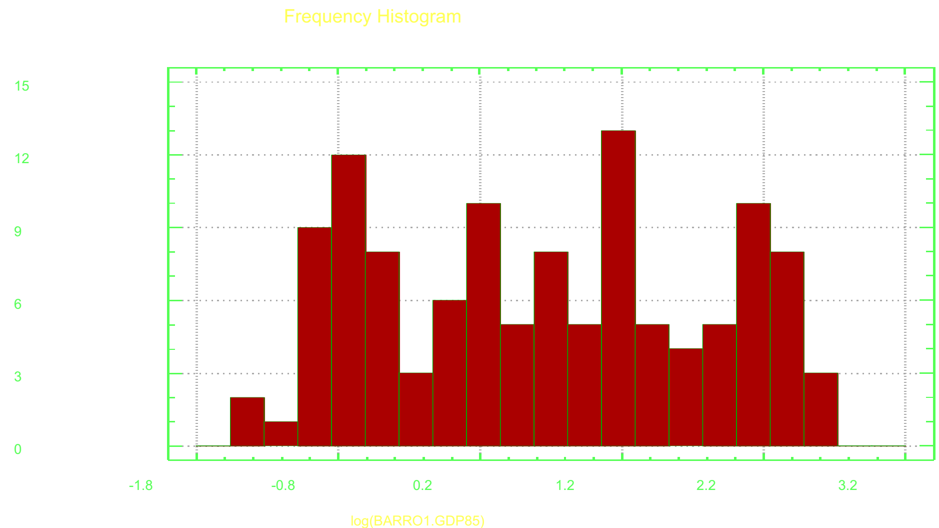

Figure 1.9: Frequency distribution of real per capita GDP internationally: 1985.

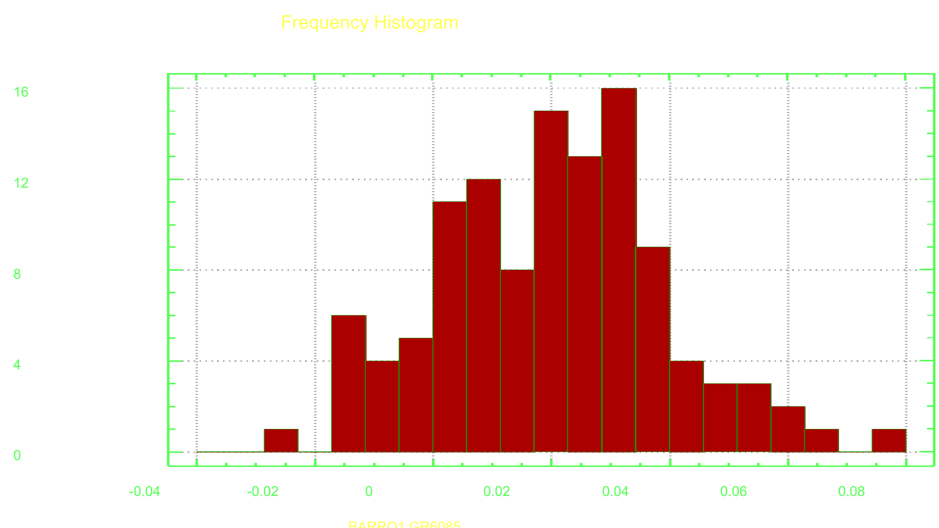

Figure 1.10: Frequency distribution of growth rates in Real Per Capita GDP

1.2.2 So how does it all work?: the general structure of growth models

Recall that in growth theory our concern is with the long run performance of the economy, abstracting from all short run business cycle phenomena. In short, we are interested in how the fundamental *productive capacity of the economy changes over time*, rather than why we may deviate from productive potential over short periods of time.

Economics captures this productive capacity in terms of the production of output that is feasible given the endowments of productive inputs into the production process. Of course, there are many sorts of inputs that are utilized in the process of production. But for the sake of simplifying the exposition we aggregate these into the two factors of production capital and labour.[11] Then production that is feasible when we fully employ all of the capital stock of the economy, and all of the labour hours that are available (recall that we are not concerned with business cycles here) will be determined by the technology of production that we employ in order to utilize the inputs into production so as to generate output.

If this is the case, then the only means of increasing output over time is by increasing factor inputs, capital and labour, or by improving the technology of production through technological progress. *All* growth theories are therefore concerned with these three basic building blocks of our understanding of the process of economic growth – and no matter how complex the contribution, it is really these three fundamental components that constitute any growth theory:

- Capital stock can be augmented over time through the process of saving, and by then transmitting the savings to investors in order to allow them to purchase additional physical capital stock. More capital then allows more output to be produced.

- The labour force will grow in terms of the demographic characteristics of the population. More labour will then allow more output to be produced.

- Technological progress has formed one of the central concerns of modern growth theory – with core concerns being the role of the endowment of human capital of a country, the magnitude of research & development expenditure, the process of investment in physical capital stock as a source of learning-by-doing. The implication is always that improved technology will allow more output to be generated with given endowments of capital and labour. In effect, inputs are more efficiently employed due to technological advance.

Growth models are therefore based on the assumptions they make concerning three central features of the economy. Output depends on the factor inputs available for

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[11] In principle this can (and has been) generalized to many factors of production in the interests of "realism". Complexity of exposition is thereby increased. The central insights are not.

production. Factor inputs are combined by means of the technology of production in order to yield output. Hence, output can increase over time, either because of an increase in factor inputs, or because the technology of product becomes more productive over time -- see **Figure 1.11** below.

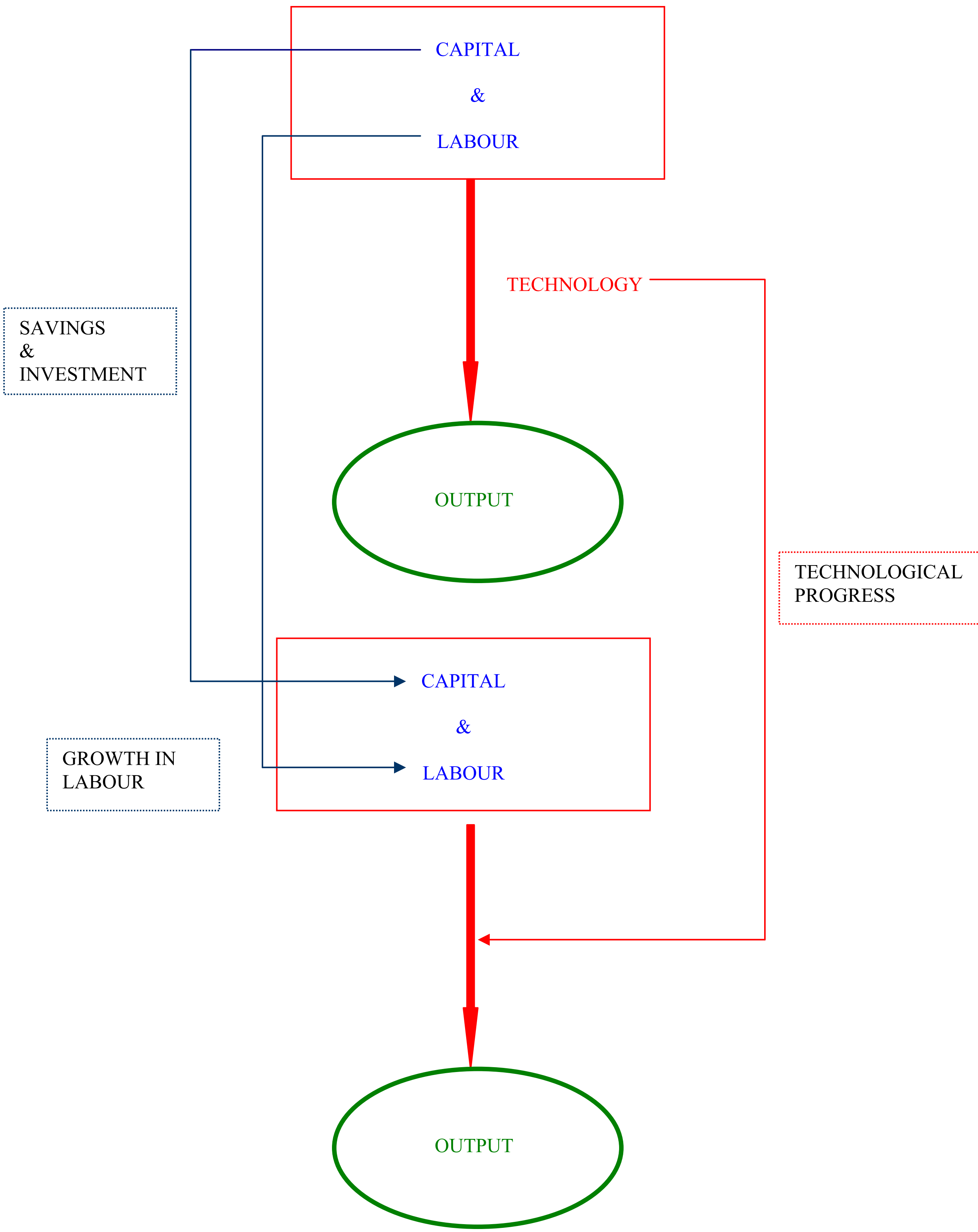

Figure 1.11: Schematic representation of growth process

Any growth model must provide an account of growth in the labour force, the change in the capital stock due to savings and investment, and the nature of the technology of production which converts factor inputs into output, from which savings, investment and hence additions to the capital stock will materialize.

Of course, while the schematic representation of growth theory may make it appear simple, each of the three processes that underlies growth in output, investment, population growth, and technological progress is complex in its own right. We will attempt to make accessible some of this complexity in the discussion that is to follow. But it will be useful if readers keep reminding themselves of the basic structure of growth theory throughout – that each contribution that emerges from the literature on growth has to fit in somehow into a relatively simple basic structure in terms of which output will grow over time.

1.3 Some further thoughts on the question of human development

We have already pointed out that in discussions surrounding development, focus on measures of output, either in absolute terms or in per capita terms, or emphasis on levels of employment may not capture the full story. Human beings are concerned with more than a command over brute resources. Their lives are structured around values that embrace aesthetic and dramaturgical[12] needs as well as material ones.

These are important and valid concerns – and in what follows we will be concerned with some of these dimensions.[13] Nevertheless, the main focus of our discussion will be on the growth in what may be termed the material resource base of the South African economy. In short, the focus will be on the question of growth in real GDP, and on questions of employment creation in the economy.

There are a number of reasons for this. The first is that the level of what we will term "human development", as a composite of the total quality of life that citizens of a country experience, is strongly correlated with the material resource base over which they exercise control. A rising command over material resources will place rational agents in a position to opt to use those resources as they see fit. To the extent that non-material dimensions are central to their concerns, it is likely that wealthier people use their wealth in order to obtain satisfaction in the full set of dimensions that concern them. The implication quite simply is that increasing command over material resources enables economic agents to utilize those resources in order to achieve *whatever* ends they deem important. Rising per capita GDP is not sufficient for rising human development. But it is perhaps necessary.

[12] We follow Habermas (1981) and Goffman (1969) in embracing the wide range of expressive and emotional needs of humans in this collective term. We are aware that this serves to hide many layers of complexity.
[13] For instance, we will devote an entire chapter to a discussion of the nature of human capital, and its impact on long run economic development

It is of course difficult to measure the "quality of life" that agents partake in. But we have already suggested that some indicators might be provided by the level of literacy, the level of education, and the health that citizens enjoy. Indeed, we have already used such measures in accessing South Africa's performance in these dimensions in order to assess its success in enabling human development. In **Figure 1.12** we provide a plot of a composite human development index comprising literacy rates, education and a health proxy against the average level of per capita GDP in 1985 for a sample of 111 countries in the world.[14]

What emerges from the evidence is a strong positive correlation between the human development index and the level of per capita GDP.[15] The suggestion is that where the average citizen of a country has command over a relatively high level of per capita GDP, on average they will also have relatively high literacy rates, relatively good health, and be relatively well educated.

Note further that the positive association is "tightly bunched", suggesting a relatively close association. Of course, some countries have a relatively low HDI index for the level of per capita GDP they maintain (Singapore, Hong Kong, Iran, Gabon), while some have a relatively high HDI index for the level of per capita GDP they maintain (Finland, Ireland, Korea, Zimbabwe). But countries that do poorly on the per capita GDP measure on average do poorly in HDI terms also (Niger, Uganda, Cote d'Ivoire), while developed countries are developed in both GDP and HDI dimensions (Denmark, Germany, Norway, Switzerland). Moreover, a slew of middle-income countries (Malaysia, Brazil, Mexico, Taiwan) appear to develop symmetrically in both GDP and HDI terms.

Nor is this association between real per capita GDP and human development restricted to the relatively objective, but indirect measures provided by education and health. Since the 1970's a number of studies on people's self-reported happiness or satisfaction have been published for a sample of 27 countries.[16] Here too, the correlation between real per capita GDP and the indicators of "happiness" remains consistently positive.[17] Of course the association is less than perfect, and some countries (Brazil, Ireland) are "happier" than one might expect given their real per capita GDP, while others are gloomier than might be expected given their average income (France, Japan).

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[14] The literacy rate is the literacy rate in 1960, education is measured by the secondary school enrollment rate in 1985, and health by the average mortality rate between 1965 and 1985. For a fuller discussion of the data set employed for this exploration, see Klitgaard and Fedderke (1995) , and Fedderke and Klitgaard (1998).

[15] The correlation coefficient between the two variables is +0.82, significant at less than the 1% level. The same implication emerges from a consideration of the three variables individually. The correlation between real per capita GDP and literacy, secondary school enrollment and average mortality rates is +0.77, +0.79, and –0.78 respectively (all significant at less than the 1% level), confirming rising literacy, educational and health levels with rising per capita GDP.

[16] For more discussion of this data, see again Klitgaard and Fedderke (1995).

[17] We employed two alternative measures – on a three and a ten point scale, though the correlation between them is +0.85. The correlation between per capita GDP and the three and ten point scale is +0.58 and +0.70 respectively.

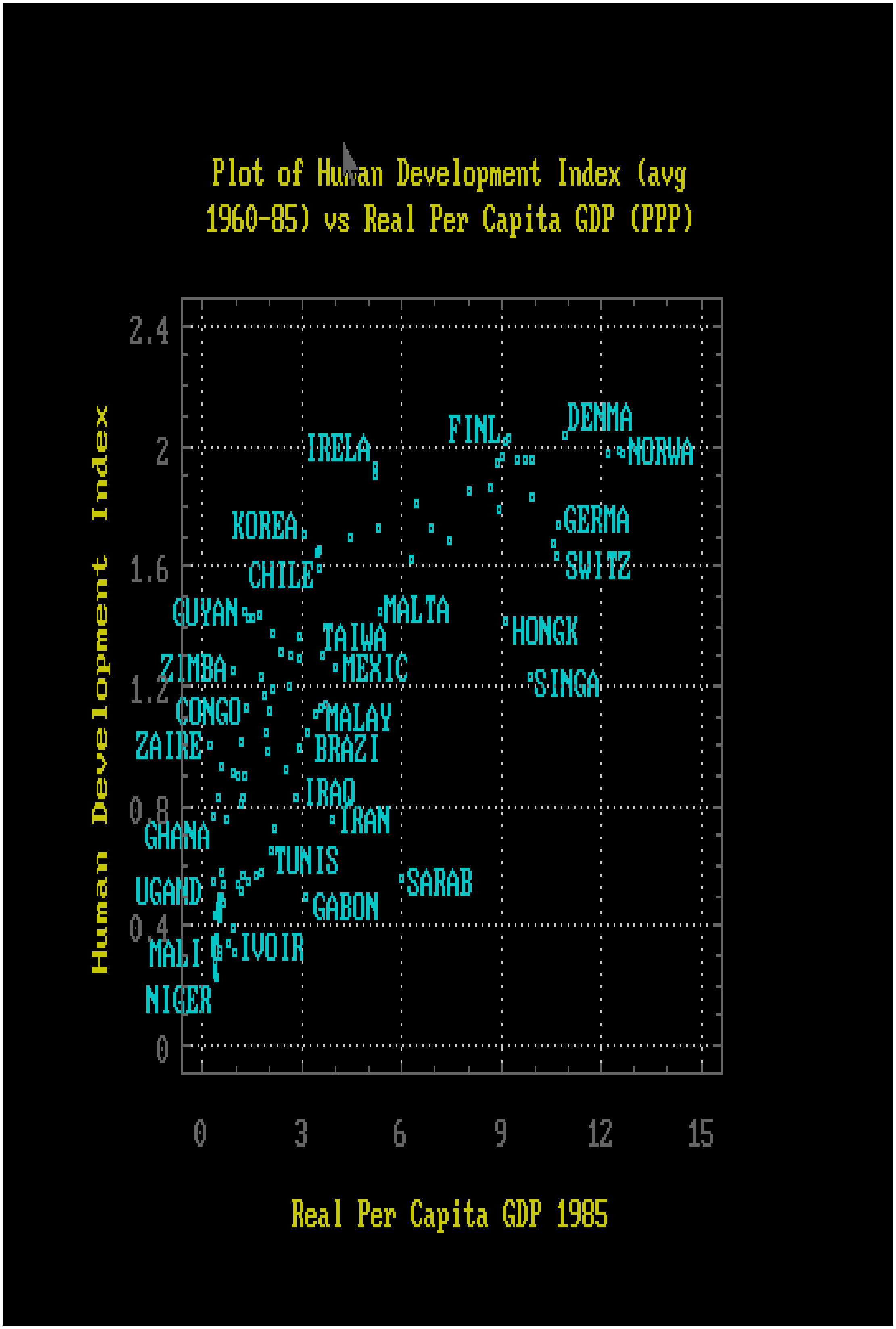

Figure 1.12: Plot of Composite Human Development Index against Real Per Capita GDP

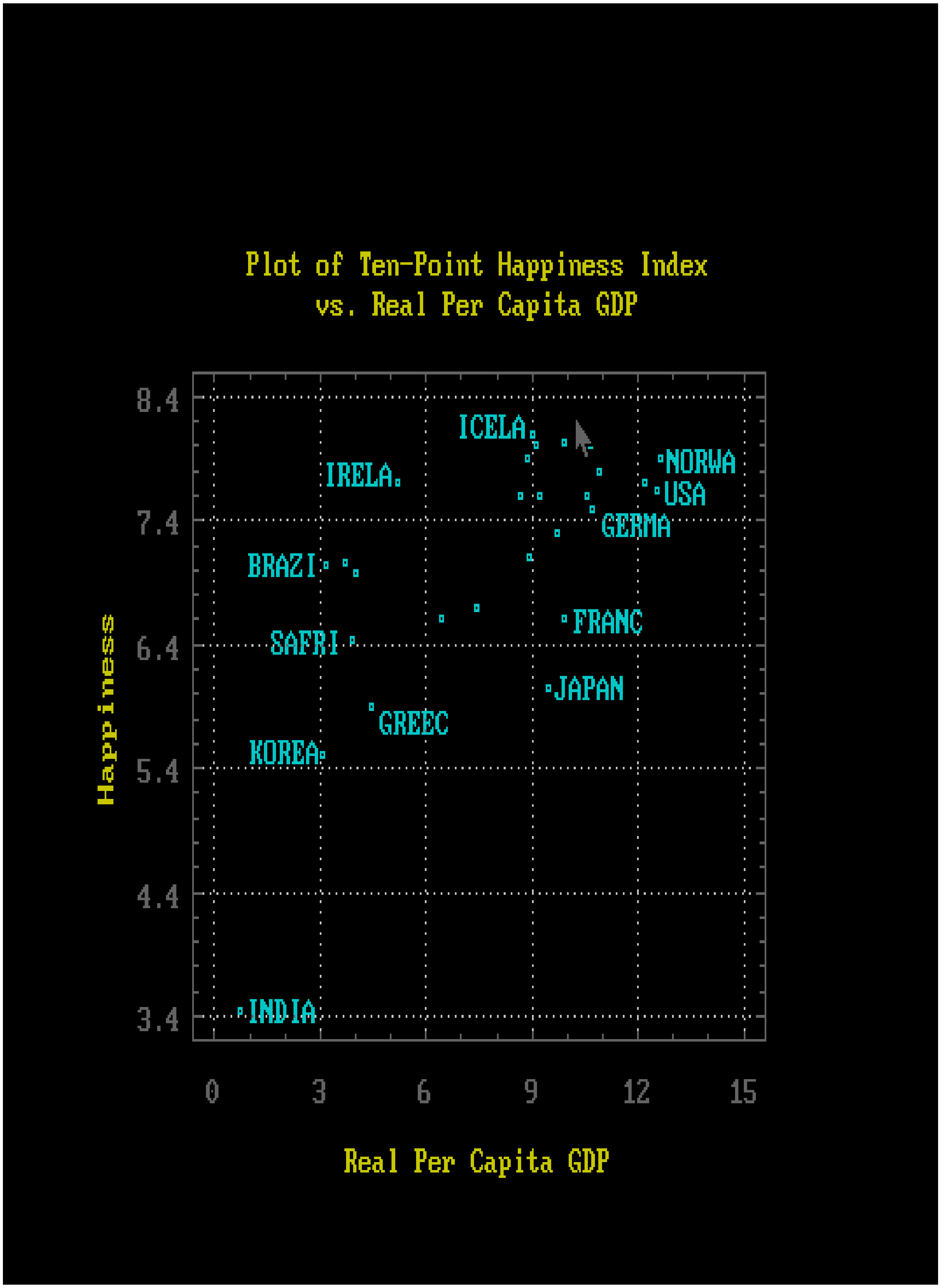

Figure 1.13: Plot of Happiness Index (ten-point scale) against Real Per Capita GDP

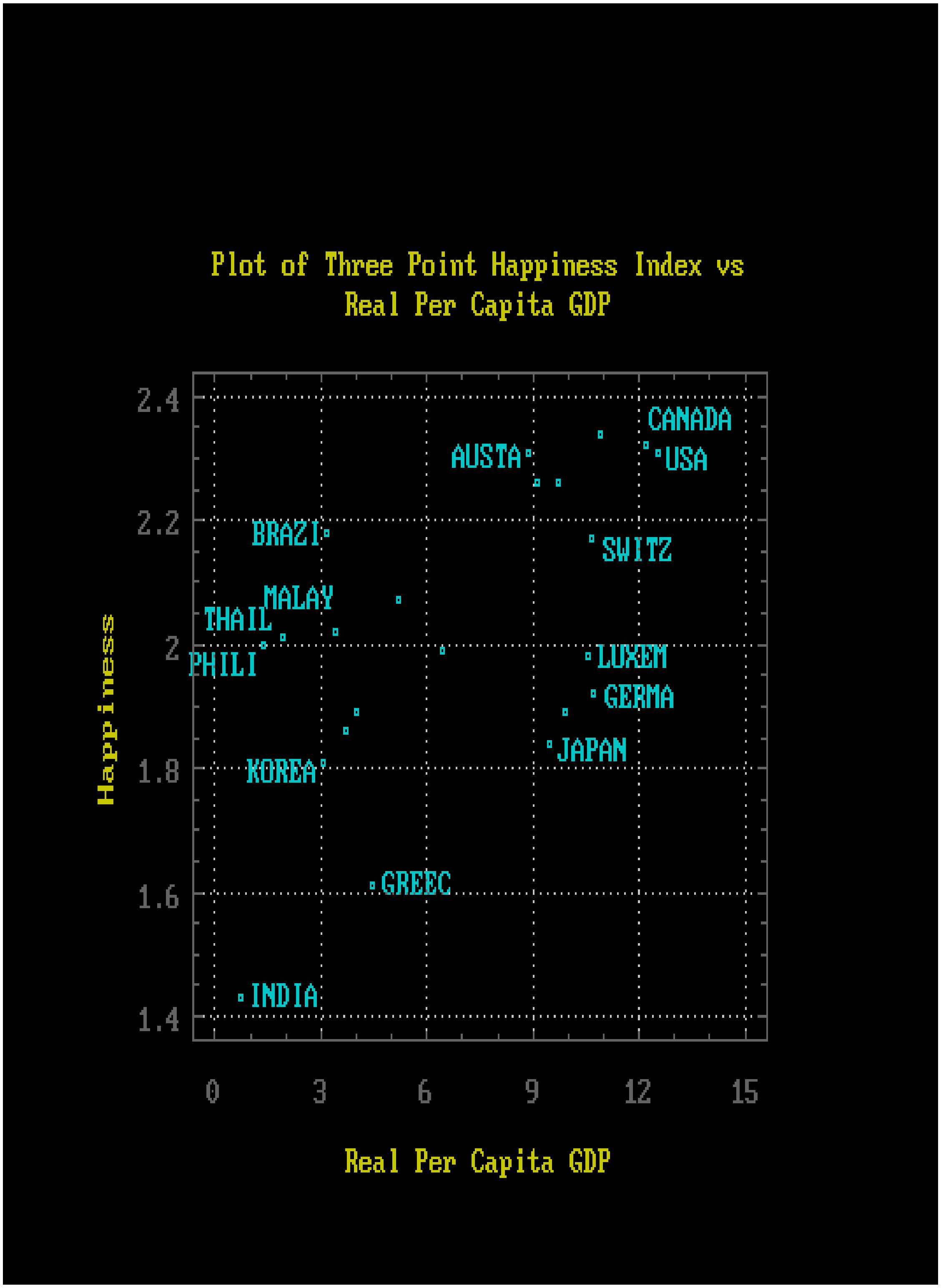

Figure 1.14: Plot of Happiness Index (three-point scale) against Real Per Capita GDP

But on average, rising average incomes appear to be associated with a higher level of self-reported satisfaction with life – see **Figures 1.13 and 1.14.** And we might wish to note that South Africans are about as "happy" as we might expect given their per capita GDP.

Both in terms of objective assessments as well as in terms of subjective self-reported assessments by individuals, therefore, there appears to be a strong positive association between broader conceptions of human development and real per capita GDP. This is precisely as we might have expected. There is no a priori reason to believe that poor people are worse than rich people in establishing what is good for them, or what will give them joy and satisfaction with existence. Thus, as they are given greater resources to dispose of in the form of average incomes, there is no reason to suppose that they will squander the opportunity to employ those resources toward the realization of the good - whether that good is material or affective in its nature.

In the remainder of this study, we will continue on occasion to touch on questions of human development in the broadest sense. However, we wish to be clear from the outset that we believe that development of the command over material resources lies at the heart of both economic and broader human development. For this reason the study will assign the study of growth in real per capita GDP primacy over all other considerations.

1.4 Conclusion

In the discussion that is to follow we shall have to answer a number of questions, and the analysis will no doubt raise many new ones.

But what we have seen thus far certainly makes clear that in the South African context questions concerning the determination of employment in the economy, and questions surrounding the determination of growth are of vital importance.

In our discussion we have also been explicit that we view wider "quality of life" to be strongly influenced by real per capita GDP. Of course, "quality of life" is about more than just income. But higher income on average is strongly correlated with improvements across a wide range of development indicators.

While not sufficient for human development therefore, we do view improved per capita GDP as a *necessary* condition for human development. Economic growth in this sense assumes primacy over other forms of development, and in this discussion will be treated as the primary factor in development.

We have also seen that technology is explicitly understood to be one of the three core determinants of long run growth, and hence by extension for broader conception of human development. Focus on the role of technology, understanding how it comes to drive and may itself be driven by the process of economic development is thus of vital importance to the process of long run developmental planning.

In what follows we begin in Chapter 2 by assessing empirically the extent to which technology has contributed to growth both internationally, and in South Africa specifically.

We then move on in Chapter 3 to a consideration of the theories advanced by economists as to why it is that technology is likely to play so crucial a role in long run economic growth.

Chapter 4 will then consider which of these specific explanations finds empirical confirmation.

Chapter 2

The Role of Technology in Long-Run Economic Development: Does it Make a Difference?

2.0 Introduction

Even if our central concern is with the contribution of science and technology to long run economic development, we will not be able to avoid the three legs of the economic growth process. Investment and physical capital formation, and growth in the labour force we will see may themselves come to be intimately wound up in the process of innovation that many consider to be the most quintessential manifestation of the progress that we associate with development.

Nevertheless, let us start with a consideration of technological progress, and an examination of precisely how large its contribution to economic growth is likely to be, before moving on to more detailed considerations of just how and why it might come to contribute to the growth process.

2.1 The magnitude of the contribution of technological advance to economic growth: some international evidence

By many estimates the contribution of technological progress to economic growth is large.

One illustration of this emerges when one considers the relative contribution of the three core contributors to economic growth that growth theory has identified. Considering the rapid and sustained period of economic growth that the developed world underwent in the period from 1950-62, it emerges that the contribution of factors of production (capital and labour) never matched that of technological advance at least in the sample of developed nations under consideration.[1] We provide some summary evidence in **Table 2.1.** In effect, the growth in output in these countries is difficult to explain by reference to growth in factor inputs, and instead the weight of

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[1] It is possible to show that as long as the technology of production is homogeneous of degree one, then we can decompose growth in output by:

$$\frac{\dot{Y}}{Y} = \eta_K \frac{\dot{K}}{K} + \eta_L \frac{\dot{L}}{L} \qquad (1)$$

where Y denotes output, K capital, L labour, η_K the elasticity of output with respect to capital, and η_L the elasticity of output with respect to labour. Since the elasticities are given by the ratio of the marginal to the average product of the relevant factor of production, under competitive factor markets in which the price of the factor of production equals the factor's marginal product, the elasticity will equal the share of the factor of production in final value added. The contribution of technological progress to growth in per capita output is then simply the growth in output not accounted for in terms of the growth in factor inputs. The contribution of technology is computed as a residual after the impact of factor input growth has been allowed for. Economists term this residual growth in total factor productivity (TFP).

expectation for economic growth begins to fall on the contribution of technological advance.[2]

Table 2.1: The decomposition of growth in per capita GDP into the contribution by factors of production and technological progress

	Growth in Real Labour Product GDP	Contribution by: Labour	Capital	Technology (TFP)
Japan	6.45	0.77	1.17	4.57
Italy	5.36	0.54	0.57	4.29
Germany	5.15	-0.12	0.93	4.43
France	4.80	0.37	0.76	3.67
Netherlands	3.65	0.09	0.78	2.79
Norway	3.27	0.02	0.85	2.41
Belgium	2.64	0.36	0.28	2.02
Denmark	2.56	-0.11	0.77	1.94
United States	2.15	0.22	0.60	1.36
United Kingdom	1.63	0.10	0.37	1.18

Source: Fagerberg (1994)

Economists have well understood that growth in factor inputs has appeared to contribute a relatively small proportion of the total growth in per capita GDP in most developed economies. One response to this finding has been some degree of scepticism as to the apparent overwhelming preponderance of technological advance as an engine for growth. As a consequence, numerous attempts have been made to refine the decomposition of per capita output growth, in order to isolate the contribution of technology more precisely.

A number of additional considerations have been proposed as candidates that might contribute to economic growth besides growth in factor inputs and growth in technology. Beginning with a seminal study, Denison (1967)[3] decomposed the contribution of technology noted in **Table 2.1** into the following substrates:

- *technological change* proper. The focus here is on the development of genuinely new technology in the economy in question.
- *catch up* with the world's technological leader. The implicit recognition here is that at any given point in time, some countries are technologically more advanced than others. Under such circumstances it is easier to "copy" more advanced technology rather than being engaged in the expense and uncertainty of developing new technology of one's own. Thus the energy of countries may

[2] This has been understood from early on in the modern discussion of economic growth. See for instance Abramovitz (1956). For continued and more recent discussion of this evidence see also Fagerberg (1994) and Maddison (1987).
[3] And subsequent studies.

be more usefully focused on "catching up" rather than forging one's own independent way ahead.[4]

- *structural change*, through the elimination of market distortions in order to improve the allocation of resources. Greater efficiency of resource allocation should improve the level of output, as well as the rate of return on investment, thus stimulating the incentive to invest, and ultimately the productive potential of the economy.
- *economies of scale*. Access to larger markets (for instance through the opening up of economies to world markets) allows for the realization of efficiency gains through the exploitation of economies of scale in large production runs.

The net result is reported in **Table 2.2**, as cited in Fagerberg (1994).

Table 2.2: Decomposition of the contribution of technology (as measured by TFP) to growth in real per capita GDP

	Technology (TFP)			
	Technological Advance	Catch Up	Structural Change	Economies of Scale
Japan	1.41		1.07	1.88
Italy	0.76	0.88	1.42	1.22
Germany	0.75	0.83	1.00	1.59
France	0.76	0.74	0.95	1.00
Netherlands	0.75	0.43	0.63	0.77
Norway	0.76	0.18	0.92	0.57
Belgium	0.76	0.07	0.51	0.51
Denmark	0.75	-0.27	0.67	0.64
United States	0.75	-	0.29	0.36
United Kingdom	0.75	0.04	0.12	0.36

Source: Denison as cited in Fagerberg (1994).

What emerges is that the contribution of technology can indeed be pared down considerably once the additional factors brought into consideration are taken into account.[5] The essentially identical contribution of technology across developed countries reflects the assumed public goods character of technological change (i.e. it is freely available to all once technological advance takes place). The United States does not evidence any catch-up since it is viewed as the technology leader in the post-war period.

While the contribution of technological progress may now appear to be more "realistic", a few words of caution at this point are equally appropriate. If it is true that technology is a public good, then it becomes difficult to explain why it is that some countries struggle with catch-up in technology, and others do not.

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[4] On many accounts, this is one of the sources of East and South East Asian success. Assiduous learning from technologically more advanced nations, rather than attempts to develop independent technologies of their own, is often advanced as the core to the rapid growth in East Asia.

[5] See also the discussion in Jorgenson (1988), Jorgenson and Grilliches (1967) and Maddison (1987).

The restriction of output growth due to technology to be constant across all countries is in itself therefore artificial. The distinction between genuinely "new" technology and the process of acquiring technology that was already in existence but a specific country did not have access to, does make sense at one level. These are two processes that are distinct both conceptually, and in terms of what renders them feasible. But at another level to the country doing the acquiring, the effect of the two acquisitions is much the same. In both instances production possibilities that did not exist before become accessible. Therefore the distinction between the two processes while useful, is also to some extent artificial. A similar argument can be made with respect to both economies of scale and structural change. Again these are innovations not in the sense of "new knowledge", but they do innovate, and they do open up new forms of production not previously in existence.

For all of these reasons, very detailed decomposition of the output growth attributed to technology may carry with it more ambiguity than insight, and we might be better advised to try to understand the factors in aggregate. TFP growth provides one with an indication of the magnitude of efforts to increase the efficiency with which factor inputs are used in production. While it may indeed be insightful to establish *why* efficiency gains are being realized, in the final instance it is the fact *that* they are being realized that matters. TFP growth is really technological change in its broadest sense. Considering the magnitude of its contribution is therefore a useful starting point. At least we know how much there is to explain, before we consider decomposing it into its constituent parts.

2.2 The magnitude of the contribution of technological advance to economic growth: some South African evidence

Thus far we have considered the impact of technology on output growth in international context. The obvious question now must be how significant the contribution of technological advance has been in the South African economy. The decomposition of output growth in the entire economy over the 1970's, 1980's and 1990's is presented in **Table 2.3a.** Compare this with evidence from the rest of the world. See **Table 2.3b.**

Table 2.3a: The decomposition of growth in GDP into the contribution by factors of production and technological progress: the South African evidence. Figures are in percent.

	Growth in Real GDP	Of which:		
		Labour	Capital	Technology
1970's	3.21	1.17	2.54	-0.49
1980's	2.20	0.62	1.24	0.34
1990's	0.94	-0.58	0.44	1.07

Table 2.3b: Contribution of Capital, Labour and Technical Progress to Output Growth (%)

Region	Capital	Labour	Technical Progress
Developing countries, 1960-87	65	23	14
Africa	73	28	0
East Asia	57	16	28
Europe, Middle East & North Africa	58	14	28
Latin America	67	30	0
South Asia	67	20	14
Selected developed countries, 1960-85:			

France	27	-5	78
West Germany	23	-10	87
Japan	36	5	59
United Kingdom	27	-5	78
United States	23	27	50

Source: - Lim (1994).

What is startling about the South African evidence is that the 1970's and 1980's saw growth that was heavily led by growth in capital and labour inputs, with very little contribution by technology. In the 1990's the situation is reversed. In the 1990's growth in the labour force input contributed negatively, and growth in the capital input contributed relatively weakly to growth in GDP. Instead, the single strongest contributor to output growth during the course of the 1990's is a strong augmentation in technology.

Thus the evidence suggests the presence of a strong structural break in the SA economy. While in the 1970's and 1980's output growth in the economy as a whole was driven by growth in factor inputs, the 1990's have seen a growing reliance on technological improvements and efficiency gains in the economy.

Part of the reason for this evidence we have already seen. The 1990's saw a decline in formal sector employment, such that growth in labour inputs could not possibly have added to the growth in real output of the economy. The declining contribution of capital to the growth performance of the South African economy is due to the declining investment rate that South Africa has experienced. Since this will form the topic of a later chapter of this report, we defer discussion and explanation of the capital stock contribution to growth until then.

We are left with a finding that the contribution of technological progress to South African growth in aggregate has been steadily rising since the 1970's.

As an explanation of long-term developmental trends in the South African economy it thus cannot be ignored. However, this insight needs to be tempered by the fact that the aggregate evidence on South Africa hides strong sectoral differences. While in aggregate technology has assumed an ever increasing importance in the growth of the South African economy, this is not true for all individual sectors.

Consideration of evidence by principal sectoral groupings in the South African economy proves illuminating. We report the summary data in **Table 2.4**. The implication of the evidence is that the principal South African economic sectors show strong differences in terms of the decomposition of their output growth. The only consistent feature across all four principal sectors of the South African economy is that the contribution of the labour factor input toward output growth has been on a downward trend from the 1970's through to the 1990's. In terms of the contribution of growth in capital stock, we find that in the agricultural sectors, the mining industry and the service[6] industries capital has been of declining importance as a contributor

[6] Included in this sectoral grouping are:
Electricity, gas & steam, Water supply, Building construction, Civil engineering & other construction, Wholesale & retail trade, Catering & accommodation services, Transport & storage, Communication, Finance & insurance, Business services, Medical, dental & other health & veterinary services, Other community, social & personal services: Profit seeking.

toward output growth, while for manufacturing industry it has become of increasing importance.[7]

Finally, in terms of the contribution of technological progress, the strongest efficiency improvements have consistently been evident in the agricultural sectors, though the trend has been a declining one. Mining by contrast, while coming off a low growth rate of technological progress, has been on an upward trend, as has service industry off somewhat higher growth rates in technological progress than are evident in mining. Manufacturing industry has shown the weakest performance in terms of technological progress in the South African economy.

Table 2.4: The decomposition of growth in per capita GDP into the contribution by factors of production and technological progress: the South African evidence by principal economic sector. Figures are in percent.

	Growth in Real GDP	Of which: Labour	Capital	Technology
Agriculture, Forestry and Fishing				
1970's	4.27	-0.10	2.00	2.37
1980's	4.30	-0.24	-0.56	5.10
1990's	-4.47	-0.20	-0.92	3.52
Mining				
1970's	-1.07	0.51	3.81	-5.40
1980's	-0.55	0.18	3.90	-4.63
1990's	-0.60	-2.32	0.10	1.62
Manufacturing				
1970's	4.94	1.67	2.78	0.49
1980's	1.48	0.78	1.21	-0.52
1990's	0.19	-0.47	1.69	-0.79
Service Industry				
1970's	3.41	1.49	2.80	-0.88
1980's	2.81	0.82	1.28	0.71

Other community, social & personal services: Non-profit seeking

[7] See also the evidence in Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000).

1990's	1.50	-0.59	0.44	1.65

In part the weak performance of the manufacturing sectors in terms of technological progress may be explained by the likelihood that if technology is to be "copied" in any sector, it is most likely to be in manufacturing. Manufacturing is the industrial grouping in which the developed world is most likely to have a technological lead, making it rational for South African manufacturing industry to rely on technological advances established elsewhere in the world, and to emulate those advances as best as possible. Moreover, since the manufacturing sectors are those most closely associated with the production of tradeables, they are also the best placed to take advantage of technology transfer between countries through the exchange of goods.

There is also an important sense in which the evidence contained in **Table 2.4** is misleading, however. The evidence merely presents the decomposition of output growth in each sector into the contributions of capital, labour and technology. This does not provide us with a means of establishing the importance of the contribution of technological progress in each economic sector to aggregate economic growth in South Africa, since the contribution of each sector is not weighted by the magnitude of output the sector contributes to aggregate output. A sector experiencing relatively low levels of technological progress, but which is a large producer in the economy, may nevertheless be contributing more to the aggregate growth in output in the economy through technological process than a very small sector whose rapid technological advance generates a proportionately small augmentation of aggregate output.

In order to assess the point, we consider the contribution of the principal economic sector's to what Harberger (1998) has termed real cost reduction in the South African economy. Effectively, the object is to weight the contribution of each economic sector's technological advance to aggregate growth in output, but weighting the contribution by the size of the sector's output. One means of doing so is by applying the average annual growth contribution of technology to output growth to the starting value of real value added[8] in the period for which the TFP contribution has been computed. In **Figure 2.1** we depict the outcome of this exercise on a decade by decade basis, having indexed the contributions of each sector.[9]

The "sunrise-sunset" diagrams illustrate that:

- the total impact of technological progress in the economy to output growth was negative during the 1970's. While technological progress in agriculture and manufacturing contributed in about equal measure to output growth in the economy, both services and mining had negative contributions of technological progress that more than eliminated the contribution of technological progress to output growth in the economy as a whole. Note also that once the relative size of the sectors is taken into consideration the relative contributions of the agricultural and manufacturing sectors to output growth through technological progress is considerably more equal than suggested by the evidence of **Table 2.4**.

[8] This refers of real net output, viz. real gross output less real intermediate inputs.
[9] For more details on this methodology, see Harberger (1998)

- by the 1980's, the total net impact of technological progress on output growth in the economy had turned positive,if only just. While technological advance in agriculture and services made positive contributions to output growth during the 1980's, in manufacturing and mining the contribution of efficiency improvements (TFP) was negative, though ;not sufficiently so to render the total impact of technology unfavourable on output growth.
- during the 1990's the contribution of technology had turned strongly positive. For all sectors but manufacturing technological progress contributed positively to real output growth, and the net impact was unambiguously positive.

The implication of the above evidence confirms our initial finding: that technology as a contributor to economic growth in the South African economy has become increasingly important. Or alternatively, that over the past three decades production in South Africa has become steadily more efficient.

The only exception to this finding is that in the manufacturing sector specifically the 1990's have seen a process of restructuring, with a strong link between growth in capital stock and output growth, and a declining importance of technological innovation. Given the opening up of the South African economy during the 1990's, and hence improvements in the ability of the manufacturing sectors to emulate the technology of more advanced nations, this finding is not entirely surprising.

In effect, the suggestion is that during the period of relative international isolation, the South African manufacturing sector may have been forced to innovate itself, since the more cost-effective path of emulating more advanced manufacturing sectors was blocked to it.

The aggregate story about the manufacturing sector again hides considerable sub-sectoral variation, however. The manufacturing sector is important in the South African economy both as an employer and as a contributor to output and exports, as well as in terms of its key role in the process of industrialization. It is therefore useful to consider more detailed sub-sectoral data for the manufacturing industry. In **Tables 2.5** through **2.7** we report the decomposition of output growth in manufacturing sectors into the contributions of labour, capital and technology for the 1970's, 1980's and 1990's.[10] What is clear is that the aggregate TFP growth for the manufacturing sector does hide strong sectoral variation in technological progress across sectors. Thus in the 1970's Other Chemicals & Man-Made Fibres and Basic Non-Ferrous Metals both had a contribution from technology to output growth in excess of 10%. And in the case of Electrical Machinery and Plastic Products the technology contribution was between 5 and 10 %.[11] In the 1980's Other Industries and the Coke & Refined Petroleum Products sectors again had technology contributions to output growth in excess of 10%, while TV, Radio & Communication Equipment and Professional & Scientific Equipment had contributions between 5 and 10%. The evidence for the 1990's conforms to the evidence we have already presented for the decade: the contribution of technology to output growth is considerably lower than in previous decades in all manufacturing sectors, with growth in capital stock being the main contributor to growth in manufacturing.

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[10] The manufacturing sectors are disaggregated into SIC version 5 three-digit classifications.
[11] The strong negative contribution by the Coke & Refined Petroleum Products sector is a result of the very substantial state-led investment in SASOL.

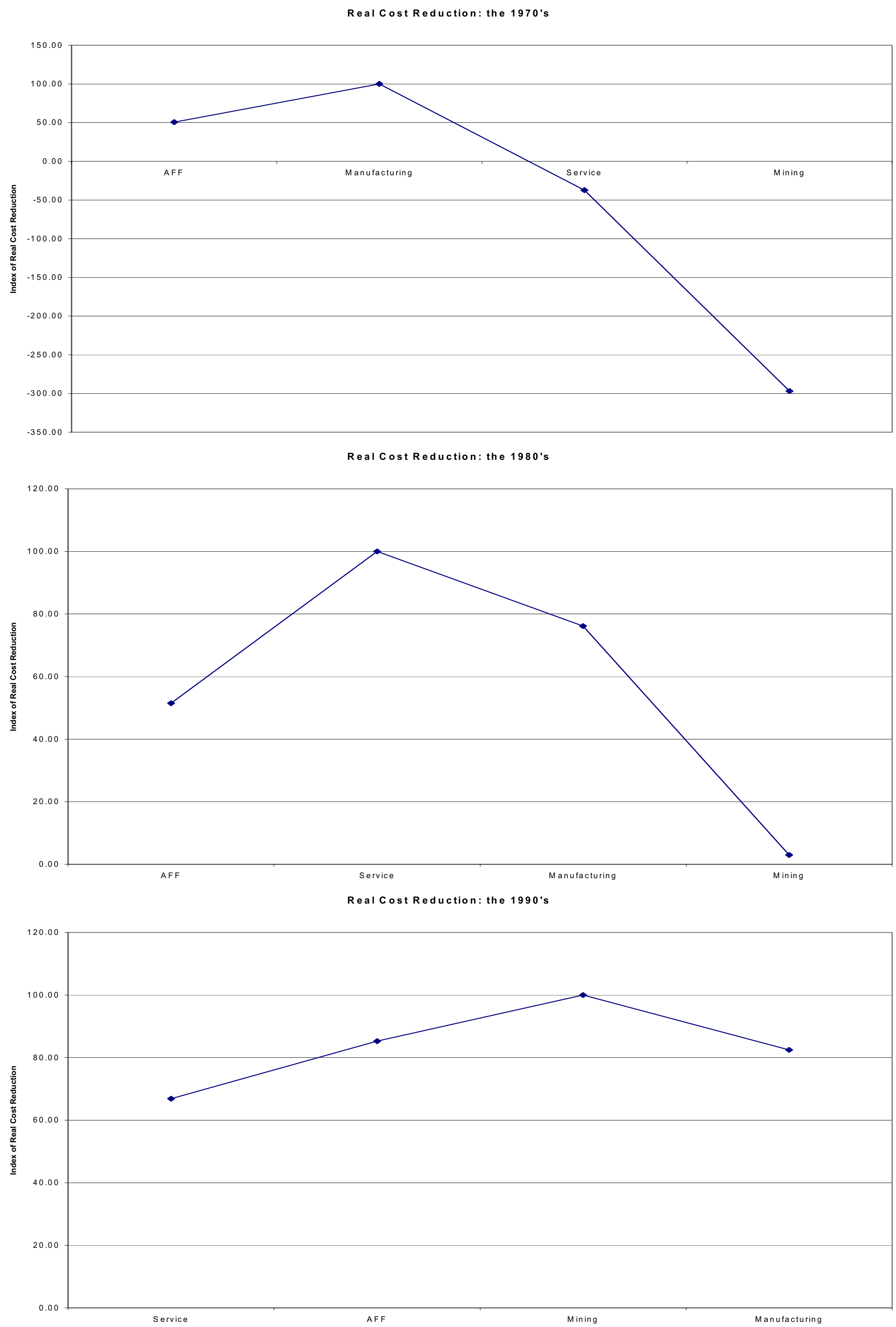

Figure 2.1: Real Cost Reduction in the South African Economy

Table 2.5: The decomposition of growth in per capita GDP into the contribution by factors of production and technological progress: the manufacturing sector in the 1970's. Figures are in percent.

	Growth in real GDP	Of Which			
		Labour	Capital	TFP	Rank TFP
Other chemicals & man-made fibres	16.12	1.02	4.00	11.10	1
Basic non-ferrous metals	15.13	2.36	2.35	10.42	2
Electrical machinery	13.26	3.20	1.55	8.51	3
Plastic products	12.01	3.13	2.10	6.78	4
Paper & paper products	7.44	0.31	2.02	5.10	5
Textiles	2.80	0.67	-0.77	2.90	6
Machinery & equipment	4.96	1.91	0.53	2.52	7
Metal products excluding machinery	4.89	1.81	0.78	2.30	8
Food	6.60	1.57	2.94	2.09	9
Wood & wood products	5.02	1.24	1.86	1.92	10
Furniture	2.15	0.46	-0.11	1.80	11
Motor vehicles, parts & accessories	5.54	2.97	1.01	1.56	12
Wearing apparel	3.80	2.52	-0.04	1.33	13
Beverages	8.09	1.83	5.02	1.24	14
Basic iron & steel	6.29	2.63	3.42	0.24	15
Rubber products	3.36	1.41	2.02	-0.06	16
Other industries	3.82	2.94	0.95	-0.08	17
Non-metallic minerals	2.69	0.49	2.74	-0.54	18
Footwear	0.62	0.54	0.64	-0.56	19
Basic chemicals	4.87	3.29	2.51	-0.92	20
Glass & glass products	1.63	-0.13	2.72	-0.96	21
Printing, publishing & recorded media	0.87	1.99	0.73	-1.86	22
Other transport equipment	3.29	3.30	2.21	-2.22	23
Leather & leather products	-0.04	1.66	0.65	-2.35	24
Tobacco	0.26	0.28	2.60	-2.62	25
Professional & scientific equipment	-4.53	-0.12	0.34	-4.74	26
Television, radio & communication equipment	-1.48	2.65	1.91	-6.04	27
Coke & refined petroleum products	-3.11	0.65	21.46	-25.22	28
Correlation with output growth:		0.40	-0.14	0.79	

Table 2.6: The decomposition of growth in per capita GDP into the contribution by factors of production and technological progress: the manufacturing sector in the 1980's. Figures are in percent.

	Growth in real GDP	Of Which			
		Labour	Capital	TFP	Rank TFP
Other industries	15.65	1.26	-0.22	14.62	1
Coke & refined petroleum products	17.63	1.51	4.10	12.02	2
Television, radio & communication equipment	12.47	2.39	0.09	9.99	3
Professional & scientific equipment	13.28	3.34	2.28	7.65	4
Plastic products	9.07	3.39	2.02	3.67	5
Motor vehicles, parts & accessories	5.89	0.58	1.76	3.55	6
Furniture	8.11	3.93	1.08	3.10	7
Glass & glass products	4.34	-0.63	2.06	2.92	8
Printing, publishing & recorded media	4.99	1.50	0.64	2.86	9
Leather & leather products	3.80	1.27	-0.22	2.76	10
Rubber products	2.49	-0.07	0.09	2.47	11
Beverages	6.54	0.92	3.85	1.77	12
Tobacco	0.53	-0.05	-1.15	1.73	13
Wearing apparel	3.26	1.34	0.20	1.72	14
Basic non-ferrous metals	3.28	0.17	1.70	1.41	15
Basic iron & steel	-0.67	-0.58	-0.26	0.17	16
Other chemicals & man-made fibres	2.44	1.95	0.68	-0.19	17
Metal products excluding machinery	-0.47	-0.04	0.21	-0.64	18
Wood & wood products	0.68	1.05	0.32	-0.70	19
Textiles	-0.71	-0.46	0.82	-1.07	20
Paper & paper products	4.28	1.47	3.89	-1.07	21
Footwear	1.82	2.40	0.53	-1.11	22
Non-metallic minerals	0.78	0.51	1.78	-1.52	23
Food	-0.05	0.79	1.13	-1.96	24
Other transport equipment	-3.04	0.73	-0.30	-3.47	25
Electrical machinery	-1.00	1.33	1.26	-3.60	26
Basic chemicals	2.04	0.77	5.38	-4.10	27
Machinery & equipment	-3.33	0.64	0.80	-4.77	28
Correlation with output growth:		0.54	0.30	0.93	

Table 2.7: The decomposition of growth in per capita GDP into the contribution by factors of production and technological progress: the manufacturing sector in the 1990's. Figures are in percent.

	Growth in real GDP	Of Which:			
		Labour	Capital	TFP	Rank TFP
Basic iron & steel	3.73	-2.29	3.02	3.00	1
Basic chemicals	1.35	-1.38	0.02	2.72	2
Machinery & equipment	1.32	-1.11	-0.16	2.60	3
Wearing apparel	1.84	0.67	-0.56	1.72	4
Wood & wood products	2.02	0.72	0.38	0.93	5
Leather & leather products	0.52	-2.61	2.56	0.57	6
Professional & scientific equipment	0.35	-0.12	0.02	0.45	7
Non-metallic minerals	-1.15	-1.49	-0.02	0.36	8
Other chemicals & man-made fibres	0.55	-0.77	1.22	0.10	9
Electrical machinery	1.71	1.83	-0.19	0.07	10
Food	1.28	-0.59	1.82	0.06	11
Tobacco	-3.68	-2.52	-1.14	-0.02	12
Metal products excluding machinery	-0.09	-0.45	0.43	-0.07	13
Textiles	-1.98	-1.65	-0.11	-0.22	14
Footwear	-3.57	-2.69	-0.48	-0.40	15
Other industries	7.45	-0.23	8.45	-0.76	16
Paper & paper products	0.11	0.01	1.46	-1.36	17
Basic non-ferrous metals	10.55	-1.16	13.58	-1.87	18
Plastic products	2.58	0.91	4.02	-2.35	19
Rubber products	-1.81	-0.88	1.86	-2.79	20
Glass & glass products	-0.27	-0.46	3.05	-2.87	21
Furniture	-1.13	0.79	2.00	-3.91	22
Printing, publishing & recorded media	-1.43	0.70	1.82	-3.95	23
Coke & refined petroleum products	-2.57	-0.31	1.90	-4.16	24
Other transport equipment	-5.43	-1.08	-0.15	-4.20	25
Motor vehicles, parts & accessories	-1.74	0.79	2.45	-4.98	26
Beverages	-2.76	-1.08	3.44	-5.12	27
Television, radio & communication equipment	-1.98	2.50	1.97	-6.45	28
Correlation with output growth:		0.08	0.74	0.38	

It is also worth noting that all the data of **Table 2.5** through **2.7** contains additional evidence of a strong structural breach in the role of technology in the manufacturing sector. Note that the correlation between output growth and the contribution to output growth by the three sources of output growth changes dramatically between the three decades. In the 1970's and 1980's, the strongest correlation is between output growth and the TFP measure. In the 1990's the strongest correlation is between output growth and the growth rate of capital stock. The implication is that in the first two decades sectors that experienced high growth rates in output, were also likely to have a strong track record of technological innovation. In the 1990's, by contrast, this association has become less prevalent. Instead, strong output growth has become associated with a strong growth rate in physical capital stock.

This evidence confirms what we have already seen demonstrated for the manufacturing sector in aggregate. During the 1970-90 period it appears as if South Africa's manufacturing sectors were able to grow primarily through innovation rather than capital accumulation. In this the South African manufacturing sectors have therefore followed a growth path quite distinct from that viewed "standard" for developing countries. The usual expectation is that developing countries should emulate rather than innovate technology. The reintegration of South Africa into the world economy in the 1990's finally saw the standard developmental pattern coming to assert itself.

In one sense this suggests tremendous missed opportunities: that South Africa followed a very *costly* developmental strategy rather than the less costly emulative route normally pursued by developing countries. On the other hand the implication is equally one of considerable *untapped* developmental opportunities for the South African economy. Since emulation has not yet been employed, the opportunities offered by emulation lie in wait. And perhaps the early reliance on innovation will have created capabilities in South African manufacturing that will stand it in good stead in the process of emulation.

Weighting the contributions of TFP by the magnitude of value added produced in each sector adds a further nuance to the manufacturing sector evidence. Again we employ the Harberger (1998) approach of applying the average annual growth contribution of technology to output growth to the starting value of real value added[12] in the period for which the TFP contribution has been computed. In **Figure 2.2** we depict the outcome of this exercise on a decade by decade basis, having indexed the contributions of each manufacturing sector. For ease of depiction and reference, **Figure 2.2** depicts each manufacturing sector by numerical code, and **Table 2.8** provides the key for identification of sectors.

What emerges from this real cost reduction evidence contained in **Figure 2.2** is that for all three decades under consideration, the positive contribution to output growth by technological progress is dominated by a small number of sectors:

- In the case of the 1970's, *six* sectors contributed 80% of the real cost reduction due to technological progress in the manufacturing sector. In declining order of importance these are: Other Chemicals & Man-Made Fibres, Machinery &

[12] This refers of real net output, viz. real gross output less real intermediate inputs.

Equipment, Electrical Machinery, Metal Products excluding Machinery, Basic Non-Ferrous Metals, Paper & Paper Products.

- In the case of the 1980's, *seven* sectors contributed 80% of the real cost reduction due to technological progress in the manufacturing sector. In declining order of importance these are: Motor Vehicles, Parts & Accessories, Coke & Refined Petroleum Products, Other Industries, Television, Radio & Communication Equipment, Printing, Publishing & Recorded Media, Plastic Products, Beverages.

- In the case of the 1990's, *three* sectors contributed 80% of the real cost reduction due to technological progress in the manufacturing sector. In declining order of importance these are: Machinery & Equipment, Basic Iron & Steel, Basic Chemicals.

Thus in each of the three decades under consideration technological progress is highly concentrated in a few core sectors. Moreover, the sectors providing the strongest contribution of technological progress to output growth are highly volatile from decade to decade. This is evident not only from the sunrise-sunset diagrams, and the position of the economic sectors within them, but also from Spearman rank correlation coefficients computed on the rankings of the technology contributions of sectors in each decade. The rank correlation between the ranks of sectors in the 1970's and 1980's is –0.39, between the ranks in the 1970's and 1990's 0.19, and between the ranks in the 1980's and 1990's –0.50. The net implication is that the position of sectors relative to others in terms of their contribution to technological progress is volatile.

This volatility of the technology contribution emerging from the manufacturing sectors carries with it a potential policy implication for the promotion of technological progress. The volatility of the technology contribution of the economic sectors, means that it may prove to be very difficult to forecast with any reliability sectors that are promising candidates in developing new technology. The difficulty of forecasting the location of technological progress by implication renders difficult the process of targeting incentives for technological advance to specific sectors. The likelihood is simply that the targeted incentives will be misplaced, and thus constitute wasted resources. What is far more likely to be successful as a policy for technological innovation is the creation of general "enabling conditions" for entrepreneurs who wish to innovate, and then to allow entrepreneurs to take advantage of the enabling conditions wherever and whenever they may deem it to be appropriate. This allows the volatility in innovational location identified above to be accommodated, and allows an economy to take advantage of all innovative opportunity rather than simply in those sectors which government happens to have targeted.

We provide some additional deliberations on these policy-related concerns in a case study insert, entitled "A Misconceived Boast? Lessons From A Planned Economy." While the reflection is on the performance of a form of economic organization (socialism) no longer seriously considered as a contender in development, the example is nevertheless instructive. This is all the more so since the technological achievements of the Soviet Union (witness for instance the space race, in which Russia is cooperating with the United States to this day) are often thought impressive. As it turns out the Soviet Union in aggregate was nevertheless eclipsed technologically over time – and comprehensively so. It is therefore the *reasons* for the relative status of socialist models of innovation that are suggestive.

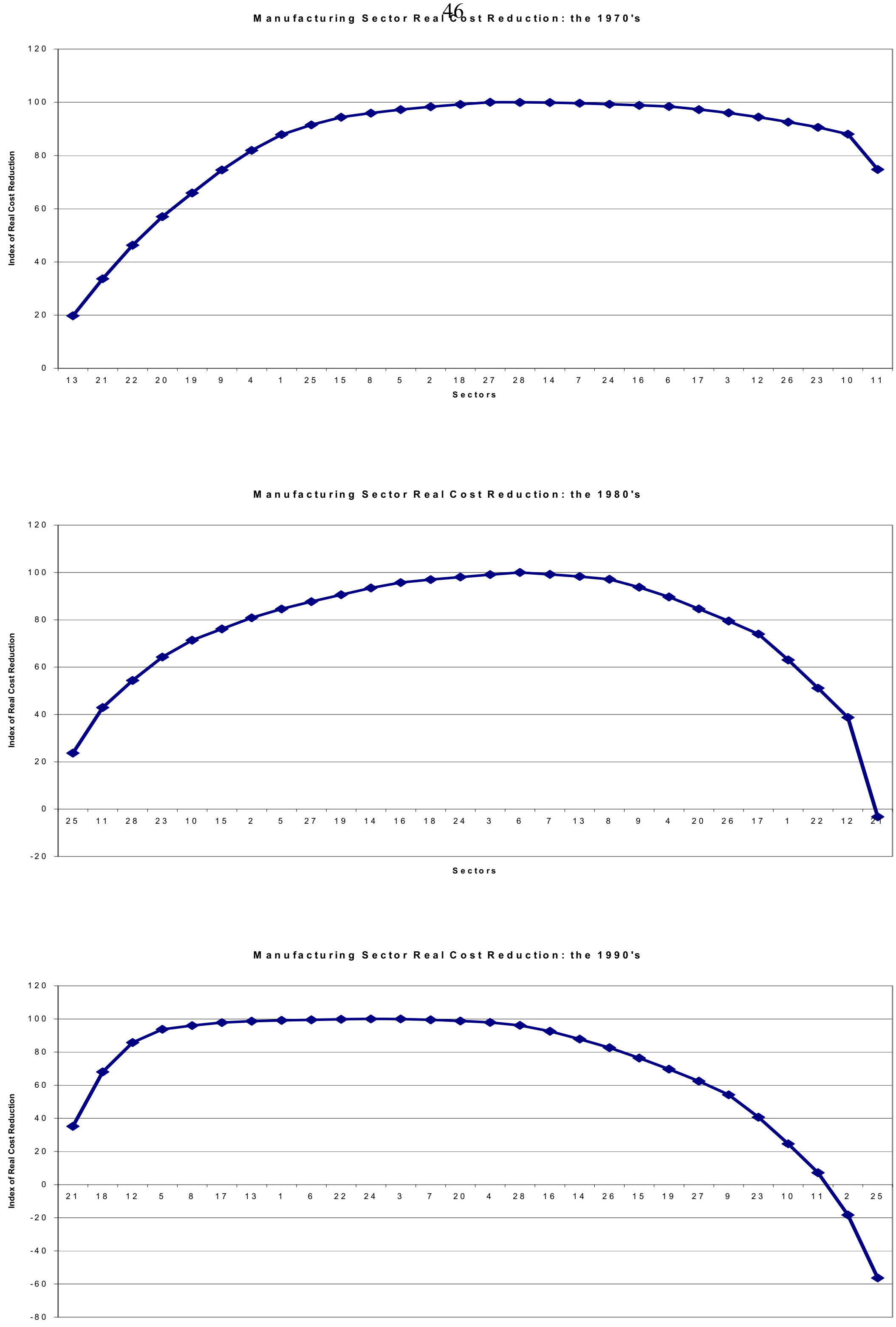

Figure 2.2: Real Cost Reduction in the South African Manufacturing Sector

Table 2.8: Key to the sectoral numbers reported in Figure 2.2

1	Food
2	Beverages
3	Tobacco
4	Textiles
5	Wearing apparel
6	Leather & leather products
7	Footwear
8	Wood & wood products
9	Paper & paper products
10	Printing, publishing & recorded media
11	Coke & refined petroleum products
12	Basic chemicals
13	Other chemicals & man-made fibres
14	Rubber products
15	Plastic products
16	Glass & glass products
17	Non-metallic minerals
18	Basic iron & steel
19	Basic non-ferrous metals
20	Metal products excluding machinery
21	Machinery & equipment
22	Electrical machinery
23	Television, radio & communication equipment
24	Professional & scientific equipment
25	Motor vehicles, parts & accessories
26	Other transport equipment
27	Furniture
28	Other industries

A MISCONCEIVED BOAST? LESSONS FROM A PLANNED ECONOMY

by Raphael de Kadt

By the standards of the OECD it is clear that an abundance of natural resources is not enough to guarantee long-term economic vitality and prosperity. Nor is the mere production of vast quantities of primary industrial goods. Nor, of course, are boasts or promises that are based on the assumption that the principal indicators of leading-edge performance in a modern economy are timeless and a matter of the mere volume of crude physical output.

In 1961, at the twenty-second Congress of the Communist Party of the Soviet Union, Nikita Krushchev launched the Third Economic Programme. This held out the promise that within two decades the performance of the Soviet Economy would have surpassed that of the USA. In its own terms, the promise was kept. As Martin Walker points out, by 1984 the Soviet Union produced 80% more steel, 42 % more oil and 55% more fertiliser than the USA. It produced more than twice as much pig iron, six times as much iron, and five times as many tractors and more than twice as many metal-cutting lathes as the US. (Martin Walker, *The Cold War,* pp233-234)

In 1961, as Martin Walker says, "these products embodied the sinews of industrial power. Had the world and its technologies stood still, the Soviet Union would have been an economic giant." And herein lies the rub: the great Soviet achievement, the result of an awesome exercise in centrally planned economic growth was flawed. And it was flawed precisely because the kind of central planning undertaken by the Soviet Union depended upon achieving targets "set by politicians and planners" in the belief that the very assumptions which underlay economic success were fixed. Walker comments: "by the time these figures of raw Soviet output overtook those of the United States, the West was living in an entirely different economic system, a post-industrial world in which the sinews of wealth were micro-chips rather than pig-iron, plastic rather than steel, and where conservation in the use of raw materials was becoming more important and more profitable than crude production". (Walker, p235) In short, the Soviet Union had lost the technological race with the capitalist West.

The question thus posed is why, and in what ways, did it lose this race? Perhaps the first point to make is that the Soviet failure was comprehensive. In virtually every domain of technological innovation from the end of the Second World War to the collapse of the Soviet system, the Soviet Union and its satellite states lagged far behind the capitalist West and, especially, the United States of America. Kornai (*The Socialist System: The Political Economy of Communism*, pp298-300) cites fifty instances of major technological advances from 1945-1982. These are grouped under the broad rubrics of *Information and Communication, Energy, Machines and Technology, Aviation* and *Medicine*. Together, these categories cover everything from transistors and programming languages to quartz watches, programmable robots, vaccines and diagnostic techniques. The remarkable fact is that 38 of these advances occur in the USA. Eleven occur in other capitalist economies and only four in the Soviet Union and its satellites. (In three instances they take place in more than one country simultaneously) This suggests that technological progress occurs in a "clustered" fashion with important dimensions of scale, indivisibility and interdependence.

Kornai, who notes that the causes are multiple, emphasises the following factors among others. First, following Schumpeter, he points to the systemic incapacity of a Soviet type economy to accommodate entrepreneurs. In a capitalist system, entrepreneurs can introduce new technologies either within the framework of existing organisations or by creating new organisations. "Capitalism allows entrepreneurs to undertake the introduction of a new technology, a new form of organisation, or a new product…..it is possible for new firms to be formed and get financing on the capital market." (Kornai, p 297) He points out that that is how a high proportion of the products referred to above were introduced.

Second, and related, he points to the bureaucratic rigidity of the "command economy" with its incapacity to fine tune supply and demand. Indeed, he claims that "the effect of bureaucratic coordination does not stop at making innovation next to impossible…it also undermines the efficiency of routine, day-to- day production". (p 297) There existed, in Martin Malia's words, "an increasingly complex productive system encased in an increasingly cumbersome administrative apparatus". (Martin Malia, *The Soviet Tragedy,* The Free Press, 1994, p475) Indeed, a paradox of the "classical socialist" system is that it is "not capable of reaching a high level of efficiency" (Kornai, p293). Kornai reflects on this "curious contradiction" in production as follows: "On the one hand, plans are taut, and those controlling production frequently complain that they are unable to produce the prescribed output from the input available to them. There are shortages of materials, parts and labour. It seems as if there were a high degree of utilization of resources. On the other hand, all the international comparisons show that the utilization of resources and the proportion between input and output are worse under classical socialism than under capitalism." (Kornai, p293)

This systemic inefficiency would seem to be linked to several factors which worked together to produce a context of "negative synergies". First, as already noted, the system was one of endemic shortages. Indeed, it has been referred to, following Kornai and Igor Birman, as an "economy of shortages" (Martin Malia, *The Soviet Tragedy,* The Free Press, 1994, p475). John Clark and Aaron Wildavsky, in *The Moral Collapse of Communism: Poland as a Cautionary Tale* (ICS Press, 1990) aver that the difficulty in securing supplies leads, insofar as innovation takes place at all, to technological innovation that "focuses on process rather than product". (Clark and Wildavsky, p286)

Second, there was an "incentive system that gave no one any motive to work" (Malia, p475). One of the features of the Soviet-type system was that the official ideology did *not* promise equality of incomes. Rather, the declared principle of distribution was "to each according to his work". This, at least in broad terms, is not entirely inconsistent with income distribution in a capitalist system. The difference, however, is that under capitalism the relationship between work and performance has a more precisely defined reward dimension. Under capitalism "performance is measured and rewards are set mainly (but not exclusively) by an anonymous, decentralised process: the labour market, on which the relative wages emerge". (Kornai, p324) However, in a "classical socialist economy the question of what income is due for what quantity and type of work is decided arbitrarily by persons appointed to do so" (Kornai, p.324). This fits with the broader point made by Kornai that the "relative prices of the factors of production under classical socialism bear no relation to their relative marginal productivity". (Kornai, p 225) Further, with respect to the efficiency of production, the "arbitrary relative prices of the factors preclude rational calculation based on costs and prices when technology is chosen". (Kornai p 225)

A more specific consequence noted by Kornai is that in the Soviet-type economy, securing good managers is difficult. Under capitalism, "firms compete for the best managers; they are in short supply and can almost dictate their own terms. The largest and most profitable firms outbid each other with offers of high pay. The zenith of a managerial career is to land one of the best-paying positions." (Pp324-325) However, under the Soviet-type system, enticing good managers into the realms of production, innovation and distribution is difficult, for managers all belong to the "same centralised bureaucracy". (p 325) "Each is a soldier of the party, which decides on one's appointment, not confining itself to economic criteria in doing so. An appointment to head the very largest firm is far from the zenith of one's potential career. The road is still open to even higher posts: one may be made a minister or a county secretary of the party, or join the apparatus at party headquarters. These higher appointments are the real reward". Thus, political and bureaucratic incentives over-ride economic incentives.

Further, in the Soviet-type command economy, the decisions to innovate and to take the associated risks are centralised. Clark and Wildavsky go as far as to suggest that the impact of technological innovation in such a system "creates the risk of disrupting the pattern of rule". (p.287) This reinforces the view that insufficient differentiation between the economy as a domain of firms, and the state bureaucracy as a domain of political power is inimical to innovation and technological progress. The disposition is to micro-manage from the top down and to reduce the autonomy of decision-making instances. This type of structure fits ill with a highly complex, dynamic, industrial/post-industrial economy with its myriad points of decision-making and outcome assessment. The seemingly "chaotic", "anarchic" character of such dynamic systems, with their inherently high levels of uncertainty and indeterminacy of outcomes, render *dirigiste* modes of economic planning inappropriate.

The much greater horizontal dissemination of nodes of decision-making in a capitalist economy – and here the United States is arguably paradigmatic – serves to underwrite technological innovation in a number of ways. First, the "paradox of innovation" - in the sense that it is difficult to "order" or "command" innovation of the kind that results in revolutionary new products that "transform production and people's way of life and consumption habits" (Kornai, pp295-296) - does not need to be addressed to the same extent. (See Clark and Wildavsky, pp 284-290) The decisions on what to produce, how and in what quantities are made by many and diverse instances. Entrepreneurs, while they might try to buy political influence and urge bureaucratic accommodation on the part of regulatory authorities, do not follow career paths mapped out within some politico-bureaucratic system. They succeed or fail, as risk takers, within the economic sphere. The consequences of decisions to invest – or not to invest - in new technologies are more immediately felt. Perhaps this is why, as Clark and Wildavsky note, in capitalist economies such as the United States and West Germany, innovations were implemented three times faster than in a centrally planned economy such as Poland.(p.286) Innovations in capitalist societies thus have many points of origin and, if successful, quickly reward those who make them. This structure of reward, furthermore, is backed up by a robust system of property rights and patent enforcement. It would seem, too, that this dissemination of decision-making entails returns on "local knowledge" – such as which university or research institute to endow, and for what purposes. All in all, it would seem to increase the overall "learning" capacity of the economy with respect to what works and what doesn't, why and for whom. The penalties for failure, as already indicated, are confined largely within the sphere of the economy and do not entail a prohibition on further risk-taking and entrepreneurial ventures.

To this may be added two further and related considerations. The first, closely examined by Alec Nove with respect to the Soviet type economy, is the lack of competition. The second is the seemingly pivotal role of the university-government-private sector nexus, especially as it evolved in the USA. The British government effectively endorsed the dynamism of aspects of this nexus in 1999 when, unprecedentedly, it financed a seven hundred million Rand partnership between the University of Cambridge and the MIT to embrace, among other things, the latter's successful strategy of creating "spin-off" companies.(See *The Financial Times,* Wednesday December 1, 1999, p 10 - "Transatlantic transfer of knowhow to build a knowledge-based economy")

As a final comment on the manufacturing industry evidence, note again that the structure of output growth within the sector appears to have fundamentally changed over the past thirty years. This is illustrated by the fact that while in the 1970's and 1980's sectors that experienced strong output growth were also sectors that experienced strong technological progress. Thus the correlation between output growth and technological progress in the manufacturing sectors was 0.79 and 0.93 respectively. By contrast, during the 1990's this between output and technological growth falls to 0.38. What replaces the technology contribution is growth in capital stock. Thus while the correlation between growth in capital stock and output growth in the 1970's and 1980's was –0.14 and 0.30 respectively, the correlation rises dramatically to 0.74 in the 1990's.

A number of explanations are possible for this transformation. The first is the evidence now accumulating that capital markets in South Africa underwent restructuring during the course of the 1990's.[13] The suggestion is that the 1970's and 1980's through state intervention in capital markets, and due to the relative international isolation of this period saw strong distortions in capital markets due to policy interventions. The liberalization of the policy environment saw changed incentives and rates of return to investment activity, such that capital came to be reallocated from sectors with strong state involvement, to manufacturing industry. Hence the strong burst in capital creation in manufacturing sectors, including those with historically small capital stock.

A second potential explanation for the changing profile in manufacturing sector output growth arises from the likely impact of the period of international isolation South Africa faced during the 1970's and 1980's. In general we might expect manufacturing sectors in developing countries to follow advances in technology generated in developed countries, rather than incurring the cost of generating new technology of their own accord. Such emulation presupposes the possibility of access, however. The period of isolation may have made access to international advances either impossible, or at the very least more costly. As a consequence it may well be that South African manufacturing industry was starved of access to international capital markets, and of access to technological progress, and thus simply had little option but to engage in technological innovation of its own accord.

2.3 Conclusion and Evaluation

We have not yet seen how or why technology contributes significantly to economic growth. But what we have seen demonstrated is strong evidence that technological progress contributes very substantially to output growth both internationally, and within South Africa in particular.

As regards the South African evidence, we note the increasing contribution of technological progress to total real output growth. But we need to be equally conscious of the very marked differences between sectors in terms of their contribution to technological innovation. As well as the strong differences that mark sectors' contribution to technological change *across* time.

[13] See for instance Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000).

Manufacturing industry has moved from relying strongly on TFP growth during the 1970's and 1980's, to reliance on growth in physical capital stock in the 1990's in order to generate growth in output. In this it has reversed the developmental path which differentiated South Africa strongly from the experience of other middle income countries, and has moved to a more conventional pattern of development.

Finally, we also note that technological progress tends to be strongly *concentrated* in the manufacturing sector, with a small number of sectors contributing virtually all the positive growth there is.

Unfortunately these innovative sectors tend to change from decade to decade, making prediction of future sources of TFP growth difficult.

Chapter 3

Four Core Explanations of the Growth – Technology Nexus

3.0 So how do we explain the impact of technology on economic growth?

Thus far we have seen that both international, as well as South African evidence supports the suggestion that technological progress has a positive impact on long run economic growth of an economy. In reaching this conclusion, we have paid some attention to sectoral nuances in the South African economy. But we have left aside entirely any attempt to provide a systematic account of how or why it is that technology should have an impact on growth. Certainly we have not considered at all the precise channels along which technology is likely to generate growth in output.

It is to this omission that we now turn our attention.

Having completed our discussion of the theoretical explanations of why technology positively affects output over time, we will return to the issue of which of these explanations finds the strongest empirical support internationally and for South Africa specifically.

While growth theory has paid attention to technical progress virtually from the outset it is really with respect to *how* technological progress has been conceived that the new or endogenous growth theory is most strongly distinguished from earlier debates. For this reason we will begin very briefly by an exposition of early treatments of technological change by growth theorists, demonstrate why the approach is not satisfactory, and then move on to concentrate on the modern debate surrounding technological advance and growth. The section is not essential to the discussion which follows, and can be omitted by readers uninterested in the full background. By contrast section 3.2 concerns itself with the core of modern growth theory, and is correspondingly important.

3.1 Technology as a public good, or the traditional view of technological change

We will begin our discussion with a consideration of what we will term the "traditional" approach to the problem of technological change. Its strongest distinguishing characteristics are (a) that it treats technological change as exogenous, determined by the activity of scientists and inventors whose activity is not itself modelled in the theory, and (b) that technology is conceived of as what economists term a public good, available to all once it is has been developed.

Here we will distinguish between two general types of technical progress, augmented and embodied technical progress. The distinction between the two is that in augmented technical progress all factors of production, old and new, benefit from technological advance. In embodied technical progress only "new" factors of production (usually capital) become more efficient. The difficulty with all these approaches is that they explain the *effects* of technological advance, not how and why it comes to be.

3.1.1 Augmented technological change

Augmented technological change affects both old inputs into the production process which were already in place before the technological progress, and new inputs that are newly added to production. Augmented technological change can take three forms, neutral, labour augmenting, or capital augmenting.

3.1.1.1 Neutral augmented technological change

Neutral augmented technological change improves the efficiency of both factors of production, capital and labour, equally. Economists term this form of technological progress Hicks neutral technological change.[1] A technological change is "neutral" if it leaves the ratio of the marginal products[2] of the factors of production unchanged for a given level of per-capita capital stock (capital-labour ratio).[3] Examples of such innovation might be provided by organisational improvements that improve the efficiency with which both factors of production are employed.

The standard assumption here is that technological change occurs costlessly in the economy, and that the growth rate in technology is constant over time. These assumptions effectively amount to saying that the process of technological change occurs exogenously to the model itself. It just happens by whatever mysterious processes drive technology and its change. In other words, the real point of this approach is to establish that technological change may come to affect the productivity of both factors of production equally, not to explain the *source* of technological change *per se*.

Incorporating this view of technological change into a decomposition of the growth in output,[4] would provide us with the following characterization of the growth process:

$$\frac{\dot{Y}}{Y} = \eta_K \frac{\dot{K}}{K} + \eta_L \frac{\dot{L}}{L} + \tau \qquad (1)$$

where τ denotes the exogenously determined rate of technological progress. The three ratios denote the proportional growth rates in output (Y), capital (K) and labour (L), while the two η's denote the elasticity of output with respect to the two factors of production. Readers should note that this depiction of technological change and its impact is indistinguishable from that which underlay the descriptive discussion of Sections 2.1 and 2.2, since output growth is parceled out to growth in capital inputs, labour inputs and what remains for technology. Thus in effect any empirical work within this framework tells us whether technological change affected the growth in

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[1] See the early discussion in Solow (1957).
[2] The addition to output that results from a one unit increase in the relevant factor of production.
[3] Economists would say that the marginal rate of substitution between capital and labour remains unchanged for a given capital-labour ratio.
[4] The assumption is of a production function homogeneous of degree one (i.e. constant returns to scale).

output, not how it did so, or why the technological change came about in the first instance.

3.1.1.2 Labour augmenting technological change

Labour augmenting technological change improves the efficiency of labour inputs, but not of capital inputs. Economists term this form of technological progress Harrod neutral technological progress. Under disembodied labour-augmenting technological change the productivity of labour improves over time, through education, training, and learning. The assumption is that all workers share in this productivity improvement equally. The growth rate of the labour force is thus not only given by the growth in physical labour time available for production, but also by the addition to effective labour time available, due to improvements in its efficiency.

Again, the analysis proceeds on the assumption that technological change occurs costlessly in the economy, and that the growth rate in technology is constant over time, so that the process of technological change continues to occur exogenously to the model itself. It just happens by whatever mysterious processes drive technology and its change.

In other words, the point of this approach is to establish that technological change may come to affect the productivity of labour specifically, rather than both factors of production equally. The point is not to explain the *source* of technological change per se.

Incorporating this view of technological change into a decomposition of the growth in output, would provide us with the following characterization of the growth process:

$$\frac{\dot{Y}}{Y} = \eta_K \frac{\dot{K}}{K} + \eta_L \frac{\dot{L}}{L} + \eta_L \lambda \qquad (2)$$

where λ denotes the augmentation of labour efficiency due to technological progress, and all other terms are defined as before.

Again this depiction of technological change and its impact is indistinguishable from that which underlay the descriptive discussion of Sections 2.1 and 2.2. Thus in effect any empirical work within this framework tells us whether and by how much technological change rather than growth in capital or labour affected the growth in output, not how it did so, or why the technological change came about in the first instance.

3.1.1.3 Capital augmenting technological change

Capital augmenting technological change improves the efficiency of capital inputs, but not labour inputs, and is termed Solow neutral technological progress. Under disembodied capital-augmenting technological change, the productivity of capital improves over time. The assumption is that all capital equipment shares in this productivity improvement equally, regardless of whether it is an “old” (already existant) or “new” piece of capital equipment. Presumably, this would relate to improvements to the use of capital, rather than improvements in the capital itself. The growth rate of the capital stock is thus not only given by the addition to machine hours available for production, but also by the improvement in the efficiency of the machine hours available.

Again, the point of this approach is to establish that technological change may come to affect the productivity of capital specifically. The point is not to explain the *source* of technological change per se.

Proceeding with the decomposition of output growth as before, we obtain:

$$\frac{\dot{Y}}{Y} = \eta_K \frac{\dot{K}}{K} + \eta_L \frac{\dot{L}}{L} + \eta_L \kappa \qquad (3)$$

where κ denotes the augmentation of capital efficiency due to technological progress, and all other terms are defined as before.

Again this depiction of technological change and its impact is indistinguishable from that which underlay the descriptive discussion of Sections 2.1 and 2.2. Thus in effect any empirical work within this framework tells us whether technological change affected the growth in output, not how it did so, or why the technological change came about in the first instance.

In all of these three traditional approaches to technological progress we have thus not really moved beyond the discussion of Sections 2.1 and 2.2. The point of these approaches is really to demonstrate that the source of the efficiency gains that we attribute to technology can really work by improving the efficiency of both factors of production equally, or by improving the efficiency of either of the two factors of production singly. We are not yet in a position to understand how or why technology comes to have the impact of improving efficiency.

3.1.2 Embodied technological change

The same limitation attaches to embodied technical progress. But the approach does add nuance to our understanding of the possible impact of technical change.

Embodied technological change is held to be "embodied" in the factor of production being added to the production process (typically assumed to be capital).[5] Thus only new capital equipment, for instance, will be more efficient, while capital equipment put in place before the technological innovation, does not benefit from the technological change. In contrast to the previous cases of technological change, the assumption here is that it is only new pieces of capital equipment which have an improved productivity. New machines are improved, and hence are more efficient than old machines. Under circumstances where aggregate investment reduces the average age of the capital stock therefore, output will increase because:

- *the size* of the capital stock has increased - there are more machine hours engaged in production than previously;
- machine hours may become more *efficient* due embodied technological change;
- the *average* machine hour will become more efficient, since the average age of the capital stock has decreased, and younger machines are more productive.

[5] Nothing in principle prevents its application to labour, however.

Instead of having capital stock in the production function, we replace it with *capital jelly*, which is simply the aggregate capital stock in machine hours, with each machine hour weighted by a technical progress factor, which reflects its newness. In contrast to capital and labour augmenting technological progress, capital jelly now generates three distinct sources of growth. The first is that the actual capital "base" may be increasing over time, and the second is the improvement in the efficiency of the capital base, much as before for capital augmenting technological change except that now technological advance is 'embodied'. However, technical progress no longer attaches to each machine hour equally, as was the case for augmenting technological progress. Instead, the newer the machine generating the machine hour, the more technical progress it would have been able to incorporate, and hence the more efficient it would be. As a consequence, a third source of growth in capital jelly arises from the fact that the average age of the total stock of jelly is constantly changing, becoming younger as more units of capital are added to the economies' stock of capital, and hence improving the average efficiency of the capital stock.

Nelson (1964) provided initial estimates of the relative importance of various sources of technological change. He began by noting that the average age of capital did change in the USA, over a number of different time periods. **Table 3.1** reports - note that while the change in the age composition of US capital over the full 1929-60 period was increasing, over the post war period there has been a consistent decline in the average age structure of the US capital stock. According to the embodied technological change approach this would imply an improvement in efficiency of the US capital stock in the post-war period.

The full decomposition under two alternative assumptions about the elasticity of output with respect to capital according to Nelson (1964) were then those provided by **Table 3.2**. Note that on the assumption that all improvements in TFP are due to technological improvements, the estimates imply that:

- the majority of growth in total factor productivity is accounted for by embodied improvements in TFP,
- and the minority by a changing age composition in the age structure of the capital stock.

Moreover, on the embodiment approach to technical change, the acceleration of growth in the post-war era in the US can be accounted for not by an acceleration of technological progress, but by a narrowing gap between best and average practice. Thus growth is generated not by strong advances in knowledge being generally disseminated across the whole economy. Instead growth arises from a process whereby more firms are moving their activity closer to the current best forms of production activity. Thus more of the economy is producing in terms of the best technology available. Thus in the pre-war era the rising average age of the capital stock implied a widening gap between best practice as represented by the most efficient (recent) capital stock, and the average practice as represented by the average age of the capital stock. In the post-war era the average age of the capital stock in the US was declining, improving the efficiency of the capital stock of the US.

Hulten provides an extended set of results for the USA, over the 1949-83 period. Some of the implications of Hulten's findings are summarized in **Table 3.3.** As for Nelson (1964), the greater proportion of the growth in total factor productivity is attributable to embodied improvements in TFP, the efficiency gain factor, and the minority by a changing composition in the age structure of the capital. Moreover, in Hulten's sample the contribution of the average age of the capital stock declines in the second half of the sample period. For 1949-73, the embodied and the average change in age factor contributions are 0.79 and 0.12 respectively, while for 1974-83 they decline to 0.76 and 0.06.

Table 3.1: Changing Age Composition of US Capital Stock: 1929-60.

Subperiod	Average Change in Age of Capital Stock
1929-60	+0.006
1929-47	+0.20
1947-60	-0.23
1947-54	-0.28
1954-60	-0.17

Source: Nelson (1964: Table 3)

Table 3.2: Components of Embodied Technological Change (percentage annual growth rate).

	Elasticity=0.25			Elasticity=0.5		
Periods	TFP	κ	Age	TFP	κ	Age
1929-60	2.1	2.1	0	1.7	1.7	0
1929-47	1.9	2.3	-0.4	1.7	2.1	-0.4
1947-60	2.5	2.0	0.5	1.8	1.5	0.3
1947-54	2.9	2.3	0.6	2.1	1.7	0.4
1954-60	2.1	1.8	0.3	1.6	1.4	0.2

Source: Nelson (1964: Table 4)

Table 3.3: Components of Embodied Technological Change by Type of Equipment, 1949-83

Equipment Class	TFP	Embodied Efficiency	Age
Furniture and Fixtures		0.1	0.02
Fabricated Metal Products		0.37	0.03
Engines and Turbines		1.74	0.21
Construction Equipment		0.33	0.03
Metal-working Equipment		0.28	0.05
Special Industry Equipment		1.76	0.35
General Industry Equipment		0.38	0.06
Office Computing Equipment		5.70	0.45
Service-industry Equipment		1.23	0.29
Communications Equipment		2.27	0.44
Electric Transmissions Equipment		0.46	0.05
Household Electric Equipment		0.10	0.04
Trucks		0.39	0.05
Autos		0.10	0.01
Scientific and Engineering		1.53	0.04
Copy Equipment		0.29	0.02
Other Equipment		0.24	0.05
ALL EQUIPMENT	1.17	0.79	0.10

Source: Hulten (1992: calculated from Appendix)

The conclusion thus is that embodied effects significantly contribute to the capital stock. However, only a very small proportion of embodiment effects are manifested in vintage effects in capital. One possible policy implication of the embodiment approach to technical change is that the rate of output growth can be stimulated by government through investment (tax) subsidies that serve to improve the average age of the capital stock and hence its efficiency, as well as the growth rate in the capital factor of production. This might take the form of accelerated depreciation allowances on capital, special tax concessions on revenue attributable to new capital stock, and special import tariffs attached to advanced capital equipment.

However, Denison (1964) argued from the start that the embodiment issue is of little importance in terms of growth accounting, as long as (a) capital goods do not have a very long life, (b) age distributions of the capital stock are not grossly distorted, and (c) where there are no constraints toward the equalization of returns on capital. The findings of both Nelson (1964) and Hulten (1992) concur with this finding, suggesting that the impact of the quality change associated with the changing age distribution of capital stock due to an increased rate of capital formation is small. From Hulten's results a 1% increase in the growth rate of producer's durable equipment, leads to a 0.127% increase in real output growth (ceteris paribus), with a 0.103 percentage point direct effect, and only a 0.024 percentage point embodiment effect. Thus the policy of tax incentives for reducing the vintage of capital stock promises very low returns, and is of questionable efficacy.

The reason for this finding is not difficult to grasp. Improvements in the efficiency of capital due to technological change will render “old” vintages obsolete, and the market will itself force the removal of inefficient forms of capital stock from production. The net result will be that under relatively constant rates of technological improvement, the average age of the capital stock will itself adjust to reflect technological advances, without the need for a stimulus from government intervention.

3.1.3 Conclusion and evaluation

Let us conclude with a final evaluation of the traditional approach to technological progress and its impact on growth.

We have introduced technological change into our account of the growth process. In the present section we noted that the impact of technical progress could be distinct, attaching to improvements in capital and labour equally, or to either of the two factors of production individually. Lastly, we noted that technological progress, insofar as it attaches to the capital stock, would make a changing vintage composition of the capital stock over time potentially important. Given that capital is likely to persist over time, with technological progress over time the capital stock of an economy would come to show a changing composition in terms of its efficiency. We introduced the notion of embodied as opposed to augmenting technical change to capture this effect, and replaced the capital stock with the notion of capital jelly.

In effect, this section clarifies to some extent what we might mean by technical progress, and identifies an additional source of growth in output over and above growth in output that is attributable to growth in factor inputs.

However, the view of technological progress presented here still suffers from some limitations.

Most notable of these are that the discussion of technical progress remains silent about the *source* of technological advance. In effect, it treats technical progress as exogenous to the economy, as emerging from a “black box” of creativity that does little to clarify how the process of technical advance might be accelerated or impeded. This represents a serious limitation, since potentially technical advance represents a very significant portion of total growth (recall the discussion in Sections 2.1 and 2.2). An admission that we are unable to shed light on the motor forces fashioning the rate of technological advance would amount to an admission of considerable ignorance. It is for this reason that concern with endogenising the process of technological advance has been the concern of new or endogenous growth theory, and we turn to such contributions in the following subsections.

There is one qualification that we might make to the assertion that the above treatment of technology renders the process of technological advance exogenous. Returning to Hicks neutral technical change, we note that the rate of technical progress we encountered was described as a constant, say τ. If true, the implication of this is the implication is that knowledge is increasing exponentially over time. The change in technology is proportional to itself, implying that it is knowledge itself that generates change in knowledge. In effect, the view here is of knowledge emerging out of a ‘perfect university system’, with knowledge producing additions to knowledge, without the need to invest any further resources, and the greater the accumulation of knowledge, the greater the additions to knowledge that would follow. In fact therefore, the traditional view of technological change *implicitly* does carry a view as to the source of the progress in knowledge. But it is also a very particular and limiting view of the knowledge-production process, and greater clarity as to what the impact of for instance the investment of non-knowledge resources in the production of knowledge might have on the rate of technological advance, is palpable in the urgency of its demand.

A second limitation of the present treatment of technology is that it does not address explicitly the nature of the knowledge that underlies technological advance. It implicitly treats technological advance as a public good, immediately available to all on discovery. This may be heroic at best, and plainly false at worst. Acquisition of advances in knowledge may be costly, and may be subject to exclusion (think of patents and their enforcement). In the jargon of economics knowledge may thus contain considerable private good characteristics, and at the very least might be best treated as a mixed rather than public good. We will see in later subsections that both the possibility of absolute exclusion, and the possibility that technology may be subject to slow diffusion (due to costs of acquisition) carries important implications for our understanding of the role and nature of technology's impact on the growth process.

We now turn to such concerns.

3.2 Endogenous technological change, or the "new" growth theory

In all of the approaches to technological change we have encountered thus far, a common feature has been that technological change has effectively been assumed to be exogenous. That is, no explanation has been offered of why technological change has assumed the pace that it has, and what might cause the rate of change in technological progress to alter over time. "New", or "endogenous" growth theory addresses just these questions directly, and as its label suggests, endogenises technological change into the theory of economic growth itself.

The attraction of this approach is clear. We have seen from an examination of the empirical evidence that a significant proportion of economic growth can be, or at least has been attributed to technological progress. Any comprehensive attempt to explain economic growth must therefore presumably sooner or later be forced to address the question of what might come to determine the rate of technological change.

Technological change has been endogenised into economic growth models by a number of different routes, of which we will focus on two. First we will examine the effects of positive externalities attached to investment in the form of learning effects. Second, we will explore the consequences of distinguishing clearly between the public and private good aspects of knowledge for economic growth, and of allowing technological progress to be the outcome of explicit R&D activity of the economy.

But we begin our discussion of a model of endogenous technological change that has been available in the literature for some time - that of Karl Shell, in order to provide a point of departure, but also to emphasize Nelson's (1994) point about the persistence of the questions that underlie economic growth theory.

3.2.1 Endogenous technological change: the perfect university view

While an earlier model of endogenous technological change is that of Arrow (1962), we leave this aside for the time being, since Romer (1986), the subject of the next section, can be regarded as being explicitly concerned with an application of Arrow. Instead, we consider the approach provided by Shell (1966), in which technological progress depends on the amount of resources devoted to inventive activity.

Shell argues that the change in technology per unit of time will be positively affected by the resources devoted to knowledge creation. He also suggests that knowledge is also subject to "depreciation", as old forms of technology face obsolescence. This provides the differential equation given by:

$$\frac{dA}{dt} = \sigma\alpha(t)Y(t) - \beta A(t) \tag{4}$$

where A denotes the level of technology, σ denotes a "research success" coefficient (i.e. how likely it is that research will result in useable technological advance), α the proportion of output devoted to research and development (R&D), Y denotes output, and β denotes the rate of decay of technology. Thus the suggestion is that technological progress will depend explicitly on the resources devoted to the advance of knowledge. One might think of this as the resources devoted to R&D, and the more resources devoted to R&D the faster knowledge will advance, subject to the research success coefficient.

An alternative proposition to the one formulated above would be to suggest that the change in knowledge is related not to the resources devoted to it, but to the level of knowledge that we have already attained. The more we know, the more we are able to add to the stock of knowledge. This is effectively the principle that motivates the formation of institutions such as universities. Agglomerating individuals with superior access to knowledge, and providing resources such as libraries which store the accumulated knowledge from the past is meant to improve the process of transmitting already existing knowledge to new initiates, and to accelerate the augmentation of technology by making it easier to research. Thus we would have:

$$\frac{dA}{dt} = \sigma\alpha(t)A(t) - \beta A(t) \tag{5}$$

with the same notation as before.

It turns out that the simple distinction drawn between these two alternative knowledge creating processes carries with it profound differences. The most salient for our purposes here is that within the context of standard growth models the first knowledge creating process will eventually cease to generate new knowledge.[6] By contrast, under the second specification knowledge will increase indefinitely,[7] and this perpetual knowledge growth will be a source of unbounded growth in output.

The important point to take away here is not a comprehensive understanding of the process driving knowledge accumulation. Rather the point is that postulating even relatively simple differences in the nature of the process governing the growth of knowledge carries important implications for growth. Here we saw two instances in which knowledge either does, or does not issue in a perpetual source of economic growth. In the one case knowledge accumulation ceases, in the other it continues indefinitely.

We turn now to the central propositions of the new growth theory explaining the technology-growth nexus.

3.2.2 Endogenous technological change: knowledge spill-over effects, or learning by doing

New growth theory received its first palpable impetus through the work of Paul Romer, notably Romer (1986). The argument presented in Romer (1986) revived insights which Arrow (1962) had already formalised - the possibility that the very process of being engaged in a productive activity generates learning effects, allows

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[6] The reasons for this are fairly complex. It is the outcome of solving the dynamics of the system in the two state variables capital and technology. The most fundamental reason however is that production is held to take place under conditions of constant returns to scale, and will drive output to steady state. Hence since output stabilizes, technology stabilizes.

[7] This follows immediately from the differential equation. Dividing through by A(t), we have the proportional growth rate in technology given by the difference $\sigma\alpha-\beta$, which will be positive as long as $\sigma\alpha>\beta$.

those who are engaged in productive tasks to become more efficient at performing them.

The impact of Romer's contribution can perhaps be attributed to the fact that by the mid-1980's, considerable empirical evidence had accumulated on the growth performance of a wide range of countries, which had pursued independent economic policies and development since independence in the early to mid-1960's. Romer's starting-point was the observation that empirical evidence on the growth performance of a wide cross-section of countries did not conform with the expectations arising out of traditional growth theory. Traditional growth theory predicted that the growth performance of countries would steadily taper off, slowing over time. Moreover, it would predict that we should be able to account for cross-country differences in per capita output after accounting for the impact of the endowment of capital stock, and after taking into account the growth rate of the labour force. Yet empirically this is palpably not the case. Instead we have observed ever increasing divergence in per capita GDP between countries (see the discussion of Chapter 1, and also the evidence in Maddison (1987)), and little evidence of per capita output growth for developed countries slowing over time.

As to the prediction of a declining growth rate experienced by countries, Romer (1986) notes that this is simply not the case:

1. An examination of the annual average growth rate in per capita GDP for the technological and economic world leader over the 1700 - 1979 period, reveals that the average growth rate of the world leader has been steadily increasing over the past three centuries, rather than decreasing as we would expect in terms of traditional growth theory. See **Table 3.4.**

2. More narrow focus on the experience over time of the most recent world technological and economic leader, the USA, reveals similar evidence. The average annual growth rate in per capita GDP for the USA has been on a steady upward trend over the 19'th and 20'th centuries. See **Table 3.5.**

3. The time-series evidence for the USA is corroborated by similar evidence for other industrialized countries, for most of whom the trend in the growth rate of per capita GDP is not only positive, but significant (Sweden and Canada might be exceptions). See **Table 3.6**.

Of course, one reason for these accelerating per capita growth rates might be that the countries are being constantly affected by technological change, such that per capita GDP becomes greater and greater. However this begs the question of why the pace of technological change has been steadily accelerating. Since the traditional theory of economic growth does not account for the source of technological change, and certainly not its rate of change, it fails to explain one of the most salient features of the growth experience over the past three centuries. Clearly its explanatory power is open to question, and there is a need to account either for the nature of the world's growth experience, or the source of the accelerating technical progress.

Table 3.4: Productivity Growth Rates for Leading Countries

Lead Country	Interval	Average Annual Compound Growth Rate of Real Output per Man-Hour (%)
Netherlands	1700-1785	-0.07
United Kingdom	1785-1820	0.5
United Kingdom	1820-1890	1.4
United States	1890-1979	2.3

Source: Romer (1986: Table 1).

Table 3.5: Per Capita Growth in the United States

Interval	Average Annual Compound Growth Rate of Real per Capita GDP (%)
1800-1840	0.58
1840-1880	1.44
1880-1920	1.78
1920-1960	1.68
1960-1978	2.47

Source: Romer (1986: Table 2).

Table 3.6: Trend in Per Capita GDP Growth Rates: π is the sample estimate of the probability that of any two growth rates chosen the later growth rate will be larger. The p-value is the probability of observing a value of π at least as large as the observed magnitude under the null that the true probability is 0.5.

	Date of First Observation	π	p-Value
United Kingdom	1700	0.63	0.06
France	1700	0.69	0.01
Denmark	1818	0.70	0.02
United States	1800	0.68	0.03
Germany	1850	0.67	0.06
Sweden	1861	0.58	0.25
Italy	1861	0.76	0.01
Australia	1861	0.64	0.11
Norway	1865	0.81	0.002
Japan	1870	0.67	0.07
Canada	1870	0.64	0.12

Source: Romer (1986: Table 3).

In constructing an alternative approach, Romer (1986) makes the crucial assumption that the process of investing in physical capital has the effect of creating knowledge which the firm undertaking the investment cannot internalize: it becomes available to all firms in the industry. Economists call such an occurrence a positive externality – there is a positive efficiency gain for all firms external to the investor in this instance.

The assumption in fact has two important components: the process of learning-by-doing, and the view that such learning will be available to all firms in an industry.

The motivation for this assumption reflects empirical experience in large scale manufacturing processes already formalized by Arrow (1962). The building of Liberty ships and bombers in World War II in the USA was characterized by increasing levels of productivity by labour and fixed capital inputs into the production process. Workers were "*learning-by-doing*", learning to do their tasks more efficiently simply in the process of doing them. The very act of investment and production was thus increasing the level of knowledge and productivity available for production, in effect expanding the effective factors of production being input into the production process.

To the existence of learning-by-doing is added the additional presumption that any knowledge gains obtained from the process of production and investment cannot be internalized by the firm in which that knowledge-creation takes place. Thus the learning spills over to become available to all labour, and all producers in the economy. With spill-over effects, the suggestion is that knowledge production is an inadvertent side-product of all production and investment activity, and would thus take place whether firms wish to undertake it or not, whenever they are engaged in their standard day-to-day activity.

In the Romer model the effect of knowledge spill-over is to ensure that the efficiency of the labour input at the social level will improve. The consequence of this is that the production function comes to show increasing returns to scale at the social level, though the production function of each firm continues to manifest constant returns to scale.[8]

The crucial difference between the Romer "new" growth model and traditional growth models relates to the nature of the capital stock in the economy. Once social returns to scale in capital are constant, it immediately follows that the marginal product of capital becomes constant also. As a consequence, in traditional growth models the incentive to invest declines with rising capital labour ratios, since the marginal product of capital and hence the profit rate falls. In the Romer model the incentive to invest does not change with the rising capital labour ratio, since now the marginal product of capital and hence the profit rate are constant also. As a consequence, there is no incentive for the economy to ever "slow down", once it has started to expand, and it will do so indefinitely.

So much for a brief intuitive exposition of the theoretical proposition. But how does it stand up to scrutiny?

[8] This is a major source of difference with the Arrow (1962) approach, and the reason why the Romer (1986) article is seminal in launching the new growth theory.

The first point to note is that the Romer model is able to account for the failure of poor countries to catch up with rich countries. Since the incentive to invest does not decline with rising per capita capital stock the growth rate of the capital labour ratio and of per capita output does not change either. As a consequence, there is no reason why countries which have high per capita output should grow any slower than countries which have low per capita output, such that there is no inherent tendency toward catch-up as is present in traditional growth models.

However, it is important to realize that the source of the non-declining incentive to invest here rests on the failure of the marginal productivity of capital to decline with a rising capital stock. The reason for the constant marginal product of capital is the knowledge spill-over effect which attaches to the process of adding to the capital stock. In the first instance, a necessary condition for this to be feasible is that knowledge have public good characteristics. That is, the act of investment, adding to the capital stock, is automatically seen to increase the effective labour force in the throughout the economy. There is no labour hour whose productivity is not improved. This is clearly a very strong assumption to make. But not only is the assumption particularly strong, it is also critical to the result. As Dasgupta and Stiglitz (1988) demonstrate, even partial excludability of the knowledge spill-over effects has the effect of destroying the result. Moreover, not only are knowledge spill-overs within countries potentially imperfect, but Barro and Sala-i-Martin (1992) demonstrate that while capital and technology may move between regions, the rate of diffusion is not instantaneous, but takes time. Hence, the public good characteristic of technology on which the result relies, is at the very least questionable. While capable of accounting for the failure of poor countries to catch up with the rich, therefore, the result is sensitive to the characteristic underlying assumptions, in particular the pure public good characteristic of knowledge.

To the extent that we accept the model, however, it carries with it clear policy implications. Since knowledge has pure public good characteristics, in the sense that spill-over effects are non-excludable (available to all), the consequence is that investors do not have the opportunity to internalize the full marginal benefits which attach to a piece of capital equipment. At least some of the benefit leaks away to increase labour efficiency throughout the economy. The consequence will be private sector under -investment in capital, such that investment will not reach the point where the social marginal product of capital is equal to the social marginal cost of capital. Investment will cease at a point where the private marginal product of capital equals the private marginal cost, such that the social marginal product remains above social marginal cost. The appropriate policy intervention is that government:

- subsidize purchases of capital goods, through investment tax credits, for instance

- or subsidize production, raising the return on investment, and hence the incentive to invest.

In effect, the objective would be to raise the private marginal product to the level of the social marginal product of capital through government intervention, thereby increasing the inducement to invest, until the point of equality between social marginal product and cost of capital is attained.

But given the limitations attaching to the approach noted above, perhaps the major achievement of the Romer (1986) approach was to place the process of technological innovation itself onto the research agenda. It was no longer acceptable to simply "assume" technological progress, and to then assign such progress to capital, labour, or both factor of production efficiency improvements.

3.2.3 Endogenous technological change: the intentional creation of new knowledge through R&D

Arguably a very surprising feature of all of the explanations of the interaction between technological progress and economic growth we have seen thus far is that the technological progress always seems to somehow "just happen", either explicitly exogenously in the case of the traditional growth theory, or as a by-product of other activity (investment or production) in the case of learning-by-doing.

The obvious question to ask is why nobody treats the production of new technology as an intentional human activity– which is purposefully engaged in with the view of making a profit? In short, surely technology is the outcome of real people who decide to "just do it" rather than something that "just happens" to humans. And quite probably they "just do it" because rewards attach to the activity of invention.

The answer to the question is that the issue has been thought about for some time by economists – at least since the time of Schumpeter.[9] Perhaps the most famous modern instantiation is the contribution by Romer (1990).

The crucial move in the argument in terms of the economics of the model developed is that knowledge is no longer treated as a public good. Recall that in both the traditional view of technological progress, as well as in the knowledge spill-over approach the view was always one that knowledge and technology was freely available to anybody who wished to access that technology. Under these circumstances it is not possible to exclude anyone from using any technological advance that happens to occur. Hence, under the assumption of technology as a public good it is impossible to explain why any rational agent would spend resources on developing new technology. Since no one can be excluded from accessing the newly developed technology, they cannot be charged for its use, and inventors of the new technology would thus not be rewarded for their trouble.

In order to make it possible for rational agents to undertake purposeful innovation of technology, it is necessary to allow technology to be a private good. That is, at least to some extent inventors of new ways of doing things have to be able to exclude other economic agents from employing their inventions, or at least they have to be in a position to charge, be rewarded for what they do. It is this proposition that underpins contributions to the technological progress debate in the Schumpeterian tradition.

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[9] See Schumpeter (1943: Chapter VII). The six page chapter introducing the idea of creative destruction must surely rank this amongst the most influential pieces of writing in economics on a per page basis.

Romer (1990) proceeds by relaxing the assumption that knowledge be a public good. Instead he replaces it with the assumption that knowledge is a mixed good, with both public and private good characteristics. The assumption is now that technological change has Schumpeterian characteristics, in the sense that:

- agents consciously engage in technological change and innovation, responding to market incentives as they do so.

- and the only reason they do so, is that they are now in a position to internalize positive net marginal benefits from undertaking innovative activity.

In effect, innovation rather than being simply an externality, a spill-over from production and investment, now has private good characteristics. Technological progress becomes a response to the promise of economic reward for innovation. On the other hand, knowledge is not held to be a pure private good either, in the sense that to some extent it will be non-rival. Once it exists, the marginal cost of allowing another agent to use that knowledge would be zero. However, since access to knowledge is excludable, agents who have control over knowledge will no longer be price-takers, but have monopoly power over the innovations they initiate. In effect we will have monopolistically competitive markets in the economy. The consequence is that the social marginal return to knowledge will exceed the social marginal cost of knowledge, and as in the case of knowledge spill-over effects the society will *underinvest in knowledge*. In contrast to the knowledge spill-over model though, where the policy prescription was for production and investment subsidies,[10] here the policy implication will be for subsidies to the production of knowledge.

In order to understand why knowledge might have both private and public good characteristics, we can distinguish between two different *forms* of knowledge:

- *Human Capital*: which is *rival*, in the sense that it is tied to physical human bodies, and humans cannot be in two places at once. It is also *excludable*, in the sense that a person in possession of human capital may choose not to make it available. We further note that human capital has a limited life: once the human bearer of that human capital dies, the human capital depreciates to a value of zero instantaneously.

- *Technological Design*: of the blue-print variety which is *nonrival*, since once created a design could be made available to other potential users at zero cost,[11] since all you need is the blue-print. On the other hand it is *excludable*, in the sense that private, profit-maximizing firms will seek to keep exclusive use of any design innovations they have funded. Such excludability may take the form of trade secrets guarded from industrial espionage, and more formally patents, whereby any user of a design innovation is forced to pay for such use. By contrast to human capital, design can be accumulated indefinitely - once a design is in existence, the rate of depreciation on the design is zero.

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[10] Since the source of the underinvestment in knowledge arose from an underinvestment in the physical capital that generated the learning effects.

[11] It is therefore this dimension of technology that will be the source of the underinvestment in technology by markets.

In terms of this conception human capital is a pure private good, while technological design by contrast is a mixed good, with both public and private good characteristics.

In the full Romer model the economy produces research output, intermediate goods (capital) as well as final output for the purpose of consumption. Again the model is fairly complex, but for our present purposes we can focus on the relatively simple process governing the production of research output, which in any event embodies the core insights of the Romer (1990) model.

In the model production of design output (new technology) uses simply human capital and the accumulated stock of human knowledge, the sum of all previous designs in existence. We can "know" patents, and in particular the principles and insights that they embody, even where we are excluded from actively using them in production. As such, the principles and insights embodied in patents are available to researchers to further their production of knowledge.

The production function of knowledge is thus very simple:

$$\frac{dA}{dt} = \delta H_A A \qquad (6)$$

where H_A denotes the human capital employed in the production of knowledge (as opposed to employed in the production of final goods), A denotes the accumulated stock of knowledge, and δ denotes a productivity (research success) factor.
We note immediately that the view of technological progress here is very like that adopted by Karl Shell, what in the discussion above we termed the "perfect university" view of technological progress. The greater the stock of knowledge, the more rapid the time rate of knowledge accumulation. However, there is one important difference here. Unlike for Shell, for Romer the rate of knowledge accumulation depends not only on the stock of knowledge, but also on the amount of *human capital* devoted to furthering the frontiers of knowledge. Thus the production of knowledge depends not only on the stock of accumulated knowledge, but also on the level of resources devoted to the production of additional knowledge.[12] Equally importantly emphasis is placed on a specific *type* of resource. Technological advance takes place not because of money being thrown at the problem. The requirement is for focused deployment of resources in the form of human capital.

The implications of this knowledge production function are important, and as follows:

- Implicit within the above process is the view that the development of new designs or blue-prints is not subject to indivisibilities or uncertainty, such that an increase in the inputs into the production of designs will increase the number of designs continuously.

- Explicitly, as the human capital input into knowledge production rises so the production of knowledge will increase also. Dividing both sides of the above equation by A, provides us with a proportional growth rate of technology/knowledge that is determined by δH_A. More investment of human

[12] One could also think of this as resources beyond human capital – such as R&D directly, for instance.

capital devoted to research will increase (permanently) the growth rate of technology in an economy.

- As the stock of knowledge rises, so the time rate of knowledge production will rise also - effectively the more productive the research sector worker becomes.[13]

- Knowledge production is technology- and human-capital intensive, with no reliance on either capital or "unskilled" labour.

- As long as $\delta>0$, technology will grow without bound. Indeed it is this (linear) specification in the knowledge production function that in the final instance is responsible for the unbounded growth in output conclusion of the present Roman model.

- The absence of any labour input suggests that there are workers present who specialize in the provision of human capital, and who do not supply any labour time at all.

We should also note explicitly that the formulation of the knowledge production function is important. The linearity of the production of designs and technology in the already existing stock of knowledge is what makes unbounded growth possible. In effect, the assumption is analogous to the introduction of a constant marginal product of capital in the knowledge spill-over model we examined in the preceding subsection. Here the relevant marginal product attaches to the human capital employed in the production of knowledge, a new factor of production in the production function, but again the ultimate effect is that production becomes subject to increasing returns to scale, such that the growth of the economy will become unbounded.[14] The fundamental implication is that opportunities for knowledge creation never die out.

In implying that the opportunities in research never die out, the introduction of the knowledge production function is crucial, and deserves some closer justification. Romer (1992) provides some suggestions as to why the particular form of the equation may be justified. The justification according to Romer is that virtually any production process may be improved virtually indefinitely. By way of example he notes that the horseshoe, a technology almost 2000 years old, was still having patents registered against it in 1920 (before horse-obsolescence in anything but the leisure activities of a few). Moreover, considering the nature of production processes this is not all that surprising. For instance, in a mixture with a total of N elements, the total number of different possible mixtures is given by 2^N-1, and this leaves aside different possible proportions. The implication is that for N=100, the total number of mixtures approximates to 10^{30}, a number sufficiently large to suggest that if every living person in the world population of 5 billion were to try one possible combination in every minute since the beginning of the universe approximately 10 million-billion minutes

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[13] The marginal change of technological change in human capital is given by δA. Thus the marginal impact of human capital increases in the level of technology.

[14] By contrast, should the knowledge production function be replaced by one which is concave in A, the marginal product of human capital employed in research would not continue to grow in proportion to A. The result would be that human capital would begin to shift from the knowledge producing to the final goods producing sector of the economy as the stock of knowledge grew.

ago, the total number of mixtures tested thus far would amount to a fraction of 1% of all possible combinations.[15] To all practical intents and purposes, the total number of even relatively limited combinations is inexhaustible, and allows for virtually unlimited innovation in the use of chemicals and other elements. Indeed, this inherent unknowability of the universe has resulted in the "shake & bake" branch of chemistry, which proceeds less on the basis of exhaustive theoretical deliberation, and more by trial and error in the development of new materials. Superconductors, developed by the combination of lanthanum, barium, copper and oxygen at high temperature and pressure were first discovered by this route, and their physics remains imperfectly understood to this day. The reasoning extends effortlessly to other production processes. For instance, in a factory with 52 production steps, the total number of sequences for the steps amounts to 52!, or approximately 10^{68}, a "big" number even by comparison with 10^{30} (for instance, the total number of protons and electrons in the visible universe is estimated to be 10^{79}), again suggesting that the possibilities for innovation are certainly substantial even in relatively simple contexts.

In essence then the suggestion is that the opportunity for innovation is to all practical intents and purposes unbounded, providing us with an initial justification for the suggestion that knowledge will indeed grow without bound – and linearly so.

The model goes on to demonstrate that under these circumstances, the growth in output in the long run will come to equal the growth rate in technology, which we have already seen to be will come to be given by δH_A. Since human capital can be used *either* in the production of new technology *or* in the production of final output, this implies that the more human capital is employed in final goods production rather than "research" into the advancement of knowledge, the lower will be the long run growth rate of output in the economy. Moreover, it is also possible to show what drives the allocative decision of human capital between knowledge production and final goods production. In particular it turns out that:

$$\frac{\dot{Y}}{Y} = \delta H_A = \delta\left(H - H_Y\right) = \delta H - \Lambda r \tag{7}$$

where H denotes the total economy wide stock of human capital, H_Y is the human capital devoted to final goods production, Y denotes output, and r denotes the interest rate. Thus the higher the interest rate the more H comes to be allocated to final goods rather than knowledge production.

The most immediate implication that follows from this finding is that the growth rate of output and the interest rate are inversely related. As the interest rate rises, so the present value of the future discounted revenue from research falls, such that less human capital comes to be allocated to research, and ultimately the growth rate of output falls.

[15] Romer points to the difficulties this presents to the producers of children's chemistry sets: as hard as they might try to avoid the possibility of lethal brews or explosive combinations, they simply cannot be sure that a swirling test tube in the hands of experimenting kids will produce neither.

Second, subsidies on physical capital do not serve to foster growth as they did in the Romer (1986) knowledge spill-over model type.[16] The reason for this is that while in the Romer (1986) model endogenous growth in technology emerged from positive externalities which attached to investment in physical capital, in the Romer (1990) model endogenous growth in technology emerges from a separate research sector, which draws on human capital rather than on physical capital. Increased investment in physical capital no longer generates positive externalities, and subsidies on physical capital while increasing the scale of production, is no longer the source of increasing returns to scale in production. Rather, it is human capital, and human capital engaged in the production of new knowledge that is the source of increasing returns to scale. Investment in human capital employed in knowledge production not only serves to increase the production of knowledge, but in doing so expands the range of physical capital which is at the disposal of producers of final output.

A further result of this finding is that there exists a scale effect in human capital, due to the increasing returns that attach to research. The greater is the stock of human capital within the economy, and the greater is the proportion of total human capital employed in knowledge production, the higher the growth in output will be. Indeed, this conclusion suggests a potential barrier to growth, which serves as a possible poverty trap for the economy. Where the stock of human capital employed in knowledge production is too small, the growth in knowledge may in turn be too small to justify the sacrifice in current output required for allocating human capital to knowledge production. In effect, human capital can simply not be spared from production in order to undertake research, thus limiting the most important single long term determinant of growth. We thus have a low-level trap in output, and one that may well be applicable particularly to the African context.

A further potential barrier to growth which emerges from the Romer (1990) model, is that the private sector will systematically under-invest in knowledge production. Since knowledge production is non-rival but excludable, the private marginal costs of acquiring blue-prints will lie above the social marginal cost. The socially optimal level of research is thus higher than what the private market will deliver, and we encounter market failure in the delivery of research output. Private markets will deliver less human capital, less production of knowledge than is socially optimal.

There is a second reason why we might anticipate market failure within the context of the present model. Research producers generate a new product in the form of new forms of physical capital which are purchased by a sector that acquires patent rights in the use of the new capital. In so doing they acquire monopoly power in the use of the physical capital, and hence engage in monopoly pricing. The consequence is that the market price of the output produced by means of the physical capital will lie above

[16] Neither the marginal cost of physical capital nor the labour input appears in the growth rate of output. The reason for this in the context of the present model, is that an increase in labour input, or a decrease in the marginal cost of physical capital serves to increase the equilibrium level of physical capital, in so doing increasing the return on human capital employed in both the production of final output, and in the production of knowledge. In the present model these effects cancel, leaving the allocation of human capital across the two sectors unaffected (though this result is sensitive to functional form). The most general conclusion as regards the effects of growth in the labour input, and changes in the marginal cost of capital, is thus that they are ambiguous within the context of the present model.

the marginal cost of production. Again, the result will be a socially sub-optimal allocation of resources, with an underproduction of output.

The policy prescription that emerges from these forms of market failure is thus that the underproduction of research below the socially optimal level must be counteracted. The prescription is not a subsidy on physical capital, but a subsidy on human capital, and particularly human capital engaged in research and development.

One illustration of this insight is the positive effect of government and private sector interaction that has characterized the American experience. In a case study entitled "the Vital Triad" we explore some themes that arise in this context in greater detail.

International experience suggests that we need to take account of a technology policy, and that such a policy can bring success. But the evidence also tells us that not all policy is equally successful. Stimulating technology in productive ways requires careful design of the appropriate incentives. Again we illustrate by reference to Brazilian experience in an attached case study.

The need is for a policy environment that is *enabling* of innovation, but which is less concerned to steer innovation into specific directions. It may be better for market participants to decide *where* to innovate. The job for policy is to make it possible for them to do so wherever it is.

A further implication of the present argument is that the private sector may perhaps overinvest in certain forms of research and development which are socially sub-optimal (though this is by no means a necessary consequence). Where R&D is undertaken merely to displace a market leader, the monopoly profits of the innovator materialize at the cost of the extant market leaders, with no net social gain. Moreover, where such investment becomes too frequent, too many resources may become devoted to a form of R&D which adds nothing to total social welfare, and which may result in too little human capital being devoted to the production of final manufacturing output.

A last implication that emerges from the model, is that there are advantages to be realized from increased international integration. As economies begin to integrate, so the total stock of human capital at their disposal will increase also, generating a higher growth rate of output for the composite set of economies. Thus, in terms of the Romer (1990) model, it is not the size of the market in terms of labour that matters, but the human capital content of the market that is crucial to the long-term growth prospects of a set of markets.

Some of the issues that arise from the impact of human capital and the impact of globalisation will be explored in greater detail in the discussion that follows in a subsequent chapter.

The Vital Triad: "Big" Research, Government Funding and Spin-off Companies – or "The U.S. boom – an endangered species?"

by Raphael de Kadt

In an earlier discussion we indicated that the *dirigiste,* command-type, economy that characterized the Soviet Union and its satellite states did not provide an appropriate environment for technological innovation. Following Kornai, we pointed to the absence of an entrepreneurial culture and to a lack of economic competition of the kind associated with the United States of America and other capitalist societies. In our view, the bureaucratic rigidities of this type of system contributed to its failure to develop both the foundations for, and the means to apply new technologies – at least beyond the level of those required by primary industry. In other words, there appears to have been a "threshold" beyond which investment in science and technology education did not translate into greater effective output. The problem seemed to lie with the properties of a system which seemed neither to reward, nor to provide appropriate support for, the kinds of innovation that would have made possible the genesis of a post-industrial economy.

It is thus instructive to look briefly at one of the overall "winners" in the twentieth century technology race: the United States of America. What features of this particular economy might invite closer scrutiny? Clearly there are many aspects on which one might focus: the better protection of property rights, especially intellectual property rights; the greater degree of political freedom; the relative willingness of the country to provide sanctuary and opportunities to immigrants and refugees with high-level skills and knowledge and, of course, a market economy characterized by a relative ease of entry to entrepreneurs.

One feature of the American system of innovation, however, that invites especially close examination is its network of research universities and institutes which, historically, have worked in close partnership with both the federal government and industry. Several aspects of this network are worth emphasizing. First, it has arguably established economies of scale that are unparalleled in the history of tertiary level instruction and research. This has made these institutions enormously attractive to top-flight scientists and scholars from around the world. This attractiveness has been further reinforced by the aggressive recruitment and nurturing of "stars" by these institutions. (South Africa has lost some of its ablest scientists and scholars to these institutions). Second, many of the top-ranked institutions have themselves become "crucibles of entrepreneurship". Their embrace – especially notable, perhaps, in cases such as the MIT and Stanford - of the "entrepreneurial spirit" has extended from the successful and profitable lodging of patents to spawning numerous spin-off companies. These spin-off companies have, in recent times, played a pivotal role in the IT and biotechnology fields.

The research associated with the development and application of technology does not occur solely within the domain of the commercial enterprise. On the contrary: the partnership between research universities and government provides a crucial underpinning for such development. One can perhaps do no better than quote at some length from the evidence presented to the United States Congress's Joint Economic Committee's 1999 National Summit on High Technology by MIT President Charles M.Vest. In his testimony, President Vest noted that "Universities are the largest performer of basic research the U.S., conducting over 50 percent of all basic research." They are, he said, "the only game in town when it comes to long-term research that ultimately generates the new ideas that define the future". Many products of the "new economy", in which "companies are fast-paced, knowledge-based, global, electronically-interconnected, and spawned by entrepreneurs" had their origins in such university based research.

The main point of Vest's evidence was to warn the United States Congress that the steady drop of about 2.6% per year in United States federal R&D expenditures was leading the United States economy in the "wrong direction". Federal spending on basic and applied research, he pointed out, fell by 12% as a share of GDP between 1993 and 1997. What especially worried Vest were projections that the U.S. "innovation index" was likely to drop below that of certain other countries by 2005 on account of cutbacks in R&D spending, a reduced pool of talent and a slowing of policy innovation. In particular, he pointed to the fact that only five percent of the 24 year olds in the U.S. had earned natural science or engineering degrees compared with 6.4% in Japan, 7.6% in Korea and 8.5% in the United Kingdom. A decade previously, however, the United States had led all of these countries in this regard.

Behind Vest's plea and concern lay an important fact. Research Universities had contributed mightily to the United States global economic and technological leadership. This contribution was borne out by a major study, *The Impact of Innovation*, undertaken by Bank Boston in 1997. Referring specifically to the MIT, the study noted that "graduates of the Massachusetts Institute of Technology have founded some 4000 *currently active* (emphasis added) companies. Worldwide, these companies account for annual revenues of almost $232 billion. On a value-added basis, that sum would be closer to $116 billion, which is more than 50% of the gross state product of Massachusetts." When compared with the size of national economies, these MIT-related companies would have "ranked 24th largest in the world – just behind South Africa and ahead of Thailand". (*Impact of Innovation,* Ch 4, p.1) Vest, in his testimony added that "In the field of biotechnology alone, there are at least 45 companies founded by MIT graduates, or else founded on MIT patents (emphases added). They employ nearly 10,000 people and produce annual revenues of $3 billion, roughly one quarter of the revenue of all U.S. biotechnology companies." All of this refers to the contribution of a single university with a substantially smaller student body (slightly under 10,000) than many major South African universities such as Cape Town, Witwatersrand, Pretoria or Natal. Speaking more broadly about the U.S. system as a whole, he noted that "Nation-wide it is estimated that about $17 billion of product sales and 137,000 jobs have been based on patents licensed by universities". (p.2) Helpful to such universities in commercializing the technologies that they had developed, Vest observed, had been the Bayh-Dole amendment that grants universities the IP rights generated under federal grants and contracts, with the federal government retaining free usage.

What must not be lost sight of here is that the "U.S. has an innovation system, based on the synergistic roles of universities, government, and industry. This system generates new knowledge and new technologies through research, and it educates men and women to use this new knowledge to create new products, processes and services and to move them into the commercial sector." The system has been publicly funded and reflects economies of scale and a high level of "concentrated excellence".

Brazil (Latin America): Technology and Industrialisation

by John Luiz

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Brazil lacks a comprehensive national industrial innovation system. During the era of import substitution there was little interaction between universities and technology institutes on the one hand and industrial firms on the other; and the firms themselves could prosper on the basis of limited innovative efforts.

1. Why there is no national system of innovation in Brazil ?

In the past, national development policies as well as development co-operation have been based on the notion that one key ingredient for industrial development was the existence of a science and technology infrastructure, and that science and technology institutes and industrial firms would somehow automatically join their hands in the development of technology. This notion was based on the experience of advanced industrial countries. However, in most developing countries policy makers failed to notice two points. First, institutes that try to conduct basic research often fail to contribute to technological development. Second, there is no automatism at all that leads to the establishment of close relationships between research institutes and industrial firms. Whether or not this happens is largely dependent on the incentives that actors on both sides face.

In the particular case of Brazil, the prevailing incentive structure first of all did not stimulate innovative behaviour inside firms, at least not in the way it is normally understood in industrialised countries. This is not to say that Brazil was a stationary economy with no technical change at all. However, the larger part of technical change followed the typical pattern of inward-oriented latecomer industrialisation where firms try to master technologies that have been developed elsewhere, try to adapt them to their needs and possibly try to improve them so that they better fit into the local environment. This kind of activity does not particularly require intra- company R&D but rather process engineering activities. In the closed market environment, firms felt little pressure to extend their technological effort beyond incrementalism. As the competitive pressure was low, they had little incentive to introduce truly innovative products or to look systematically for radical improvements in the production process.

In Brazil the numbers point to the fact that it was the misallocation rather than the shortage of resources that restricted technological dynamism. In 1976/77, there were 1,050 firms that included R&D expenses in their tax declarations. This number shrank to 780 until the end of the recession of 1981/83 and then grew again to 1,090 in 1985. The average R&D/turnover ratio of these firms was only 0.4%. No less than 62.5% of the R&D expenses came from state companies, eight of which accounted for more than half of the total. The low R&D effort on the side of private firms is confirmed by looking at the data on research personnel. In 1986, the clear majority of the 52,863 persons engaged in R & D activity worked for the state – 62% in universities, 20% in technology institutes, 3.4% in state firms and 6.1% in other government bodies. Further 6.5% worked for private universities, which leaves 1.9% for private firms. This points to the fact that the number of firms who are seriously and systematically investing into R&D is far lower than 1,000; Brazilian observers have offered estimates that range from 200 to 366. The true R&D/turnover ratio may have been as low as 0.16% in the early 1990s.

Most Brazilian firms do not have R&D departments. This is problematic because it inhibits R&D co-operation with external agents and does not allow for the internalisation of research results from external sources. In fact, as a rule Brazilian firms did not confront problems, challenges, and opportunities that would have made it necessary or advisable to look for research results or external research support. Therefore, researchers in universities and research institutes had the impression that there was little potential demand for their results in industry. Yet, this was only one reason for the clear separation between research and industry. Other reasons were:

- the easy availability, particularly in the 1970s, of research funds from public financing institutions which gave the emerging scientific community a lot of space to define research priorities according to their personal interests;
- the research ideals that PhDs returning from abroad brought with them, leading them to strive for academic reputation rather than application of their research results.

2. Technology policy in Brazil: Old approaches to a new situation

In 1990, the government radically changed the framework conditions for industrial development. Acknowledging that the import substitution model had run into a dead end, it opted for a policy of gradually opening its markets to foreign competitors, thus creating an environment that requires international competitiveness and thereby forces companies to attain international levels of quality and efficiency. This has been accompanied by a number of technology and industrial policy programmes. However, they were either not implemented, or only after long delays, or have had little impact so far because the recession inhibited private sector investments.

2.1 Fiscal incentives

Brazilian policy makers perceive fiscal incentives as a major, if not the central technology policy instrument. However, there are some major problems with the use of fiscal incentives in technology policy.

- From a strictly economic point of view, the justification for fiscal incentives for R&D is much more linked to R than to D. In industrialised countries, innovative behaviour, i.e. a high development effort, is simply a basic feature of any competitive strategy, and this needs not be stimulated by fiscal incentives. In Brazilian companies, the larger part of R&D outlays is in development. It reflects the specific characteristics of the Brazilian industrialisation experience that policy makers consider stimulating 'normal' behaviour, i.e. systematic product development efforts, with fiscal incentives. Contrary to D, fiscal incentives for R are justified. Research activities in companies generally generate externalities. One can even easily imagine a situation where the externalities are much larger than the direct benefits to the company. They may also stimulate companies which hesitate to enter into R because of high risk and uncertain benefits.
- A practical point is linked to the fact that the discipline of Brazilian companies in paying their taxes is fairly limited. There exist various semi-legal means of tax evasion and a general habit of exploiting them. It may be assumed that fiscal incentives for R&D only add more complexity to an already overly complicated tax system so that firms perceive them more as a general nuisance rather than as a stimulus.
- Fiscal incentives that refer to income taxes by definition benefit only those companies which are profitable. However, they are not necessary those which put most effort into R&D. Under the prevailing conditions, those companies which are most profitable are more likely to be most inventive in terms of financial management. Therefore, income tax related incentives will have a very limited effect.

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- Fiscal incentives are not necessarily maintained for a long time period because erratic macroeconomic management has prevailed in Brazil and because the actual costs of R&D incentives are unpredictable. Economic agents may expect this and therefore will not necessarily change their long-term strategies because of fiscal incentives.

2.2 Implicit vs. explicit technology policy

The government's explicit technology policy initiatives are often at odds with the implicit technology policy, i.e. the effects of other policies on technological activities in the companies. In particular, the following three factors are detrimental to technological development:

- ***Economic instability***: An important consequence of the unstable, unpredictable economic environment of the 1980s and early 1990s is a general short-term orientation of companies. This environment deters technology capability building which is generally a long-term venture.
- *Taxation:* Inter-company transactions are subject to relatively high, cumulative federal and state taxes. This means that vertical disintegration and specialisation are being punished by taxation policy, and vertical integration is stimulated. This makes it difficult for companies to direct their technological efforts towards certain promising areas. Instead, companies will tend to spread their already insufficient technological effort over a broad spectrum of activities.
- *Neglect of the education system*: Nowadays, it is a generally accepted fact in Brazil that the education system, especially in primary education, is in a poor state. Drop-out- and repetition-rates are high, payment, morale and qualification of teachers is low. Therefore, the average youth will be insufficiently educated.

2.3 Some questionable assumptions of the Brazilian technology policy discussion

The transition to more promising technology policy initiatives is made difficult by a number of basic assumptions that are widespread in the Brazilian discussion. Many of these assumptions, however, are highly debatable.

Technology imports vs. technology capability building. Although technology imports (including capital goods imports) have continued to be low even after the reduction of customs tariffs, Brazilian company executives seem to perceive technology purchasing as the superior alternative to in-house efforts. They often fail to notice that technology purchases and in-house efforts in technological learning are complementary activities. The full potential of technologies which are new to a company can only be exploited after extensive adaptation of the technology as well as the company's organisational structure.
High-tech vs. high-performance industrialisation. Many Brazilian policy makers and scholars are fascinated by fancy high technology. They tend to perceive entire industrial sectors as either high or low technology, equating this with high or low growth potential. They have not noticed that most industrial sectors feature low as well as high technology segments (and in fact Brazilian industry tends to operate in most sectors, including computer equipment, in the low technology segment); and that many so-called low technology sectors (e.g. toys or furniture) have a stronger performance in the world market than some high technology sectors.

3.3 The technology gap approach, or technology as a private good

One of the most obvious points to challenge on the traditional view of technological progress, is the notion that technology is a public good. Technology is not necessarily automatically available to all agents who might wish to use it, regardless of where they are located. Firms jealously guard production secrets to prevent access by potential competitors, and the suggestion that Rwanda is on the same production function as the USA, Japan or Germany, requires strong supporting argument at the very least.

The technology gap approach to economic growth reflects scepticism regarding the homogeneity of the technology of production across countries. In particular, proponents suggest that technology is typically not public but private, in the sense that it is excludable. A technology leader can and does take steps to maintain a technological edge over rivals, preventing ready access to technological advances, and hence a rapid spread of technology. Contributions to the technology gap literature have tended to be appreciative rather than formal, resting on historical appraisal of empirical regularities, and an attempt to provide a causal account for such regularities, rather than the development of an analysis of formal mathematical relationships. For the technology gap approach to economic growth, the real world is too complex to make mathematical modeling conclusive (though there is no reason to deny its usefulness as an aid to thought), and its very messiness requires techniques of analysis which have the capacity to register nuance and historical uniqueness to compensate for what they may lack in rigour and elegance.

3.3.1 The Nature of the Technology of Production

The most fundamental proposition of the technology gap approach concerns the nature of technology. In the traditional view of technological progress, since the technology of production is public, differences in technology cannot account for differences in the growth performance of countries. For the technology gap approach, differences in the technology of production lie at the heart of differences in long run economic performance between countries. The reason for this is that for the technology gap approach technology of production does not take the form of *blue prints* of production lines. Blue prints are readily reproducible at low cost, and therefore disseminable over wide geographical and cultural spaces. Blue prints are indeed required in production, they embody knowledge which concerns a knowing that certain objective features of the world (say using the laws of physics, chemistry, biology as some examples) can be used in organised and intentional productive processes. But the hypothesis here is that of far greater significance to production is an additional form of knowledge, which is not of the objective *knowing-that* variety that we have just referred to, but rather implicit knowledge which concerns *knowing-how* to carry out the physical process of production.[17] Such knowledge is frequently of a sort which is not easily written down explicitly, indeed the agents who have that knowledge are frequently not even aware of the fact that they have it. Such knowledge comes to be located in firms, rests in the very organisational structure of firms, in the networks that firms create amongst themselves in order to facilitate information flows, and may even rest on very specific and highly localised

[17] See also the discussion in Arrow (1994).

personalities, physical and geographical contingencies, and cultural requirements. In effect, the process of production being used becomes an expression of a specific and very particular history, and is an expression of economic agents' adaptation of their activity to their specific circumstances, and the events which have shaped the history and development of the society in which they find themselves. Firms and organisations become combinations of intrinsic capabilities and strategies, which they have unique and privileged access to, and this is as vital to the entire process of production in which they are engaged as the blue prints which are used in order to design, build and maintain their production lines. Technology becomes in effect a private good, not generally available to all who might want to use it, and not only because each firm may wish to guard its technology of production, but because the technology of production comes to be inherently only partially transferable.

Given the organisationally specific nature of technology, immediate and significant corollaries follow for the nature of technological change also. Given that the technology of production is in part reposited in the organisational structure of organisations, technological change becomes the outcome of *learning and innovation* of that *specific organisation* in interaction with its environment. Moreover, the change is *cumulative*, an expression and outgrowth of a specific historical sequence. Such historical sequences may become very difficult to change, so that once organisations develop certain practices, and organisational structures, suited to their historical developmental path, it may become very costly to change, in part because alternative structures and procedures are not readily transferable given their implicit knowledge character. In effect, technological change comes to manifest *path-dependence* characteristics. Lastly, since technology, and technological change has such a strong institutional dimension, it may come to assume a “national” or at least cultural or geographical flavour. Shared language, communication channels, histories and a common culture (shared values, norms and so on), play their own role in fashioning the structure and nature of production, and make the response of organisations to the demands which the surrounding environment places on them, unique and possibly only imperfectly transferable.

3.3.2 Leaders and Followers, and the Technological Frontier

The world has seen a succession of either geographical areas, or since the middle ages, nation states, which have been more advanced technologically than others. Thus, for instance, since the seventeenth and eighteenth centuries this position was occupied by the Netherlands, which in turn was replaced by Britain during the eighteenth century to the concluding decades of the nineteenth century, since when the USA has been the worlds technological and productive leader. The implication of the succession of technological and productive leaders of the world demonstrates that it is possible for “followers” to “catch-up” with the “leader”. But the very possibility of this occurring, poses the puzzle of what conditions need to be satisfied if followers are to be successful in their quest to “catch-up”.

In at least one sense followers have advantages over technology and productive leaders. Since the leader at any time-point is already at the world's production possibility frontier, the only possibility of technological improvement lies in research and development, the devotion of resources to the development of new technologies. It thus becomes an inherently costly process, and, to the extent that new innovations and scientific activity is difficult, systematic and slow, technological improvements in the technology leader may be gradual and incremental rather than rapid. By contrast, technology followers have at least the potential advantage of being able to realise technological improvements simply by copying the technology that the leader has already developed. Instead of having to devote costly resources to the discovery and development of new technology, resources in follower nations can be devoted to production, and the latter's efficiency can be dramatically improved simply by adopting techniques which are already in existence.

Followers thus have an advantage over technology leaders, and it is this advantage which explains why the position of technology leaders is never secure, and why over time new leaders come to emerge. On the other hand, the conception of technology held by the technology gap approach to economic growth, should alert us to the fact that while in principle technology may be "copied", such copying will not be without its costs, its limitations, and indeed in the limiting case may simply not be appropriate.

Such limits may take a number of forms. The first is that the institutions of the follower may be resistant to the adoption of new technologies of production. Old elites may have vested interests in preventing the adoption of new forms of organising production. Gerschenkron (1962)[18] for instance cites the resistance of the nobility in Russia over the course of the nineteenth century to abolish serfdom. While more efficient forms of organising agricultural production were available, Gerschenkron suggests that the realisation of such productive processes would have entailed losses to the traditional owners of estates, with the consequence that they successfully resisted change. Olson (1982) presents a related argument. He suggests that over time states tend to be captured by interest groups, who are concerned to use the institutions of the state for the redistribution of output to the rent-seeking group, rather than with the adoption of those policies which would maximize the long run productive potential of society (examples might be legal bar associations, and chartered accountancy groups, which are able to maintain a cartelised restricted supply of the relevant skills through legal fiat, thus raising their income at the expense of users of their skills). Unless political upheaval manages to break the hold of traditional elites on the state, their interests may prove to be an insuperable barrier to economic development, and the chance of followers to catch up with technology leaders (Olson cites the economic success of Japan and Germany relative to the performance of the USA and Britain after the Second World War, as examples of the benefits to be obtained from sweeping away traditional elites).

A second limitation that attaches to followers' attempts to "catch-up", is that the gap between leader and follower may be very substantial. The relative size of the capital stock may be such that the investment in capital stock, and other advanced factors of production (such as human capital) may be very substantial. The suggestion is then that the institutions which may allow such high levels of investment to be realized, may have to be tailored to the specific needs of the follower. Gerschenkron (1962) for instance cites the example of Germany during the course of the nineteenth century. Britain had gone through a process of gradual industrialisation, slowly accumulating a capital stock which eventually dwarfed that of her European rivals. By the time

[18] Which continues to be a seminal text in this tradition of analysis. But see also Nelson and Winter (1982).

Germany began industrialising, for her manufacturers to be competitive with British manufacturers, required very substantial and risky investment in capital, of a scale that private banks in Britain would not have countenanced. As a consequence, for Germany to successfully catch up, required the development of unique institutions which enabled firms to raise sufficient financial capital to obtain physical capital in proportions which made them competitive with their British rivals. In particular, banks in Germany evolved into much larger institutions than existed in Britain, and their granting of financial investment came in part at the cost of quite substantial involvement in executive management decisions of manufacturing firms. In effect, a very close relationship developed between banks and manufacturing firms, with banks taking a long term view on the investment projects of manufacturers, in return for stronger involvement in the running of firms. In Russia, where the private sector, and above all the manufacturing sector was even more poorly developed than in Germany, the distinctive financial system Germany developed would have been of little use. The demand for financial capital was simply not present, so that the provision of large sums of financial capital would have had little effect. Instead, the state had to intervene directly in order to create the demand for physical capital, in order to create and maintain a nascent manufacturing sector, which toward the end of the nineteenth century, and during the first decades of the twentieth century was able to become independent, and created a demand for financial capital independently of state intervention.

In effect, backward countries have to develop and adapt institutions and technological solutions to their unique circumstances:

> Countries that are technologically backward have a potentiality for generating growth more rapid than that of more advanced countries, provided their social capabilities are sufficiently developed to permit successful exploitation of technologies already employed by technological leaders. The pace at which potential catch-up is actually realized in a particular period depends on factors limiting the diffusion of knowledge, the rate of structural change, the accumulation of capital, and the expansion of demand. The process of catching up tends to be self-limiting, but the strength of the tendency may be weakened or overcome, at least for limited periods, by advantages connected with the convergence of production patterns as followers advance toward leaders or by an endogenous enlargement of social capabilities (Abramovitz, 1986:390).

So countries are required to adapt to their unique circumstances. But they are also required to develop *social capabilities*, which will enable them to successfully adapt their institutions and practices to the needs of their environments. Such social capabilities are wide in scope, covering:

- *institutional dimensions*, such as the financial, commercial, and industrial systems of countries, and even the nature and stability of the political process.

- *social practices and values*, such as the extent to which entrepreneurial activity is encouraged and valued, the extent to which societies have conservative biases, prohibiting the breaking of traditional practices.

- *educational attainments*, both in terms of the quality of institutions, and in terms of the technical competence of the work force, its ability to absorb and work efficiently with new technological advances.

It is not only social capabilities which have to be appropriate if catch up is to be realised. A further requirement is that there is *technological congruence* between the leader and the follower. Differences in the nature of factor supplies between countries, differences in market size, the nature of industrial relations may all determine whether a technology is appropriate for a given setting or not. Introducing the technology of production developed for and under the specific conditions under which the leader operates, may not invariably prove to be appropriate in other locations.

Catching up, while in principle possible, and facing the inherent advantage of being able to proceed by relatively cost-free imitation, faces strong potential opposition from traditional elites, and requires the appropriate social capabilities, and technological congruence in order to be successful.

Nelson and Wright (1992) consider the particular case of the experience of the United States over the past century, both in terms of how it came to catch up with the previous technology leader (the United Kingdom), to surpass it and pull considerably ahead of other industrialised countries in terms of a technology lead, and how this lead came to be steadily eroded. They argue that the ability of the USA to catch up in the nineteenth century depended on its natural resource base, and the scale of its markets (compared to protected European markets) which allowed it to exploit economies of scale. A shortage of labour ensured a high turn-over of labour, such that any expertise such labour had quickly circulated through the US economy's firms. Moreover, the US policy of encouraging immigration from technologically more advanced countries (Europe) meant that it was able to effectively import the social capability of absorbing more advanced technology in the process also. Finally, the USA developed a system of training institutions with a wide diversity of focus areas early on in its process of industrialisation. The consequence was that the labour force was highly educated (only Germany had higher literacy rates than the USA), with a high capacity to absorb any technological advance that took place. On the other hand, the educational system was concerned with widening education, not with establishing a lead in foundational research (in which Nelson and Wright rate Germany as the leader in the nineteenth and early twentieth century).[19]

On the other hand, even though the USA had not yet developed a lead in foundational research, it had by the end of the 19'th century developed the necessary infrastructure to be able to assume world-leadership in foundational science and science-based technology also. This was based on three distinct developments:

- By the end of the 19'th century the USA had a nation-wide university system, with attempts to standardise the requirements for degrees and assessments well advanced (though there also existed strong differences in the quality of qualifications from different institutions). Furthermore a tradition of wide-spread secondary and to some extent tertiary education was well-established, such that literacy rates in the USA were second only to those of Germany.

- US industry had begun to set up independent research centres.

[19] Which goes to show that leadership in foundational research is not the same thing (necessarily) as leadership in technology.

- Abrogation of German patents in World War I allowed the release of, and absorption of a vast stock of already existing technology into already existing production facilities able to take advantage of economies of scale.

The USA thus had access to an infrastructure which was able to broaden and deepen its technological lead over other countries.

The net result was that the USA was able to make large inroads into industries such as automotive production, electrical industries, chemical engineering, particularly in the interwar years. Such inroads became the more dramatic since other nations could not respond, given smaller markets, lack of congruence in natural resource bases, and above all because of political and social upheaval, such that the necessary social stability (social competence) was not available (see Abramovitz 1986:395).

While according to technology gap proponents the USA established a technological lead over its rivals amongst industrialised countries over the course of the nineteenth, and early twentieth century, therefore, this technological lead was not in foundational scientific knowledge. Yet as of the middle of the twentieth century, the nature of technological change in the USA altered its course, from the practical management and resource extraction skills which had characterised the previous ten decades:

> Technological change tended to raise the relative marginal productivity of capital in the form of the education and training of the labour force at all levels; in the form of practical knowledge acquired by deliberate investment of resources in research and development; and in other forms of intangible capital, such as the creation and support of corporate managerial structures and cultures and the development of product markets, which are the infrastructure of the economies of scale and scope (Abramovitz, 1993:229).

In effect, the suggestion is that the share of physical capital in output was falling, while the use of intangible, or human capital was rising. This manifested itself in the USA in changing patterns in the use of education, and different patterns of expenditure on research and development.

The USA as of the 1940's came to dominate foundational research also, as evidenced by the pattern of cumulative Nobel prizes in Chemistry and Physics noted above. But there were further indicators of a different pattern of usage of educational inputs into production in the USA:

- The development of a *national technology & national leadership in science-based fields*: science-based technology is advanced through community, rather than individual isolated effort. Moreover, scientific progress requires more than just learning by doing and experience. Rather, it depends on being located in wider networks of problem-solving activity, and ongoing exchange between scientists working on similar problems. In effect, scientific activity manifests not only strong economies of scale, but also significant positive externalities. During the 1940's the USA undertook large investment in the expansion of its university sector, in the training of scientists, and in the R&D of new technologies. As a consequence the USA was well-placed to take advantage of the virtuous economies of scale and positive externalities inherent in scientific work. Refer once again to the discussion in the case study on “The Vital Trend”.

- Rapid *expansion of R&D expenditure*: the rapid expansion of the secondary and university sector in the USA, brought with it a rapid expansion in the supply of highly trained scientists. This was matched by a rapid expansion of the demand for their services. This was only partly fuelled by the expansion of the university sector, which required more scientists, and was strongly supported by the associated expansion in public funding. The expansion of NASA and defence expenditure further fuelled the public sector demand for greater research activity. But the private sector also increased its demand for the services of scientists. This is evident from a consideration of (a) the number of laboratory foundations in the US manufacturing sector over the first half of the twentieth century, which shows a rapid acceleration of such foundations; (b) the number of scientists engaged in R&D per 10000 workers which shows the USA to be clearly leading its main industrialised rivals, though the lead has come to be eroded over time (particularly by Japan and Germany); and (c) R&D expenditure as a percentage of GDP, which again shows the USA to hold a clear lead over rival countries in the early 1960's, (though again with strong erosion of that lead by Japan and Germany).

The result was that US scientists not so much outstripped European scientists in the quality and depth of their knowledge, but that they were located in organisational structures which proved to be superior to those in Europe, and over time came to develop better experience of front-line research. In effect, the USA replaced Germany as the foundational technological leader in the world, thereby cementing and broadening the nature of its advantage over its industrialised rivals. This advantage was evident in the widening gap of per capita GDP between the USA and the average of other industrialised countries from 1945 through 1955.

Ironically, while the US was able to extend its lead over its immediate technology rivals until the mid-1950's, in subsequent years this lead in turn came to be eroded according to proponents of the technology gap approach.

A number of pieces of evidence are advanced in support of the contention. First, the US lead over its rivals in terms of per capita output has declined. Second, while the USA has maintained its share of high technology exports, it has come to increasingly rely on high-tech imports from its rivals. Third, since 1970 the share of patents registered by the USA has declined, with an increased share going to Europe and Japan.[20]

Technology gap theorists have advanced a number of reasons for the steady catch-up realised by the US's rivals. Recall that since the technology gap approach denies the public good characteristic of technology, the catch-up cannot have been driven by access to science and technology. Each country is expected to have faced is own, unique production function. This makes the question of why catch-up has taken place strongly pertinent. Some of the reasons advanced are that:

1. *Declining transport costs and falling trade barriers* have resulted in an increased flow of world trade, which has rendered the size of domestic markets less important. All firms now effectively have access to the same market, and can take advantage of the same economies of scale. Low transport costs have also made the availability of

[20] Though see Griliches (1994) on doubts concerning the validity of the R&D evidence.

raw materials in the domestic market significantly less important than before, since they may be imported at relatively low cost (viz. Japan). Added to this is that the USA has become a net import of raw materials, so that its natural resource base no longer suffices to supply its manufacturing industry. Thus the two sources of advantage that the USA had developed over the course of the nineteenth century have been effectively eliminated.

2. Over the course of the twentieth century, *technology has become increasingly accessible to those with the correct skills and training*, thus reducing the importance of national boundaries. Again, access to large world markets makes mass production technology appropriate to all producers. The development of multinational firms also means that production now tends to be globally rather than nationally located, so that the organisationally specific aspects of technology come to be transferred beyond national boundaries in a manner they were not in the previous century. Perhaps most significantly of all, however, many technologies have begun to increasingly resemble pure science. This is evident from the increased citation of scientific literature in patents, particularly in leading high-tech industries such as chemical products, electronics, and bio technology. More of technology in effect has come to be "written down", has assumed the characteristics of blue-prints, such that it has become transferable between locations. Anybody with the requisite skills required to interpret the scientific literature, is in a position to gain access to the technology.[21]

3. Since other industrialised countries have an *increased percentage of the workforce trained in science and engineering, and an increasing proportion of GDP allocated to R&D*, such competitors to the USA have developed a strong competence to adopt and adapt technology from abroad. The significant input required from trained scientists and engineers, and the R&D expenditure aimed at tailoring scientific advances to specific, and potentially localised conditions and relevant uses, was or became part of the social capability of US rivals.

4. Since World War II "spill overs" from military to civilian R&D technology has declined in importance. While initially the civilian demand for computers, semi-conductors and aircraft lagged behind military usage, and to some extent emerged from military usage, this relationship has now reversed. Innovation and quality standards in civilian usage now tend to outstrip the pace of innovation and quality standards set by the military, and increasingly the military borrows from civilian innovations rather than the reverse. Civilian R&D has begun to develop an edge over military R&D. In part this is an expression of the fact that military needs have become increasingly specialised, so that innovations which do take place are increasingly inherently non-transferable to comparable use in civilian applications. In part it is due to the fact that the percentage of military R&D on experimental design has declined significantly, as the opportunity of taking advantage of spill overs from civilian R&D has increased. The net result is that the clear-cut lead of the USA in military technology has declined in significance over the second half of the twentieth century, creating the opportunity of catch-up for its competitors.

5. Lastly, the social capabilities of the European nations and Japan have been more readily realised, given the *less chaotic political environment* and systems even in the defeated nations in World War II. Political reconstruction, weakening strong vested

[21] Though note that this presupposes access to the correct sort of social capability.

interest groupings, the relatively flexible labour movements in Europe (from South to North, in general), government support for technological innovation, and an environment of stable international money markets, in effect are held to have favoured heavy and sustained capital investment.

In effect, the USA's competitors have invested heavily in the “social capabilities” necessary for success in a global economy which places increasing stress on high-tech advances. Nelson and Wright go so far as to say:

> a well-educated labour force, with a strong cadre of university trained engineers and scientists at the top, is now a requirement for membership in the “convergence club”. This is not to denigrate the continued importance of hands-on learning by doing and using, but in modern technologies this is not sufficient. It is no accident that countries like Korea and Taiwan, which have been gaining so rapidly on the world leaders, now have populations where secondary education is close to universal for new entrants to the work force, and where a significant fraction of the secondary school graduates go on to university training (Nelson and Wright, 1992:1961).

Thus the reasons for the USA's original forging ahead lay in the fact that countries with the requisite “social capabilities” to catch up with the USA, lacked the “congruence” characteristics, since their market sizes were too small, and they did not have the same natural resource availability as the USA. The development of a “high-tech” lead on the part of the USA was developed because its competitors did not develop the appropriate “social capabilities” in terms of the nature of their educational systems, and their R&D capacities, and it took time for them to catch up in these dimensions. That they have managed to catch up, rests on the fact that globalisation has made for greater “congruence” in terms of market size and the technologies appropriate for success in such markets, and that “social capabilities”"have been strongly invested in by competitor nations.

It is instructive to note that amongst the successful countries of East Asia, considerable attention has been paid to the development of human capital capabilities to allow them to absorb technological advance. Moreover, East Asian countries have been able to absorb technological advance to different degrees – in accordance with their preparation of their human capital capabilities. See the case study discussion entitled ‘Technology and the Human Capital Base in the Asian Tigers’.

Technology, the Human Capital Base and R&D in the Asian Tigers

By John Luiz

Source: Adapted from Sanjaya Lall. 1997. Coping with New Technologies in Emerging Asia. Mimeo.

International evidence points to the importance of human capital in the promotion of economic growth. However, it has also been demonstrated that particular types of human capital contribute more towards this process than others. The mathematical and natural sciences have, in particular, been singled out for their importance. The Asian tigers support this hypothesis. Their very high economic growth rates coincide with extraordinary investments in human capital formation. Almost all the Asian tigers have universal coverage in primary educational enrolments. Basic numeracy and literacy forms the backbone of any economy as it allows its workforce to participate in the development process. It represents the minimum. However, tertiary education plays a particularly critical role as economies become more sophisticated. The human capital base is represented here by education enrolments, though it is far from a perfect measure. Education is not equivalent to capabilities, but provides the base on which learning takes place – without further technology-specific experience and search formal qualifications do not yield technological know-how or know-why. Thus, formal education is only one way to create skills; on-the-job learning, experimentation, interaction and training are often more important. Nevertheless, it is true that formal education is a condition for industrial skill acquisition, and enrolment data *can* serve as a reasonable proxy, in the absence of other human capital formation on a comparative basis.

Table 1 shows *general enrolments* at the three levels, as well as tertiary students abroad and the adult literacy rate. While most countries claim to have universal primary enrolment, there is still considerable illiteracy in Pakistan, India, and to a lesser extent, China, Indonesia and Malaysia. Secondary enrolment rates are very high in the Tigers, with Korea and Taiwan at developed country rates. Hong Kong and Singapore are slightly behind, followed by Malaysia, China and India. The quality of schooling is also apparently higher in the Tigers than in South or South-East Asia: drop-out rates are lower, and there is a stronger emphasis on numeracy (which is particularly relevant for emerging information based technologies), in which Tigers tend to surpass even the developed Western countries.[1]

[1] For instance, in terms on international comparisons of school children in mathematics, the East Asian countries score the highest in the world.

Table 1: Educational Enrolments and Literacy Rates (1990-2)
(per cent of age group)

Country	Primary	Secondary	Tertiary	Per cent Tertiary Abroad (a)	Adult Literacy Rate
Hong Kong	117	75	20	32	91
Singapore	107	71	9	25	90
Korea	105	90	46	2	97
Taiwan	100	88	38		
Indonesia	115	38	10	2	83
Malaysia	93	58	7	38	82
Thailand	97	33	19	1	94
China	121	51	2	3	79
India	102	44	6	1	50
Pakistan	46	13	3	9	36

At the tertiary level, Korea and Taiwan are at developed country levels. Then come Hong Kong and Thailand (around 20%). There are 4 countries with tertiary enrolments of 5-10%: India, Indonesia, Malaysia, and Singapore. Well behind the others come Pakistan (3%) and China (2%). There are high proportions of tertiary students going overseas in Hong Kong, Singapore and Malaysia. The larger Tigers have in place attractive incentives for nationals studying or working overseas to return, and in both Korea and Taiwan these have provided an important input into their capability development.

The observed variance in enrolment levels is expected, with the pattern generally corresponding to the distribution of technological capabilities traced above. The correspondence is not exact, of course; the *stock* of educated manpower is not reflected fully by current enrolment levels. In addition, large countries can have large *numbers* of trained manpower available for industry (i.e. the agricultural sector does not need many high-level skills). China stands out by virtue of its very low tertiary enrolments combined with a booming export sector – clearly, exporters find sufficient skilled manpower for the relatively low levels of technology that they use. Whether or not this is sustainable as the industrial sector upgrades is another matter.

Enrolment at the *tertiary level in technical subjects*, more relevant than general education for our purposes, is shown in Table 2 in numbers and as percentages of the total population. This table includes some advanced industrial countries for comparison, and shows, not just wide differences between the Asian countries, but also that some Asian countries, in particular Korea and Taiwan, are far ahead of many technological leaders in the OECD in technical skill creation.

Take enrolments in all technical subjects, which may be a good indicator of the general technical base in a country. The norm in European countries (the table shows only the technological leaders, and this may not apply to others) is around 1%, while the USA is 1.47%. Korea and Taiwan have 1.66% and 1.45% respectively, higher than Europe or Japan; the former is ahead of the US and the latter is about the same. There is a large range among the other Asian countries; the lowest figure (below 0.1 per cent) is for Pakistan, with India, China, Indonesia and Malaysia slightly better (under 0.2%). China and India have large absolute numbers, of course, with 1.8 and 1.2 million of technical tertiary enrolments respectively, but in relation to the size of their populations this is poor.

In *natural science,* the Asian countries lag behind the OECD countries, where France and Germany lead. Korea has by far the highest proportion of science enrolments in Asia; Taiwan has a relatively low figure, trailing Thailand and Hong Kong. In *mathematics and computer science,* Korea leads both Asian and OECD countries; in relation to the size of the population, its enrolments in this field are over twice that of UK and Japan (German and French data are not available separately) and 58% higher than in the USA. The nearest Asian follower, Taiwan, has less than half the proportion of its population in these disciplines, though it leads most European countries. Hong Kong performs better here than Singapore; this may seem surprising in view of their production structures, but the competitive edge of Singapore lies in production of electronic hardware rather than computing – and here it is engineering and production-relation training that is important.

Engineering is strongly emphasised in most, but not all, Asian countries. Korea has 0.83% of its population enrolled in engineering and Taiwan 0.86% (it is worth noting that the *absolute* number of Korean engineering students is 70% larger than India's). Singapore follows far behind with 0.47%. China's figure is only 0.1%, but its size means that its 1.2 million engineering enrolments are almost equal to the entire EU's 1.23 million.

We may compare relative enrolments in engineering and natural science, an indicator of the emphasis on the practical versus the theoretical aspects of technology. In Asia, there is clear bias towards engineering. Only India has more enrolments in science than engineering. China is at the other extreme, with a ratio of engineers to scientists of 12. Japan has a ratio of 8, Taiwan 11, Singapore 10 and Korea 5. In Europe and the USA, the norm is 2 or below, with France having more enrolments in science than engineering. This may have implications for coping with new technologies, but it is difficult at this stage to discern this clearly: arguments may run both ways, depending on emerging skill and knowledge requirements.

Turning now to R&D activity, we see a similar pattern. Though Asian countries are highly dependent on technologies imported from the mature industrial countries, they undertake significant technological activity to absorb complex technologies, adapt and improve upon imported knowledge, and, increasingly, create new technologies. The extent of formal R&D does not capture the full extent of technological activity, but it is one activity on which comparable data are available. Moreover, it is arguable that with growing industrial maturity, formal research activity becomes a more accurate measure of inter-country technological differences.

Table 2: Tertiary level students in technical fields (numbers and per cent)

Country	Year	Natural Science		Maths & Computer		Engineering		All Technical Subjects (a)		Science + Maths & Computers + Engineering		Ratio of Engineers to Scientists
		Nos.	%population	Nos.	%population	Nos.	%population	Nos.	%population	%total tertiary	%population	
Hong Kong	1992	5503	0.095	6661	0.115	14788	0.256	35068	0.607	30.3	0.47	2.69
Singapore	1994	1281	0.046	1420	0.051	13029	0.465	16767	0.599	20.4	0.56	10.17
Korea	1993	75778	0.172	145948	0.331	367846	0.834	730346	1.655	31.2	1.34	4.85
Taiwan	1993	16823	0.080	32757	0.157	179094	0.857	303964	1.454	42.3	1.09	10.65
Indonesia	1992	22394	0.012	13117	0.007	205086	0.109	315325	0.167	13.4	0.13	9.16
Malaysia	1990	8775	0.049	4557	0.025	12693	0.071	32222	0.180	21.4	0.15	1.45
Thailand	1992	77098	0.135	1292	0.002	105149	0.185	249952	0.439	15.9	0.32	1.36
China	1993	95492	0.008	174862	0.015	1156735	0.098	1831966	0.155	31.7	0.12	12.11
India	1990	869119	0.102			216837	0.025	1236414	0.146	27.9	0.146	0.25
Pakistan	1991	29433	0.025			41244	0.035	75168	0.065	34.0	0.065	2.55
Memo Item: Some OECD Countries												
Japan	1991	59030	0.048	20891	0.017	488699	0.394	730637	0.590	19.6	0.46	8.28
France	1991	266299	0.467	N/A	N/A	123514	0.217	614159	1.078	21.2	0.68	0.46
Germany	1993	310435	0.384	N/A	N/A	389182	0.481	805801	0.997	37.3	0.87	1.25
Netherlands	1992	16707	0.110	8742	0.058	N/A	N/A	137510	0.905	N/A	0.17	N/A
UK	1992	105983	0.183	76430	0.132	219078	0.378	596404	1.029	26.3	0.69	2.07
USA	1990	496415	0.199	525067	0.210	801126	0.320	3676985	1.471	13.3	0.73	1.63

Notes: (a) All technical subjects include the three categories earlier plus medical, architecture, trade & crafts, and transport & communications.

Table 3: R&D Expenditures

Country	Year	As % of GDP Total	By Enterprises	R&D per capita $
Hong Kong	1995	0.1	N/A	19.8
Singapore	1992	1.0	0.6	153.6
Korea	1993	2.3	1.98	176.2
Taiwan	1993	1.7	0.8	179.6
Indonesia	1993	0.2	0.04	1.5
Malaysia	1992	0.4	0.17	11.2
Thailand	1991	0.2	0.04	3.1
China	1992	0.5	N/A	2.4
India	1992	1.0	0.22	3.1
Pakistan	1987	0.8	0.0	2.6
Memo Item: Some OECD Countries				
Japan	1992	3.0	1.9	762.9
France	1991	2.4	1.0	512.7
Germany (a)	1989	2.8	1.8	427.3
UK	1991	2.1	1.1	365.7
USA	1988	2.9	1.5	540.9

Note: (a) Figures for the former Federal Republic

Table 3 shows R&D as a proportion of GDP in emerging Asia. The clear leader is Korea, which now spends 2.3% on this activity, just behind a few of the technological leaders in the OECD, though in *per capita* terms it is still one-third of the US and 23% of Japan. Nearly 85% of Korean R&D is financed by enterprises rather than the government, making its private R&D/GDP ratio one of the world's highest.[2] Taiwan comes next in emerging Asia, with *per capita* spending slightly higher than Korea. However, more than half of Taiwanese R&D comes from the government: its SME-dominated industry means that a large part of the private sector is unable to undertake expensive research. The government compensates with an extensive infrastructure of public institutions that offer extension, contract R&D and productivity improvement services for the SMEs.

Private industrial R&D is relatively weak in the other Asian countries. Singapore has increased enterprise R&D in recent years, but much of it is in foreign affiliates and universities and may not feed into the capabilities of local firms. Hong Kong, in line with its specialisation in low-technology activities, lacks a significant R&D base. There are pockets of technological development in large economies like China and India, some of it quite advanced (space and defence technology in China or chemicals and pharmaceuticals in India), but much of the industrial sector does not invest in significant R&D.

[2]*By 1993, Korea had nearly 100,000 researchers, up from 41 thousand in 1985 and a mere 10 thousand in 1975; the number of corporate R&D units had risen from 1 in 1975 to 183 in 1985 and 1690 in 1993.*

Table 4: Scientists, Engineers and Technicians in R&D

Country	Year	R&D S&E per m. pop.	R&D technicians per m. pop
Hong Kong	1990	N/A	N/A
Singapore	1987	1284	583
Korea	1992	1976	347
Taiwan	1991	1673	573
Indonesia	1988	181	N/A
Malaysia	1988	326	69
Thailand	1991	174	51
China	1992	1129	428
India	1990	151	114
Pakistan	1990	56	80
Memo Item: Some OECD Countries			
Japan	1992	5677	869
France	1991	2267	2972
Germany (a)	1989	1634	867
Netherlands	1991	2656	1777
USA	1988		3780

Table 4 shows R&D manpower per million population, Korea has the highest number in developing Asia, followed by Taiwan, Singapore and China (which apparently has 1.3 million scientists and engineers in R&D, higher in absolute numbers than the USA, under 1 million). Malaysia follows some distance behind;

Indonesia, India and Thailand come next with roughly equal numbers of R&D scientists and engineers. Pakistan again lags well behind the other countries. The leading Asian economies are still a long way from technological leaders like Japan, but Korea and Taiwan now have more R&D scientists and engineers per head than (pre-unification) Germany and not too far behind France.

The link between human capital formation and R&D activity yields some interesting insights. The international growth sectors over the past few decades have made enormous demands on sophisticated skills, namely the service sectors, high tech industries and the IT sectors. As a result, investment in the appropriate types of tertiary education has become critical. By this we mean education which provides the necessary skills for graduates that will enable them to understand the principles of technology and not just some operational capability. This means that the ability of a country to adopt and adapt and promote technology is enhanced. The Asian tigers have consistently scored amongst the top countries in terms of their mathematical and science graduates. They have invested in the right forms of education and have reaped the rewards as can illustrated in their pioneering role in the knowledge based economies. This is borne out by the following evidence: the correlation coefficients between tertiary enrolments (as a per cent of age group) and R&D per capita in our Asian sample is 0.7468, between secondary enrolments and R&D per capita it is 0.7888, whilst between primary education and R&D per capita it is a meagre 0.131. This provides at least some anecdotal vindication for the relationship between human capital investment and the ability to absorb technological advance. Early literature in the field of development economics stressed the enormous returns on primary education but it would appear that as economies become more sophisticated so the returns to higher education increase. Further support is provided by the high correlation coefficient of 0.9077 between the natural science, maths, computer science and engineering students as a per cent of the population and per capita R&D expenditure.

3.3.3 Conclusions and Evaluation

The technology gap approach to economic growth has the merit that it emphasises the possibility that countries may not be homogenous in their ability to access technology. By noting both the need for technological congruence - similarities in the opportunity of using the most advanced technology - and the need for social capability - that the most advanced technology only becomes available where social institutions are such as to make its use feasible - the approach alerts us to the possibility that countries may not be located on the same production possibility frontier. Differential access to technology may be the reason for strong differences between per capita incomes around the world, and this in turn may be linked back to technological incongruence and the dearth of social capabilities.

The technology gap approach has a research agenda at its disposal, voiced by for instance Nelson (1994). This is to develop (a) a more thorough understanding of the nature of technological progress, and the particular form it adopts in any given setting; (b) a more thorough understanding of the role of organisations, particularly firms in the process of economic development and technological change in particular; and (c) a clearer understanding of the background institutions and social capabilities that enable technological change and economic development - which category needs to be understood as broadly and inclusively as possible.

A number of criticisms of the technology gap approach have been voiced, however. The first is that the argument which accounts for "catch-up" with the USA on the part of Europe and Japan, that technology has become increasingly "accessible" over the course of the twentieth century, is contestable. Multinationals, despite having a presence in many diverse markets, continue to carry out the majority of their research in their country of origin, or so the counter-argument goes. And the nature of the technological advances adopted by multinationals continue to reflect the technological characteristics of the country of origin as a consequence, and technology spill-overs continue to be relatively localised. Fagerberg (1994) goes so far as to suggest that if the nation-state is abandoned as the unit of analysis (with the associated claim of a shared history, culture, language and institutions facilitating information exchanges), the core of the technology gap approach is abandoned.

But this does not necessarily follow. The crux of the technology gap approach is that there are "culturally-contiguous" areas, in which information and hence technology exchange takes place at relatively low cost. That such contiguity should take the form of the nation state is not inherent in the argument, but may simply be an expression of historical forces prevalent during the course of the nineteenth and parts of the twentieth centuries. The appropriate unit of cultural contiguity may simply have changed with increasing integration of the world economy, and the convergence among the industrialised countries suggests that one appropriate cultural in-congruity may no longer be between nation states, but between developed and less developed economic areas.

Nor does it necessarily follow that because R&D takes place in multinational home countries, that only the home country has access to such technological progress. To the extent that such R&D is translated into production, such technological advances are made available more widely than simply in the home country of the multinational. Moreover, to the extent that all technology has to take account of local cultural specificities, any technological advance would still require modification to local conditions, thus requiring yet further innovation, and encouraging the development of technological progress even in countries which are not located in the home country of the multinational.

Such concerns can thus be accommodated in the general technology gap approach relatively easily. Far more serious however is the fact that in the technology gap approach technological innovation, which comes to replace one world leader (such as the UK in the nineteenth century) with another (the USA), occurs exogenously. It is not quite clear what underlies the sudden bursts of creative energy, which allowed the Netherlands to supplant Spain, the UK to supplant the Netherlands, and the USA to supplant the UK as world leaders over time. The source of technological progress, even though its organisationally and culturally specific character is clearly identified by the approach, remains essentially exogenous in the explanation offered by the technology gap approach. It is a matter either poorly understood or attributable to luck. Given the primacy attached to technological progress by technology gap theorists, this must surely be of some concern.

In conclusion then, the central suggestion of the technology gap approach, that there exist barriers to the diffusion of technology, is certainly worthy of serious consideration. However, the approach has a tendency to overemphasise these barriers as insurmountable, rather than as costly. Moreover, the approach tends to be highly historical and discursive in nature, such that argument tends to turn on very specific and localised examples rather than general theory. The difficulty with such an approach is that the conclusions drawn are uncertain as to their generality, and the strength of any policy conclusions that are derived is open to question. Distinction between the ad hoc, and the general insight is open to question.

3.4 Conclusion

In this chapter we have encountered a variety of approaches to technological progress. There is little point in repeating questions of detail here. But it is worth highlighting two fundamental dimensions in terms of which differences between the various approaches to technological change become apparent.

The first fundamental difference concerns the accessibility of technological advance as it occurs. In the "traditional" approach to technical progress, and in the knowledge spill-over approaches technological advance is freely available to all as it occurs. No one is excludable from taking advantage of the advance. By contrast, Schumpeterian and technology gap approaches proceed on the presumption that not all potential beneficiaries will turn out to have access.

The second fundamental distinction between the alternative approaches is that only the endogenous growth theories seriously attempt to explain why technological progress may in fact occur. Other approaches, including the technology gap approach remain largely silent on this question.

Chapter 4

Testing for the Nature of the Technology Impact

4.0 Introduction

We have seen evidence showing that technological progress does appear to be contributing to output growth both internationally, as well as for South Africa in particular. We have now also seen some of the explanations that have been offered explaining why and how it is that technological progress is likely to influence output growth.

What remains to be established is which of the various suggestions explaining the technology-growth nexus are likely to hold, both in terms of the international evidence, and in terms of the evidence we can muster on the South African experience.

4.1 The international experience

The traditional approach to understanding the impact of technological progress was effectively preempted in the discussion of Chapter 2. We saw that technology, as measured by the efficiency gains implied by total factor productivity growth contributes significantly not only to growth in the developed world, but does so in South Africa also. The only qualification here is that we have to be conscious of sectoral nuances in making this assertion.

Since we have already examined this evidence extensively in Chapter 2, we do not return to it at this point.

4.1.1 Does endogenous growth theory find empirical support?

Instead we turn our attention to the contribution made by endogenous growth theory, and ask whether any evidence has emerged detailing whether technology is likely to have the impact anticipated by endogenous growth theory.

For developed countries, one set of results is provided by Ochoa (1996). Ochoa employs OECD manufacturing sector data in a panel estimation, in order to establish the contribution of capital stock and labour force growth to output growth. The result is reported in **Table 4.1,** column 1. The implication of the finding is that growth in capital stock not only has the expected positive sign in influencing the growth in output measure, but does so statistically significantly.[1] By contrast, the contribution of growth in the labour force, while carrying a positive sign, is statistically insignificant.

The base model thus performs in line with expectations, since growth in factor inputs should indeed allow for an explanation of the growth rate in output. However,

[1] Readers should note that in the regressions Ochoa included a range of dummies for outlier sectors: machinery & equipment, and the chemicals sectors. We do not report their coefficients since they have no bearing on the results for our purposes.

regression equation (1) does not allow us to establish whether the view of the technology-growth nexus advanced by endogenous growth theory can be said to hold. For this reason Ochoa, adds a number of additional variables in the regression equation reported in column 2 **of Table 4.1**, controlling for the contribution of the following additional factors:

- the natural logarithm of the number of full-time R&D scientists and engineers employed by business in each relevant industry. It serves to proxy for the industry level R&D effort. Since this is anticipated to provide an indication of the access to knowledge and technological advance, a positive impact on output growth is expected from this variable.

- a proxy for the possibility of "catch-up". This is measured as the labour productivity gap between each country and the international industry leader across all identical sectors in the OECD at the start of the panel data set. The smaller this difference, the closer the sector would be deemed to be relative to the technology frontier, and hence the less the opportunity for catch-up. Hence the expectation would be that should catch-up opportunities exist, the coefficient on the catch-up proxy should be negative and significant.

- the growth rate in the share of professional, technical and related workers of the employed labour force. Ochoa has the initial expectation that the variable controls for the accumulation of human capital in the economy as a whole, and thus should reflect the strength of the research effort that is possible by industry. It is thus viewed as an indicator of the extent to which an industry finds itself in a general "enabling" environment within it can pursue both production, and its own research activity. His prior expectation is of a positive sign on the variable. However, readers should recall that in the Romer endogenous growth model the impact of human capital depends on whether it is allocated to final goods production or to knowledge production. Where the allocation is to final goods production rather than knowledge production, the long run equilibrium impact on growth may in fact be negative. Thus at best the sign of this variable can be said to be ambiguous.

It is worth remarking at the outset that the specification employed by Ochoa does not really serve to address the question of whether a generalized R&D sector in the economy (such as that proposed in the Schumpeterian model of Romer (1990)) contributes to economic growth. The specification must thus be recognized as being only a partial test of the Schumpeterian approach to endogenous technology growth.

The results reported in regression equation (2) of **Table 4.1** confirms the positive impact of factor input growth (growth in capital and labour inputs) on output growth. Moreover, in equation 2 growth in both factors of production turns out to be statistically significant, in contrast to equation 1.

But the really significant result to emerge from regression equation 2 is that the allocation of resources by industries to R&D activity and personnel is associated with a higher growth rate in output, and statistically significantly so. In addition, we find that catch-up effects are also present even in the developed countries that constitute the OECD. The further a country's manufacturing sectors lag behind the relevant technology leader, the faster they are likely to grow, presumably because of the relatively cheap "copying" opportunities that are offered by emulating the technology leader.

Table 4.1: OECD Manufacturing Sector Results: Dependent variable is output growth. Figures in round parentheses are t-ratios. Statistical significance is indicated by *. Estimation is on a panel of OECD manufacturing sectors. The panel sample is over the 1970-87 period.

	1	2
Capital Growth	0.857*	0.758*
	(6.57)	(5.32)
Labour Growth	0.223	0.141*
	(1.14)	(0.60)
log of R&D scientists and engineers in the industry		0.0035*
		(2.86)
Catch-up		-0.023*
		(2.57)
Avg. Growth Rate of Share of Professional, Technical & Related Workers		-0.206
		(0.69)
R^2-adj	0.822	0.87
N	33	27

Source: Ochoa (1996: various tables)

It is perhaps worth noting that these results already carry implications for South Africa, given the evidence that we saw on South Africa in Chapter 2. If even OECD countries have opportunities for "catch up" to the technology leader through "emulation" strategies, then this is certainly the case for South Africa. This makes the particular growth path chosen by South Africa, that of relative autarky in technological advance, all the more remarkable.

The third "endogenous" growth variable, the growth rate in R&D scientists, while carrying a negative sign turns out to be statistically insignificant, therefore not contributing to the explanation of variation in growth in output between countries and manufacturing sectors.

The upshot of the empirical results is that the "new" or endogenous growth theory does indeed find support from empirical evidence for OECD countries. Resources devoted to R&D, and the opportunities afforded by the ability to emulate technology leaders through catch-up, do indeed contribute toward the explanation of output growth rates.

Thus the evidence is in favour of endogenous growth theories, and casts some doubt on theories of technological progress that emphasize an extreme private good characteristic of technology. Technology does appear to diffuse internationally, and such diffusion allows improvements in the output performance of sectors and economies. To the extent that private good characteristics are present for technology, therefore, they are at the very least limited.

The one sense in which the results do not support endogenous growth theory is that the accumulation of human capital in the economy does not appear to have the positive impact that we might have expected. However, given the specification of the variable by Ochoa, this is not entirely surprising. We have already noted that in Romer the crucial consideration is whether or not the human capital comes to be allocated to final goods production or to the development of new technology. The specification employed by Ochoa does not allow this distinction to be made – and hence the results attaching to this variable may indeed prove to be ambiguous.

4.1.2 The impact of positive externalities: testing for spill-over effects

What the evidence thus far omits from consideration, however, is the extent to which knowledge spillover is a significant component of the growth process. We have considered only the direct impact of R&D, and the direct impact of catch-up on output growth rates. Yet one of the central tenets of modern growth theory is that one of the strongest motor forces for growth, and the possibility of unbounded growth in particular, is the presence of knowledge spill-over effects. The possibility of a general diffusion of technological advance strengthens the impact of technological progress on output growth, accelerating it over time. It is also the source of one of the policy implications that emerge from the modern growth literature. The presence of spill-over would imply underinvestment in physical capital, and hence suggests the desirability of subsidized support for investment.

It is therefore important to establish whether spill-over is empirically present, and what degree of significance it has in production and investment.

In a series of studies Bernstein and Nadiri (1988, 1989) examined the evidence on the presence of spill-over effects in developed countries.[2] They examine the separate potential impact of R&D spill-overs on physical, R&D capital and labour inputs into production. Their specifications are concerned with whether the R&D activity of other industries has any impact on the usage of physical and research capital as well as labour in a number of identified sectors.[3] Data is detailed and at the firm level for the United States.[4]

Their findings strongly favour the presence of externalities from R&D activity of industries. Such spill-overs are found to be present both in the short as well as in the long run. In **Table 4.2** we detail the short and long run impact of R&D spill-over effects Bernstein and Nadiri (1989) reported, in the form of elasticities.[5] The estimates are of the impact of the spillover effects on the use of R&D and physical capital, as well as labour and average cost of production in the selected industries. The evidence is unambiguous.

First, it strongly confirms the presence of labour and average cost reduction due to the presence of spillover of R&D activity that takes place in industries other than where the cost reduction is taking place. Thus the first effect of spillover is cost reduction.

The *second* effect of the spillover is reduced investment in physical and R&D capital.

[2] See also Cockburn and Griliches (1988), Levin (1988).
[3] They employ Chemicals, Petroleum, Machinery, Instruments.
[4] Such detailed data is rare even for developed countries.
[5] Elasticities report the percentage change in the outcome variable in response to a 1% change in a determining variable.

Third, in all dimensions the effect strengthens into the long run. Moreover, it is notable that the spillover effects tend to be stronger for *smaller* rather than large firms.

Finally, the presence of spillover means that social returns on R&D capital will be higher than the private rate of return. Bernstein and Nadiri compute the wedge between private and social rates of return for the four industries under consideration. Their findings, reported in **Table 4.3**, suggest that the wedge varies in magnitude from 30% (the smallest), to 123% (the largest).

On any account therefore, if these data are accurate the implication is of very substantial spillover effects, with dramatic impacts on the divergence between social and private marginal rates of return. If such wedges are indeed present, the implication would indeed be for the need to correct the market failure through policy intervention.

In effect the findings confirm the presence of a positive impact (a reduction) on the cost structure of production in industries other than where the R&D actually takes place. Furthermore, the findings confirm the reduction in investment in both physical and R&D capital predicted by endogenous growth theory. Thus *both* the Romer suggestions, subsidies to physical a well as R&D capital would apear to be justified on these findings.

Table 4.2: Estimated Elasticities of R&D Spillovers.

Industry	Firm Size	R&D Capital	Physical Capital	Labour Cost	Average Cost
Short Run Elasticities					
Chemicals	Largest	-0.0123	-0.0088	-0.0289	-0.0165
	Smallest	-0.0528	-0.0625	-0.2166	-0.1525
	Mean	-0.0290	-0.0088	-0.1800	-0.1269
Petroleum	Largest	-0.0054	-0.0012	-0.0069	-0.0049
	Smallest	-0.1553	-0.1293	-0.3086	-0.1615
	Mean	-0.0865	-0.0347	-0.1825	-0.1144
Machinery	Largest	-0.0121	-0.0069	-0.0221	-0.0142
	Smallest	-0.1723	-0.0870	-0.1685	-0.1147
	Mean	-0.0550	-0.0383	-0.1134	-0.0768
Instruments	Largest	-0.0321	-0.0072	-0.0557	-0.0379
	Smallest	-0.0070	-0.0201	-0.1794	-0.0937
	Mean	-0.0968	-0.0151	-0.0929	-0.0489
Long Run Elasticities					
Chemicals	Largest	-0.0306	-0.0323	-0.0407	-0.0397
	Smallest	-0.0978	-0.1260	-0.2485	-0.2202
	Mean	-0.0764	-0.1010	-0.2187	-0.1867
Petroleum	Largest	-0.0113	-0.0168	-0.0147	-0.0134
	Smallest	-0.3133	-0.2046	-0.4604	-0.3615
	Mean	-0.1649	-0.1410	-0.2678	-0.2167
Machinery	Largest	-0.0255	-0.0114	-0.0280	-0.0252
	Smallest	-0.1987	-0.1120	-0.2457	-0.1403
	Mean	-0.1125	-0.0504	-0.1508	-0.1179
Instruments	Largest	-0.0360	-0.0082	-0.0588	-0.0416
	Smallest	-0.1224	-0.0395	-0.1743	-0.1169
	Mean	-0.0732	-0.0299	-0.1416	-0.0967

Source: Bernstein and Nadiri (1989).

Table 4.3: Net Social Rate of Return on R&D Capital.

Industry	Net Social Rate of Return	% Difference between net social and private rates of return
Chemicals	0.1199	67
Petroleum	0.1604	123
Machinery	0.0936	30
Instruments	0.1364	90

Source: Bernstein and Nadiri (1989)

4.2 The South African Evidence: findings on the relevance of endogenous growth theory

Again, empirical findings relevant to the traditional understanding of the impact of technology on economic growth in South Africa has already been explored in some detail in Chapter 2. We have seen that the generalized efficiency gains that result from total factor productivity growth in the South African economy are potentially substantial. We also demonstrated the importance of being aware of distinctions between the performance of different economic sectors within the economy.

For this reason we do not reiterate this evidence, and instead consider endogenous growth theory directly.

We begin by considering the explanatory performance of growth in factor inputs in determining output growth. In this section, the focus of the empirical work is on the manufacturing sector of the economy. The reason for the choice is determined predominantly by data reliability and availability considerations.

We employ a panel data set for purposes of estimation, with observations from 1970 through 1997. The panel employs data for the 28 three-digit SIC version 5 manufacturing sectors in the South African economy for which data is available. The list of sectors included in the panel is specified in **Table 4.4.** This provides a 28x28 panel with a total of 784 observations, though for some estimations some sectors did not have the requisite data available. We indicate the need for sector exclusions where this is appropriate.

The focus on the manufacturing sector is for data consistency and reliability reasons. Reliability of consistent data definitions across other sectors is less assured than within manufacturing sectors,[6] and with respect to some variables data is available only for the manufacturing sectors.

We begin with a consideration of the contribution of factor input growth to output growth. In **Table 4.5**, column 1 we report the results from the PMG panel data estimator[7] applied to the South African manufacturing sector. Details of the estimation method are supplied in Appendix 1 to Chapter 4.

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[6] See the discussion in Fedderke and Vaze (1999), and Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000) and Fedderke, Henderson, Mariotti and Vaze (2000).

[7] Pooled Mean Group Estimate.

The only reason for reporting the most simple specification is to point out that it fails to explain output growth in the manufacturing sector. While it is true to say that the coefficient on the labour input is positive and significant, that on the capital input is of the incorrect sign as well as statistically insignificant. Even if significant, its (standardised) coefficient would have implied a small impact of capital stock growth on output growth.

Table 4.4: Sectors included in the study

Manufacturing
Food
Beverages
Tobacco
Textiles
Wearing apparel
Leather & leather products
Footwear
Wood & wood products
Paper & paper products
Printing, publishing & recorded media
Coke & refined petroleum products
Basic chemicals
Other chemicals & man-made fibres
Rubber products
Plastic products
Glass & glass products
Non-metallic minerals
Basic iron & steel
Basic non-ferrous metals
Metal products excluding machinery
Machinery & equipment
Electrical machinery
Television, radio & communication equipment
Professional & scientific equipment
Motor vehicles, parts & accessories
Other transport equipment
Furniture
Other industries

Moreover, the finding of insignificance for the growth rate in capital stock is insensitive to alternative measures of the variable. In Column 2 of **Table 4.5** we replace the growth rate of the physical capital stock by the investment rate maintained by each economic sector. The results are symmetrical to those we obtained for regression equation (1). Capital growth remains insignificant (as well as of the incorrect sign, and with a small coefficient), and only the growth of labour inputs appears to contribute to economic growth according to these results.[8]

[8] For the remainder of our discussion we will employ the investment rate variable. Results produced are always symmetrical to those for the raw capital growth rate. The investment rate has greater resonance in terms of wider growth theory, however, and is therefore the preferred specification.

The implication of these findings is that output growth in South African manufacturing is not adequately captured by any simple specification that focuses simply on the growth rate of factor inputs.

The obvious question in the current context is to what extent the results can be improved by considering the contribution of technological progress.

Table 4.5: South African Manufacturing Sector Results: Dependent variable is output growth. Figures in round parentheses are standard errors. Figures in square parentheses are standardized coefficients. Statistical significance is indicated by *. Estimation is on a panel, with the 1970-97 sample period.

	1	2	3	4	5
Capital Growth	-0.000	-0.053	0.002	1.115*	1.128*
	(.001)	(0.053)	(.055)	(.028)	(.028)
	[-0.04]	**[-0.08]**	**[.00]**	**[1.72]**	**[1.74]**
Labour Growth	0.004*	0.005*	0.004*	0.007*	.007*
	(.001)	(.001)	(.001)	(.00)	(.00)
	[0.19]	**[0.24]**	**[0.19]**	**[0.33]**	**[0.33]**
Skills Ratio			-0.033		-0.001
			(.018)		(.003)
			[-0.01]		**[0.00]**
TFP				0.951*	0.954*
				(.01)	(.011)
				[1.16]	**[1.16]**
φ[9]	-0.926*	-0.912*	-0.908*	-0.913*	-0.908*
	(.039)	(.036)	(.041)	(.063)	(.06)
LR	80.05*	79.59*	101.3*	439.61*	475.02*

To do so we begin by testing for the impact of a sectoral proxy for "innovative orientation" for which we employ the ratio of highly skilled workers employed in the sector to the total labour force of the sector.[10] The argument here is that the higher the ratio, the greater the capacity of the sector to generate or to absorb technological advance should be.[11] Hence our expectation would be of a positive sign on the variable in an output growth equation. **Table 4.5** reports the estimation results in column 3.

As a second specification we include the measure of sectoral total factor productivity growth we computed and reported on in Chapter 2. We report the resultant estimation in column 4 of **Table 4.5.** Care should be taken in interpreting the results, however. Recall that the growth in total factor productivity variable is itself computed as a

[9] Measures speed of adjustment to the long run equilibrium relationship.
[10] Note that skills data was not available for the Tobacco, Plastic products, Television, radio & communication equipment, and Other transport equipment sectors. All estimations including the skills ratio therefore exclude these sectors.
[11] It could be argued to be the counterpart to the Ochoa (1996) variable for the number of R&D scientists per industry – though of course rather imperfectly so.

difference between output growth and that mandated by factor input growth appropriately adjusted for factor shares in total output. Thus our prior expectation would be of an association between the TFP measure and output growth. The real question here must concern the relative size of the contributions provided by growth in capital and labour inputs, and that contributed by gains in total factor productivity (i.e. general efficiency improvements in production). And subsequently, whether any other factors generate an *independent* impact on sectoral efficiency gains.

Finally, we incorporate both the skills ratio as well as the measure of TFP growth to establish whether the variables have any independent effect, in column 5 of **Table 4.5.**

We find that the impact of the skills ratio on output growth turns out to be negligible. It is statistically insignificant in all output growth equations in which it is included in **Table 4.5.** By contrast the inclusion of the TFP measure is not only (highly) statistically significant when included, but it also serves to render growth in both factor inputs statistically significant and of the theoretically anticipated sign.

For this reason we employ the specification which controls for factor input growth as well as TFP as our base specification.

The implication of the statistical findings thus far are that in order to adequately explain growth in output in the South African manufacturing industry, we need to account for at least:

- growth in capital inputs,
- growth in labour inputs,
- and crucially, the generalized improvement in the efficiency of production that growth in total factor productivity represents.

One interpretation of this evidence is that the TFP variable (in the absence of more precise information) could be taken to proxy for the innovative effort of the industry.

Moreover, standardized coefficients[12] indicate that:

- the strongest impact on output growth emerges from the growth in capital inputs. Thus an increase of one standard deviation of the capital input results in a 1.74 standard deviation increase in output growth.
- followed by the impact of TFP. An increase of one standard deviation of the capital input results in a 1.16 standard deviation increase in output growth.
- and the weakest impact on output growth attaches to growth in the labour input into production. An increase of one standard deviation of the capital input results in a 0.33 standard deviation increase in output growth.

We thus confirm the evidence of Chapter 2 which identified a relatively strong impact of growth in total factor productivity on output growth in South African manufacturing industry, at least over the 1970-90 time frame.

It is worth also reminding ourselves that in this respect South Africa is somewhat distinct from other developing (and some developed) countries, in which the general expectation would be that the manufacturing sector grows primarily through the

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[12] Estimated coefficients cannot be interpreted directly, since the scales of the variables included in estimation differ. Standardised coefficients correct for this, and allow for an assessment of the relative size of the impact of variables included in estimation.

augmentation of the physical capital stock, rather than through TFP growth. In Chapter 2 we saw that in South African manufacturing this has not been the case. Instead, the reliance on emulating more advanced technology from elsewhere, while rapidly expanding the capital stock of the manufacturing sector is really a feature of the 1990's in South African manufacture, and certainly in the 1970's and 1980's a much greater reliance on TFP growth was manifest.

This much we already know from the discussion of Chapter 2 therefore. The point here must be to establish whether the endogenous growth model prediction, of an additional impact on output growth due to

1. explicit investment of resources in innovative (R&D) activity,
2. the presence of spillover effects,

is borne out by the evidence.

We do so by controlling for a number of additional factors that might be said to proxy for the extent of innovative activity of a specific industry, or for the extent to which a sector finds itself in a general enabling environment for innovation. Thus we add the following variables to our base specification from **Table 4.5** column 5:

- The total number of degrees issued by South African universities.[13] We illustrate the data in **Figure 4.1** as *Degrees*. We report the resultant regression equation in column 1 of **Table 4.6.**

- The total number of degrees issued by South African universities in the mathematical and engineering sciences.[14] We illustrate the data in Figure.1 as *M&E Degrees*. We report the resultant regression equation in column 2 of **Table 4.6**.

- The school enrolment rate, for all racial groups in South Africa. The variable is given by the ratio of pupils enrolled in primary in secondary schooling as a proportion of the total age cohort eligible for schooling. We report the enrolment rate in **Figure 4. 2**.[15] We report the resultant regression equation in column 3 of **Table 4.6.**

- Apprenticeship contracts issued per capita.[16] We illustrate the data in Figure 1 as *Apprenticeships*. We report the resultant regression equation in column 4 of **Table 4.6**.

- The ratio of total degrees issued to the sum of degrees and apprenticeship contracts. We report the resultant regression equation in column 5 of **Table 4.6.**

[13] For details on the construction of this variable see Fedderke, de Kadt and Luiz (2000b).
[14] For details on the construction of this variable see Fedderke, de Kadt and Luiz (2000b).
[15] The enrolment rate is constructed from the base data contained in Fedderke, de Kadt and Luiz (2000a).
[16] For details on the construction of this variable see Fedderke, de Kadt and Luiz (2000b).

- The ratio of mathematical and engineering science degrees to the sum of mathematical and engineering science degrees and apprenticeship contracts. We report the resultant regression equation in column 6 of **Table 4.6**.

- The total real cost reduction for the manufacturing industry. This represents the total contribution to output growth by all manufacturing industries through efficiency improvements. The variable is constructed as three decade averages, for the 1970's, the 1980's, and the 1990's, for each industry in the panel. We report the resultant regression equation in column 7 of **Table 4.6.**

- The total number of patents registered in South Africa.[17] We report the data in **Figure 4.3**, together with the ratio of patents registered as a ratio to real GDP. We report the resultant regression equation in column 8 of **Table 4.6.**

The evidence that emerges from the estimation of the base model with these alternative variables incorporated is remarkably consistent.

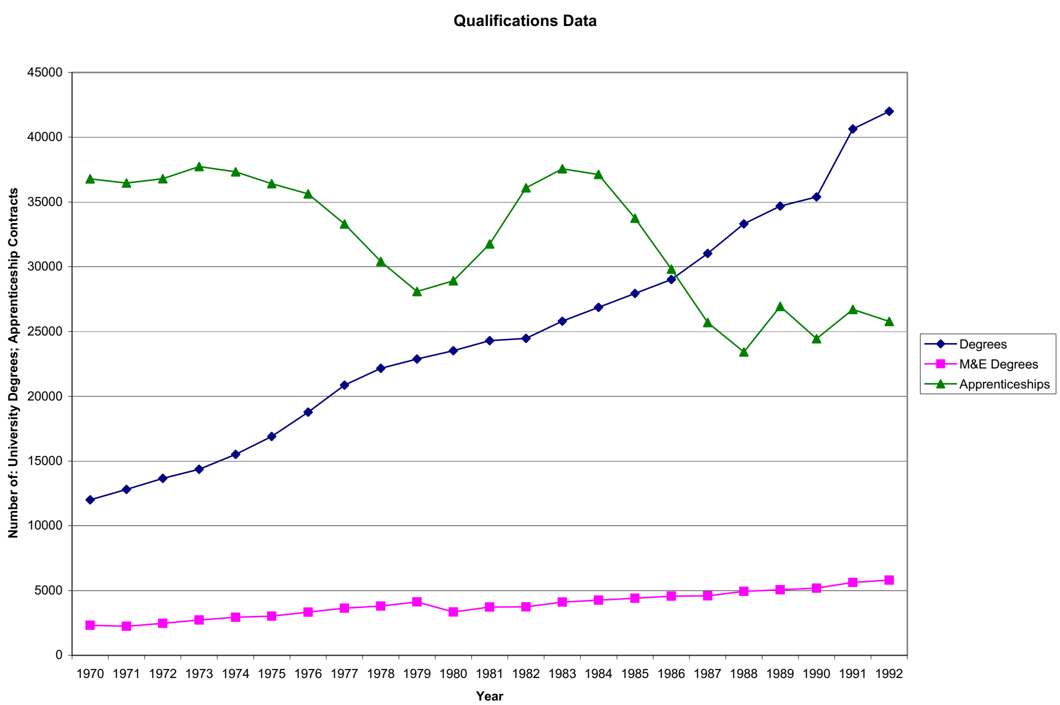

Figure 4.1: University Degrees and Apprenticeship Contracts. Source: Fedderke, De Kadt and Luiz (2000b).

[17] For details on this variable see Fedderke, de Kadt and Luiz (1999a).

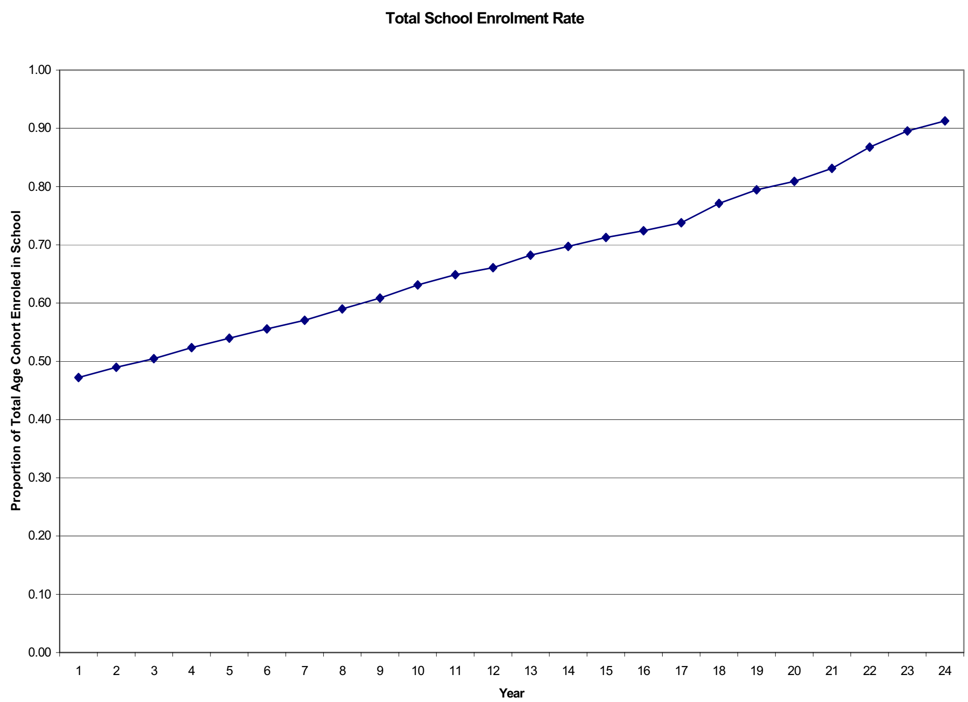

Figure 4.2: School Enrolment Rate

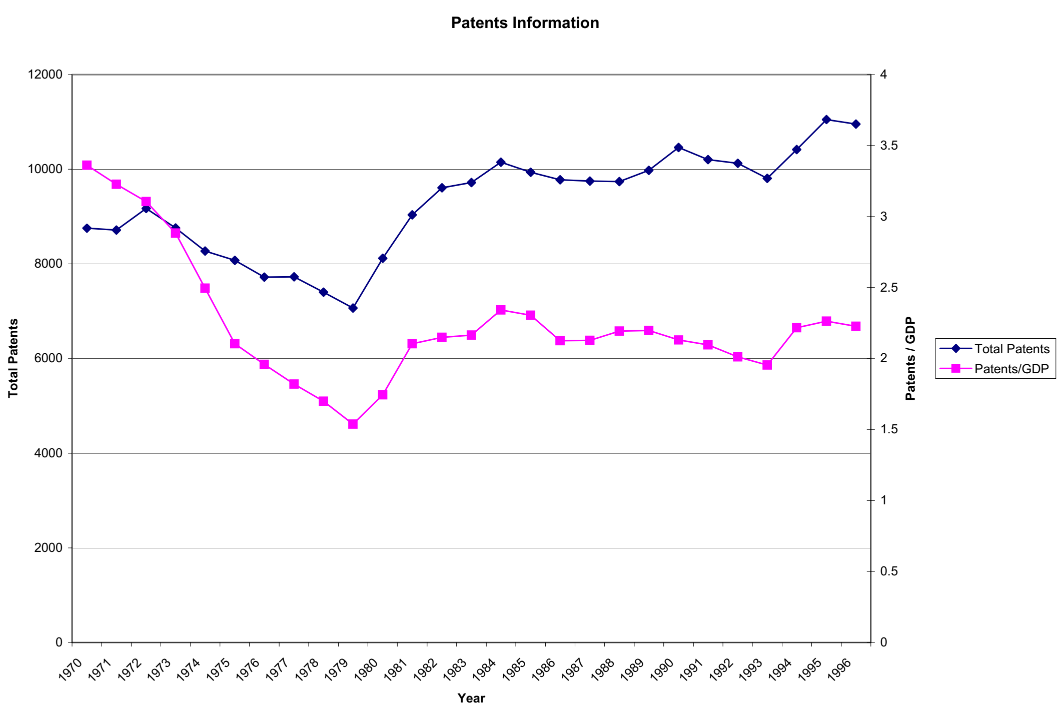

Figure 4.3: Patents Registered; absolute number and as proportion of GDP. Source: Fedderke, De Kadt and Luiz (1999a).

In particular, we find that the investment rate (the capital input growth) consistently contributes positively and statistically significantly to output growth. Moreover, its standardized coefficient is consistently such as to suggest that a 1 standard deviation increase in the investment rate is associated with an increase in output growth of approximately 1.8 standard deviations.[18]

Similarly, the labour force growth rate is consistently positive and significant, suggesting that a 1 standard deviation increase in the labour force growth rate is associated with an increase in output growth of approximately 0.33 standard deviations.[19]

Total factor productivity is also consistently a positive contributor to output growth, and is always statistically significant. In this instance the contribution of a 1 standard deviation increase in the sectoral measure is an increase in output growth of approximately 1.15 standard deviations.[20]

The skills ratio is on occasion negatively signed and statistically significant, on occasion positively signed and significant, and most consistently statistically insignificant. Results attaching to the variable are thus not robust, and as a consequence must be treated with caution. Indeed, given the lack of robustness of the result, we drop consideration of the variable in the discussion that follows.

However, readers may wish to note in passing that one possible explanation of the negative sign on the skills ratio variable might come from Heckscher-Ohlin trade theory, which predicts that trade liberalization would favour output growth in sectors intensive in the abundant factor of production. Since over the sample period South Africa’s trading partners have been predominantly industrialized countries relatively abundant in skilled labour, it follows that skills intensity in production might not have been favourable for output growth.[21]

This leaves us with the task of interpreting the remaining variables, proxying for the impact of the enabling conditions that endogenous growth theory introduced in the form of a research sector within the economy. Our findings in the present study are again remarkable for their consistency, in the sense that all of the proxies introduced into the base estimation intended to control for the general enabling conditions prove to be:

- positively signed,
- statistically significant,
- and on the standardized coefficient measure, suggest that a 1 standard deviation increase in the enabling environment measure is associated with a 0.03 standard deviation increase in the growth rate of output.[22]

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[18] The only deviations from this magnitude of coefficient occur in equations 4 and 8.
[19] The only deviations from this magnitude of coefficient occur in equations 4 and 8.
[20] The only deviation from this magnitude of coefficient occurs in equation 4.
[21] For evidence that would confirm the appropriateness of this interpretation see Fedderke, Shin and Vaze (2000).
[22] The only deviations from this magnitude of coefficient again occurs in equations 4 and 8.

Table 4.6: South African Manufacturing Sector Results: Dependent variable is output growth. Figures in round parentheses are standard errors. Figures in square parentheses are standardized coefficients. Statistical significance is indicated by *. Estimation is on a panel, over the 1970-97 sample period.

	1	2	3	4	5	6	7	8
Capital Growth	1.194* (.04) **[1.84]**	1.190* (.04) **[1.84]**	1.169* (.03) **[1.81]**	0.089* (.03) **[.14]**	1.199* (.04) **[1.85]**	1.192* (.04) **[1.84]**	1.117* (.028) **[1.73]**	0.052* (.02) **[.08]**
Labour Growth	0.007* (.00) **[.33]**	0.007* (.00) **[.33]**	0.007* (.00) **[.33]**	0.008* (.00) **[.38]**	0.007* (.00) **[.33]**	0.007* (.00) **[.33]**	0.007* (.00) **[.33]**	0.008* (.00) **[.38]**
Skills Ratio	-0.194* (.08) **[-.07]**	-0.165* (.08) **[-.06]**	-0.188* (.07) **[-.07]**	0.614* (.29) **[.23]**	-0.145 (.08) **[.05]**	-0.136 (.08) **[-.05]**	-0.075 (.05) **[-.03]**	0.189 (.17) **[.07]**
TFP	0.943* (.01) **[1.15]**	0.943* (.01) **[1.15]**	0.953* (.01) **[1.16]**	0.772* (.03) **[.94]**	0.939* (.01) **[1.14]**	0.942* (.01) **[1.15]**	0.955* (.01) **[1.16]**	0.893* (.02) **[1.09]**
Total Degrees	$6x(10^{-7})$* (.00) **[.04]**							
M&E Degrees		.000004* (.00) **[.03]**						
Enrolment Rate			0.033* (.01) **[.04]**					
Apprenticeships per Capita				-58.23* (23.38) **[-.16]**				
Degree Proportion					0.035* (.01) **[.03]**			
M&E Degree Proportion						0.065* (.02) **[.03]**		
Real Cost Reduction							$-7x(10^{-7})$* (.00) **[-.02]**	
Patents								0.00001* (.00) **[.09]**
φ[23]	-0.865* (.06)	-0.871* (.06)	-0.887* (.06)	-0.553* (.05)	-0.864* (.06)	-0.865* (.06)	-0.91* (.06)	-0.61* (.08)
LR	504.87*	519.52*	514.52*	329.90*	503.47*	503.47*	511.14*	321.11*

[23] Measures speed of adjustment to the long run equilibrium relationship.

The contribution of the general enabling environment is thus relatively small, when compared to the contribution of the growth rate of the capital stock, and the sectorally specific efficiency gains controlled for by means of the TFP variable. However, what is noteworthy here is that we are able to detect the contribution of these general enabling conditions at all. This is the case for a number of reasons:

- *First*, we have already noted on a number of occasions that the likelihood that independent national technological innovation will have an impact in a developing country such as South Africa is relatively remote. The far greater probability is that manufacturing industry emulates its more advanced sister sectors in the developed world, leaving innovation to them. What the evidence of the present section demonstrates is that *despite* these limiting factors, the general enabling environment continues to exercise an influence. The implication appears to be that the general enabling environment is important even for the purposes of emulation of more advanced manufacturing sectors. There are good reasons to suppose that this might indeed be the case. In particular, even emulation (copying) is not costless[24] – and indeed, the more complex the technology being emulated, the greater the cost of doing so, and the greater the skill required in being able to develop the capacity to emulate. Under these conditions, it is plausible that even for a developing country such as South Africa the need to develop enabling conditions remains essential, even if this is initially for the purposes of emulation.

- *Second*, what is in fact remarkable is that the variables proxying for the general enabling conditions remain significant even after we have controlled for the sectoral TFP variable, not that their coefficient is small. Again, during the course of Chapter 2 we have remarked on the fact that TFP controls for the *generalized* increase in productive efficiency of a sector. To this extent we might anticipate that the impact of the general enabling conditions might already have been captured in the TFP term. That the variables proxying for the general enabling environment *nevertheless* prove to be significant might thus be taken to attest to the robustness of the impact of the enabling environment.

These considerations give us some confidence in concluding that the endogenous growth theory prediction that the presence of general enabling conditions for the process of innovating activity finds confirmation for the South African manufacturing sector.

Moreover, while the finding that the TFP variable is significant in explaining output growth is not surprising, that the variables proxying for the general enabling conditions prove to be significant, suggests that spillover effects as well as sectorally specific technology impacts characterize the South African manufacturing sector.

Before concluding on this positive note for the technology impact, we need to deal with the two exceptional sets of results reported in column 4 and 7 of **Table 4.6.** Only for these two regression equations the proxies for the general enabling conditions prove to be negatively signed, and significant. However, it is likely that these two proxies issue in a misspecification in estimation of the two equations. They prove to be two variables that are statistically positive in regressions of the TFP variable on

[24] See Mansfield, Schwartz and Wagner (1981) and Teece (1977).

potential determinants of the sectoral indicator of improved efficiency.[25] Thus, the impact of these two variables may well be more appropriately viewed as being exercised indirectly through improvements in sectoral efficiency of production, rather than directly on output growth.

The evidence on the South African manufacturing sector thus confirms the relevance of the endogenous growth framework for South Africa. The general enabling conditions provided by the creation of human capital, and the allocation of such human capital to innovation appears to be carrying an impact on output growth even when we have already accounted for the sector specific improvements in the efficiency of production.

4.3 Conclusions and evaluation

Both internationally and for South Africa in particular, therefore, endogenous growth in technology appears to matter. The implication is that the general enabling environment for innovation, the allocation of resources to the creation of new knowledge matters for growth.

The world thus appears to be fundamentally Schumpeterian rather than neoclassical.

Readers should also remind themselves that these findings carry with them strong policy implications. The suggestion is one of market failure – of a tendency by the market to underinvest in physical and/or human capital.

Fostering the enabling environment which leads to innovation, and the activities that lead to innovation, appears to be of central importance to economic development – both internationally, as well as for South Africa in particular.

[25] The standardised coefficients of the Apprenticeships per Capita and Real Cost Reduction Variables are 0.06 and 0.10 respectively.

Appendix 1: Dynamic heterogeneous panel estimation methodology

Introduction

Panel data refers to the pooling of observations on a cross-section of households, countries, firms, etc. over several time periods. The estimation techniques available to analyse such data have attracted much interest in econometric research. There are a variety of estimation techniques that may be applied to panels. The methodologies vary across the dimensions of the panel and with respect to the modeller's prior belief about how the system works. Generally, a long panel has the advantage that the long-run economic relationships of the modelled system can be estimated.

The number of time periods can be referred to using *T* with the size of the cross-section being *N*. If *N* is one, then the traditional method is to estimate an autoregressive distributed lag (ARDL) model. This has recently been superseded by techniques based around cointegration.[26] Both techniques have the advantage that they provide an estimate of the long-run relationship between the economic variables. When *N* is small, the chosen method is usually the seemingly unrelated regression equation (SURE) technique. This is similar to running ordinary least squares on each of the panel categories but allowing for some covariance in the error terms across the categories.

The data set used in this study is a panel of 45 sectors annually over the period 1972-98. This is a balanced panel in the sense that *T* and *N* are of similar magnitudes. This allows the use of techniques to estimate a long-run equilibrium relationship while at the same time modelling the heterogeneous short-run dynamics that may be exhibited across the *N* groups in the panel. The methods utilised here is referred to as the **pooled mean group (PMG) estimator**, proposed in [Pesaran, 1997:433].

Overview

Panel data regression differs from a regular time series or cross-section in that variables can be identified by both group and time, indicated by the double subscript in both *i* and *t*. Thus, the behaviour of a dependent variable $y_{i,t}$ can be modelled in

$$y_{it} = \alpha + X_{it}^{'}\beta + \varepsilon_{it}$$

terms of a set of explanatory variables, $X_{i,t}$:

The number of panel methods available to the econometrician in recent years has seen a large increase reflecting the diverse standpoints of time-series and cross-sectional specialists. In this section four methodologies are outlined: the fixed effect model, dynamic fixed effect, the pooled mean group estimator and the mean group estimator. The first of the methods is the most basic panel methodology; the latter methods improve on the treatment of the time-series dimension of the panel. This is done through more explicit consideration of two aspects of the time-series behaviour across the panel: the short-run dynamics and the long-run equilibrium relationship.

These two aspects of the time-series are inter-linked. The nature of the long-run equilibrium relationship is clearly of empirical interest. However, the variation of the

[26] It should be noted though that cointegration and ARDL are not mutually exclusive. Thus Pesaran, and Shin (1995b) and Pesaran (1997) outline an ARDL approach to cointegration.

relationship across the panel can be further investigated. Does the same relationship hold across the panel or do different groups have different long-run equilibrium relationships? Once a long-run relationship has been determined, interest focuses on how quickly deviations from the long-run are corrected. When a panel is quite long, these dynamics can be explored. Again, one can either assume different groups behave differently across the panel – heterogeneity in short-run dynamics – or the short-run dynamics are similar across the panel of groups – homogeneity in short-run dynamics. The table identifies four methods in terms of how these modelling aspects are treated.

Panel methodology	Dynamics modelled	Long-run relationship across panel	Short-run relationship across panel
Fixed effect model	No	N.a.	N.a.
Dynamic fixed effect model	Yes	Homogenous	Homogenous
Pooled mean group	Yes	Homogenous	Heterogeneous
Mean group	Yes	Heterogeneous	Heterogeneous

Fixed effect modelling of a panel

The fixed effect models of this phenomenon capture the panel nature through the disturbance term. The most common means to model the disturbance term is a one-way error component:

$$\varepsilon_{it} = \mu_i + \upsilon_{it}$$

This suggests that the unexplained factors in $y_{i,t}$ can be separated into a time-invariant component and a portion which varies for each observation both in time and across groups. The time-invariant component captures unobservable group-specific effects. Put another way, the mean of y is allowed to vary across groups so that group i's mean would deviate from the mean across groups by μ_i. By introducing some assumptions about the nature of the distribution of the disturbance terms, a likelihood function can be derived and this is then maximized to give parameter estimates. This is a relatively simple treatment of the panel properties modelling little variation across groups. A common improvement is to allow cross-sector variation in slope coefficients.

Dynamic fixed effect modelling of a panel

Economic relationships modelled by panel are often dynamic in nature and time-series is often used to analyze the dynamics of adjustment. This is most commonly done by introducing a lag dependent variable to the specification. This technique has been used by a number of analysts in panels. Essentially, the above model is re-written as:

$$y_{it} = \delta y_{i,t-1} + X_{it}^{'}\beta + \varepsilon_{it}$$

The disturbance can be modelled as with the fixed effects model. Again there would be two error terms: one group specific, the other different for each observation. Given the disturbance terms follow a normal distribution, the likelihood function can be derived and maximization will yield parameter estimates. Again, the treatment is quite simple modelling variation across the panel only in terms of its effect on the mean value and not on slope coefficients.

Mean group estimation

A means to allow for the maximum degree of heterogeneity across a panel is to treat each group separately and to estimate separate relationships for the time-series data of each group. The long-run equilibrium relationship and the short-run dynamics can then be derived as the average of the estimated equations. This is the basis for the mean group estimators (MGE). Such a model is discussed in Pesaran and Smith (1995). They show that the restrictions imposed on the slope coefficients by the pooling of groups in earlier techniques is not justified. That is, there is a great deal of heterogeneity across the panel in the long-run relationships and in the dynamics. Fixed effects models will bias parameter estimates because they do not model this.

A consideration noted by Pesaran and Smith is that while there may be heterogeneity in the slope coefficients across a panel, some subset of the parameters may be identical across groups. This possibility is explored in the pooled mean group estimators discussed in some detail below.

The pooled mean group estimator

The ARDL representation allows the estimation of a long-run equilibrium relationship. For an economic analysis, this property of the estimation technique has some inherent appeal. When there is a panel structure to the data, recent adaptations of the ARDL technique allow this benefit of the estimate to be utilised across a panel.

In the present analysis, T is large enough so that an ARDL could be estimated for each of the cross-section categories separately. The number of categories, N, is of the same order as T. The pooled mean group estimator applies an ARDL model to each of the N cross-sectional categories. Let the dependent variable for each category i be a vector $\mathbf{y}_i$ such that each element represents the observation of a particular time period, t, and the independent variables be a matrix $\mathbf{X}_i$ where the rows represent the different time periods, the columns a different independent variable. A standard representation of the ARDL (p, q, q, … q) model is:

$$y_{it} = \sum_{j=1}^{p} \lambda'_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} \mathbf{x}_{i,t-j} + \varepsilon_{it} \tag{1}$$

In this model, the dependent variable, y, is regressed against p lags of itself, and q lags of the independent variables. This is then represented in terms of differences:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta'_i \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q} \delta'^*_{ij} \Delta \mathbf{x}_{i,t-j} + \varepsilon_{it} \tag{2}$$

As noted, above, the ARDL model nests a long-run relationship between dependent and independent variables. The long-run parameters can readily be identified in (2) by modelling the system when it is stable. This is done by setting $y_{it} = y_{i,t-1}$ so that

$\Delta y_t = 0$ and setting $x_{it} = x_{i,t-1}$ so that $\Delta x_t = 0$. This leads to the long-run relationship: $y_{it} = -(\beta_i' / \phi_i)\mathbf{x_{it}}$.

[Pesaran, 1997:433] extend this model to analyse a dynamic panel where the time-series observation for the *i*th category is pooled with the other *N*-1 observations. This is achieved in two stages. Firstly, the disturbance term is modelled allowing for the possibility of some correlation between the errors across a category in the panel. This is an application of standard technique in panels and is a common first step in an unbalanced panel (e.g. where *T* is large, *N* small, SURE[27] techniques are used). Thus:

$$\varepsilon_{it} = u_i + v_{it} \tag{3}$$

As the present panel is balanced, the non-zero error covariance modelled by (3) can be explored in more detail and model specification can be improved by allowing explicitly for common effects across the panel. This is often achieved by including the cross-category means of the independent variables in the model. Such a method is termed **mean group** (MG) estimations. The parameter estimates would then measure the group-wide impact on an individual group so that no restrictions are imposed on the relationship across categories. For example, it would be expected than average output across industries would affect the output of an individual sector of an economy; however, the extent of this effect may differ across sectors.

This assumption implies that the coefficient on the **x** will be identical across groups in the long-run. The short-run variation of the data is modelled separately in each group through an error correction process

Estimation of PMGE

Estimation proceeds by using maximised likelihood techniques given the error terms are independently distributed with zero means. The familiar Newton-Raphson method of maximisation can be used fort his. Alternatively, parameter estimates can be derived through a back-substitution algorithm. The former method requires estimation of the first and second derivative of the likelihood function while the latter requires only the first derivative. Estimation of standard errors is more complicated as allowance has to be made for non-stationary regressors. [Pesaran, 1997:433] explores this aspect and derive the asymptotic distribution of the PMG parameter estimates.

Gauss code has been written by Shin and is available on the web to produce the parameter estimates and calculate asymptotic standard errors. This code is used in the present estimation.

[27] Seemingly unrelated regression equation

Chapter 5

Revisiting the Role of Human Capital

5.0 Introduction

We have now seen that technological advance matters for long run economic growth, and explored the channels that economists see as those responsible for the transmission of technological progress to improvements in output produced. We have also seen that "new" or endogenous growth processes are finding empirical confirmation not only internationally, but for South Africa also.

In the process of exploring the role of technology we have repeatedly made reference to the role and impact of human capital. Indeed technological progress is frequently though not exclusively associated with the focused application of human inventiveness, often in formal institutionalised contexts of explorations such as the laboratory.

This may well be so, but this then raises the question of how the contribution of human capital to the process of technological innovation is to be properly understood. How, why, and when does it make a difference to innovation? What forms of human capital are the appropriate ones? And does human capital contribute to growth only indirectly through technological progress, or does it have an independent and direct impact on growth also?

It is to these and related questions that we now turn.

5.1 The significance of having a learning society

When confronted with what is meant by the concept of human capital it is difficult to understand why the concept would *not* be thought of as central to the process of economic growth and development more broadly defined. In its broadest sense human capital is understood to embrace at least three separate and distinct components.[1]

The first is perhaps the most obvious. It refers to the *pure skills* obtained by economic agents, encompassing the education they have been exposed to, the scientific knowledge they have acquired and can dispose over, as well as skills acquired on-the-job. Thus it identifies the improved productive capacity of economic agents that results from education and training of all the different forms that they may encounter either in educational institutions or in the work place.

In the Schumpeterian tradition, e*ntrepreneurial capacity* forms a second form of human capital. This is not captured by formally taught sets of skills, but by the willingness to countenance risk in productive activity, to explore and create opportunity where previously there was none, and thereby to create new areas of economic activity.

[1] See for instance Theodore Schultz (1993) in his Nobel-prize winning work.

Finally, the *stock of accumulated knowledge* is also seen as crucial to fully understanding the accumulated stock of productive capacity a society has at its disposal. Since individual human beings are finite (they die), the threat is that the stock of knowledge accumulated by individuals over a lifetime comes to pass with their passing also. Efficiency therefore dictates that human capital (in whatever form) not only comes to be created, but comes to be transmitted to the next generation of economic agents at as low a cost as possible. Accumulating a stock of knowledge, and the means of transmitting it are vital if the full benefits from the resource represented by human capital are to be fully realised.

It is difficult to imagine that the three components of human capital should not matter to long run economic development. And indeed even that they should matter well beyond the impact they have on the process of technological innovation narrowly defined. The efficiency gains they promise are on production of final output directly, as well as on the improved capacity of society to improve the process of knowledge accumulation.

In a sweeping review of "all" of human economic development Landes (1998) places perhaps his very strongest emphasis on the role and impact of knowledge creation and accumulation as the key to long run success in economic development.[2] This and the importance of a work ethic. Landes' discussion is impressive for its sweep, and the richness of the historical evidence that he advances in his cause. In the course of accumulating the historical track record from many different societies and epochs around the world, Landes details a number of factors related to the contribution of human capital as critical to long run developmental success during the course of his exposition:

- Having access to stocks of knowledge, particularly as regards technology of production. Knowing how to operate, manage and build, and then to modify and further design the machines and techniques by which we produce is crucial to the continued health of the process of production.
- Having the institutional means of transmitting knowledge between generations.
- Assigning people to tasks on unambiguous basis of merit and competence, rewarding good and imposing penalties for poor performance are essential to healthy incentive mechanisms.
- Creating opportunity for individual and collective entrepreneurship.
- Allowing people to keep and employ as they see fit the outcome of their enterprise – in short, having secure property rights.

Most intriguingly of all perhaps, such enabling characteristics have institutional requirements. Secure property rights to encourage savings and investment, and the facility of enforcing such rights. Secure personal and civil rights, to prevent the arbitrary exercise of power by either public or private instances. Stable government with consistent rules of conduct, responsive to complaint and the need for redress, honest and devoid of corruption, and which limits its claims on the social surplus, so

[2] See the more extensive discussion in Fedderke (1999).

as to enable investors to allocate scarce resources to projects with the highest rate of return.[3]

Importantly, different nations have possessed such characteristics at different points in time, and flourished as a result. Britain had them in greater measure than her competitors for much of the 18'th and 19'th centuries. Ming China had them with spectacularly successful results. Consider just one telling example: the greatest European explorers, the Portuguese, undertook their voyages of discovery in the caravel. An example of such a caravel, Columbus's *Santa Maria* measured 85 feet in length. At approximately the same time (the first half of the 15'th century) the Chinese mounted their own voyages of discovery in the Indonesian archipelago. The voyages were undertaken with fleets, the first (in 1405 under admiral Zheng He) used 317 vessels and 28000 men, the biggest ships were 400 feet long, 160 wide, with 9 masts, included dedicated horse ships to transport the animals, supply ships, even dedicated water tankers. Compare this with Vasco da Gama's 4 ships, and 170 crew of which only 54 survived the trip. Astonishing Chinese achievements, and well ahead of the Europeans of the time. Yet the sting in the tail of the moral is that China squandered its advantage. China turned inward (they appeared to have nothing to learn from barbarians), the voyages of discovery were abandoned, prohibited. Of course, a fierce internal court struggle preceded the decision. Yet the fact remains, in 1477 the vice-president of the Ministry of War hid or destroyed all records of the voyages of discovery, by 1500 anyone building a ship of more than two masts was subject to the death penalty, in 1525 all ocean-going ships were destroyed and their owners arrested, in 1551 to go to sea in a multimasted ship even for trade was criminalized.

All were critical mistakes because China forfeited the opportunity to learn, to acquire additional resources and information from other civilisations, no matter how much less advanced than they were themselves. As a consequence by 1500 Portuguese vessels entering the East, while perhaps smaller than their Chinese predecessors, came in greater and greater numbers and above all with now far superior technology of killing. Naval cannon using gunpowder (a Chinese invention) were unanswerable. The culmination of this pattern of development lay in the humiliation of the opium wars for China.

The interest of the anecdotes and examples lies in the systematic lessons that emerge. The success of the Portuguese voyages of discovery, and the gradual decline of the Chinese are not accidents of history. The Portuguese had invested long, systematically, and far-sightedly in the ability to improve their navigational skills and other technology of seafaring. Above all they had developed systematic learning strategies which ensured the updating and development of their technologies of discovery. And they went in the search of the new, of additional wealth, to bring back yet more information and knowledge, to gain additional competitive advantage against their European rivals. The Chinese by contrast went to fly the flag, to impress and have homage paid to them. Such expensive luxuries are not conducive to further development, and above all they inhibit learning.

[3] In Fedderke, De Kadt and Luiz (1999b) we show on the basis of a time series statistical study of the South African experience that at least some of these factors were important to long term investment in the capital stock of the South African economy. Fedderke and Liu (1998) makes the same point for international capital flows to South Africa.

The difference lies in what we term the institutionalised learning capacity of the two civilisations. For the Portuguese high, for the Chinese low despite their impressive achievements. Europe was able to develop and extend an ever greater competitive lead over rivals, with the attendant capacity to exercise military force precisely because they institutionalised learning, curiosity, acquisition of information and understanding of the world about them, regardless of their relative levels and degrees of development. In this regard a number of factors become critical.

First is the *autonomy of intellectual enquiry*. In Europe, the authority of the church came to be challenged by secular authority (the state), by religious dissent (the Reformation), by the increased independence of institutions of learning from religious authority. The importance of Galileo lies not so much in the substance of his claims (they had been made before, within the ambit of the church), but in the nature of the claim to validity of his hypotheses.[4] Science, empirical evidence alone, vetted by peer review were to be the arbiters, not the institutional demands of the church, and its judgement as to the appropriateness of the claim to a larger telos. Truth alone was to count. The result was a more unfettered accumulation of knowledge, of technology, and hence of the ability to exercise power, both economic and military.

The *method* of learning and enquiry also became central to the institutionalised capacity to learn. Emphasis after the Renaissance in Europe came to be placed increasingly on seeing and explanation, of simplification as a means to deal with the complex, and on mathematics as a means of organising knowledge. Observation, precise description, replication, verification not only served to undermine authority, it led to the process of experimentation, the embrace of controversy, debate and an exchange of ideas and argument as a means to settle differences. All had the positive consequence of accelerating the advance of knowledge.

Third, learning was *routinized*. A common language of learning (Latin) facilitated the exchange of information. Improved communication helped the spread of knowledge. The discovery of the printing press proved to be the lubricant of information exchange on an unprecedented scale. Frequent meetings of learned societies, the development of periodical journals, allowed for the exchange of ideas, helped cooperation between researchers. Rivalry for honour and peer recognition spurred on individual researchers.

Lastly, but critically, *systematised means of storing, recovering, cross-referencing knowledge* allowed learning to follow Newton's example of using the shoulders of others to stand on.[5] Reinventing wheels is a costly inhibitor to progress; improving the

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[4] In fact, Giordano Bruno came closer to our present thinking about the structure of the universe than either Galileo or Copernicus (infinite space, billions of stars with orbiting planets - sun and earth among them - atomic structure of matter, etc.) and earlier than either. He was burnt at the stake for his trouble.

[5] Consider the contrast: “China lacked institutions for finding and learning - schools, academies, learned societies, challenges and competitions. The sense of give-and-take, of standing on the shoulders of giants, of progress - all of these were weak or absent. Here was another paradox. On the one hand, the Chinese formally worshipped their intellectual ancestors; in 1734, an imperial decree required court physicians to make ritual sacrifices to their departed predecessors. On the other, they let the findings of each new generation slip into oblivion, to be recovered later, perhaps, by antiquarian and archaeological research. The history of Chinese advances, then, is one of points of light, separated in space and time, unlinked by

means by which information is disseminated from commonly recognised stocks allows research resources to be focussed on the advance of knowledge, rather than on the remembrance of things already past.

Adoption of such institutions is a necessary (though not sufficient) condition for success. The example of the Iberian Peninsula illustrates this amply. Leaders of the European exploratory enterprise in the 15'th and 16'th century, the resultant glut of wealth was correlated with a waning of the questing spirit, a shift of centres of manufacturing elsewhere (Northern Europe),[6] and above all the institutionalised process of learning shifted decisively to the North. Before the Reformation, Spain, Portugal, Italy were the centres of learning not least because of the contact their geographical position offered to Islamic civilisation. With the Reformation things changed. Interdictions followed from 1521 against publishing and reading heresy. In 1558 the death penalty was introduced for the importation of officially unapproved foreign books and for unlicensed printing. Universities were placed under strict control in terms of what could be taught, and books required official approval. Scientific books were banned in Spain simply because their authors were Protestant. Study abroad by Spaniards was forbidden except at approved centres,[7] such that attendance at the University of Montpellier for medical training slowed from 248 students between 1510-59, to 12 from 1560-99. The consequence: the Iberians missed the scientific revolution, and ultimately lost out in the development race, while Northern Europe overtook in technological and productive capacity.

The Weberian work ethic also played its role not only in generating the commitment to accumulation. Far more significant was that the rupture of the authority of the church *generalised* the competitive advantage afforded by the ethic:

> The heart of the matter lay indeed in the making of a new kind of man - rational, ordered, diligent, productive. These virtues, while not new, were hardly commonplace. Protestantism *generalized them among its adherents, who judged one another by conformity to these standards*. (Landes 1998:177 - my emphasis)

Stress was placed on literacy (for girls as well as boys since everybody had to be able to read the Bible), with the result that a larger population pool was available for advanced schooling, with learning capacity and transmission growing appropriately.[8]

The advantage the Iberian peninsula had once enjoyed over China and other competitors was lost - and ironically for much the same reason that China lost out to the latecomers in the East. Closure of societies is fatal for purposes of long-term development, and openness combined with an institutionalisation of acquiring knowledge crucial if societies are to maintain competitive advantage.

Institutionalised learning, openness to the new, curiosity, are critical to long term success. But the process itself must be open and subject to evolution and revision. The learning process must itself be subject to learning. Britain led the world through the 18th and 19th centuries, in significant part because of its ability to innovate and its

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replication and testing....Much of the vocabulary was invented for the occasion and fell swiftly into disuse" (Landes, 1998: 343).

[6] It became easier to buy the output of others than to manufacture it oneself.

[7] Rome, Bologna, Naples.

[8] Literate mothers are also likely to matter in the reproduction of the learning impulse.

learning capacity. Yet its institutions became increasingly obsolete over the course of the 19'th century, and came to be overtaken by continental rivals (Germany). Invention, training, learning were decentralised and relatively haphazard in Britain. Over time the larger, better funded, systematised research institutions provided by German and ultimately American universities were simply better at both producing and transmitting knowledge suited to the industrial revolutions and finally information revolution.

All of these considerations emanate from a very long view of the process of economic development. And they point to the importance of what has already been termed a "learning society", with an institutionalised capacity to be open to the new, to absorb it and turn it to its own advantage. Human capital surely serves as one of the central enabling mechanisms of such institutionalised learning capacity. But it is perhaps useful to begin with an overview of what of required in the very long run, all the better to make sense of the detail work that is also required.

It is useful to have a sense of the very long run pay-offs that attach to human capital creation before we move on to questions of more detail. Creating human capital takes a great deal of time. The endowment of such capital that a society has will therefore take considerable time to change also. The true impact of human capital therefore is perhaps only evident in the very largest sweep of things – that which concerned Landes in his study. This does not preclude the detail work, and indeed it is with this that our discussion now continues.

5.2 A direct impact of human capital on economic growth?

We move now to consider the more detailed different mechanisms by which human capital may come to exercise an influence on the growth rate of an economy. Our starting point is the question of whether there exists any evidence to suggest that there may be a straightforward direct impact that runs immediately from human capital to growth in output.[9]

Certainly there is evidence to suggest that the question at least is plausible. In **Figure 5.1** we plot the average growth rate in per capita GDP of a sample of 118 countries in the world over the 1960-85 period, against the primary school enrolment rate in 1960.

What emerges from the evidence is a clear and strong positive association between the growth performance of countries and their human capital endowment at the beginning of the period. The greater the human capital endowment at the start of the period, the greater the likelihood that countries will have grown faster subsequently. The question being posed on the possible impact of human capital on growth is clearly plausible. The issue we confront is how and why human capital may come to exercise its influence.

[9] On the presumption that human capital also exercises an indirect effect via technology.

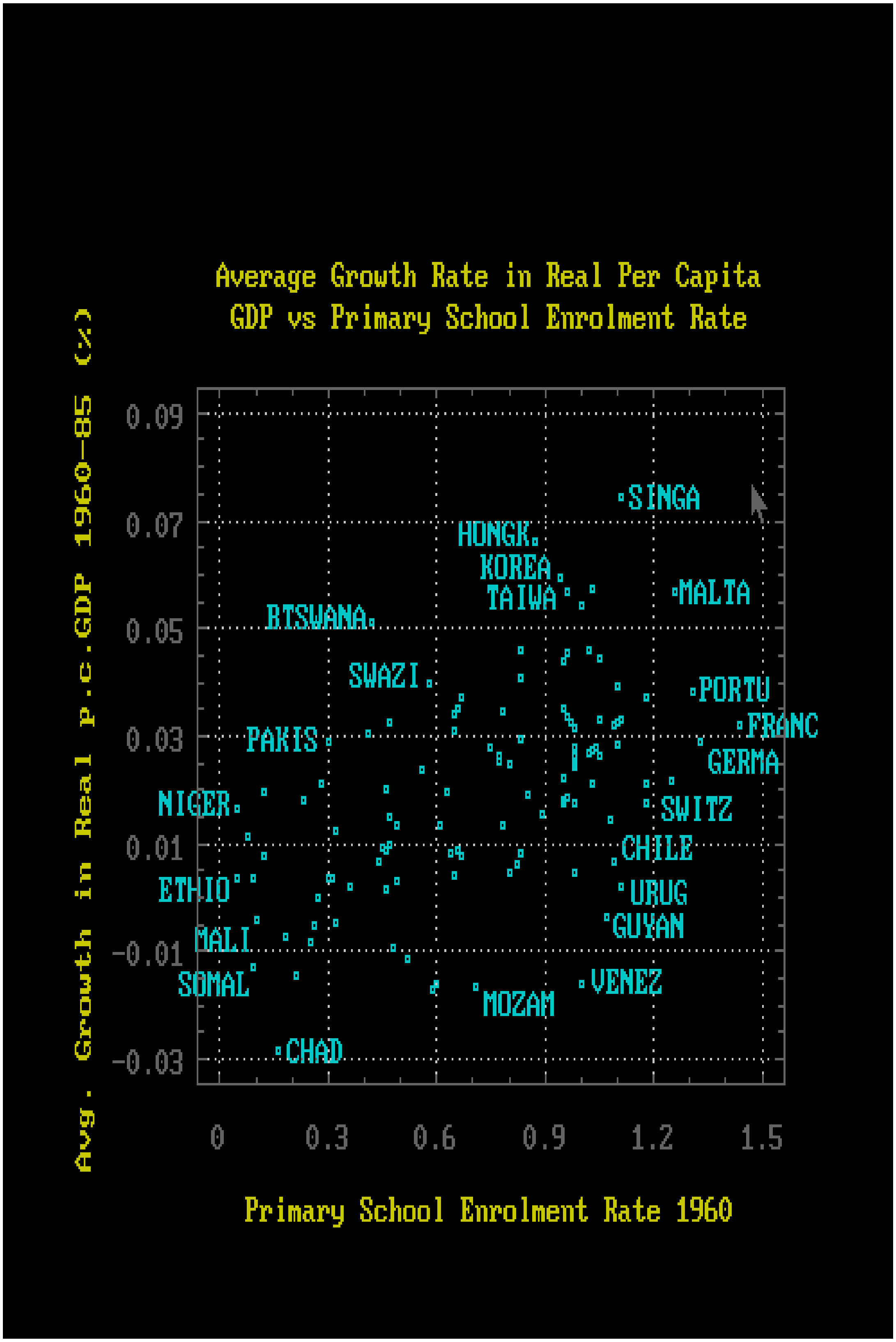

Figure 5.1: Plot of average growth in real per capita GDP, 1960-85, against primary school enrolment rate in 1960.

In the endogenous growth models encountered in Chapter 3 the introduction of technological change had the effect of generating increasing returns to scale, such that the growth process became such that the economy does not move to steady state, but instead experiences unbounded growth. In the case of the Romer (1990) model unbounded growth is the result of the role human capital plays, in particular in terms of adding to the physical capital stock through the research sector of the economy through innovation.

But the introduction of human capital need not have unbounded growth as a consequence. On the contrary, human capital can be successfully introduced into a traditional growth model of the economy,[10] maintaining the salient features of a neo-classical growth model, particularly convergence to steady state. Mankiw, Weil and Romer (1992) suggest that the introduction of human capital into a Solow model is justifiable, indeed desirable, since in excess of 50% of the capital stock of the USA in 1969 took the form of human rather than physical capital stock. Moreover, they argue that the introduction of human capital into the Solow model successfully enhances its explanatory power to such a degree as to preclude the necessity of resorting to endogenous growth models of either the Romer (1986) or (1990) variants.

In making this argument they suggest that all that is required is the introduction of human capital as an additional factor of production over and above physical capital and labour inputs. This renders the production function augmented to:

$$Y = F(K, L, H) \tag{1}$$

where Y denotes output, K capital, L labour and H human capital. The presumption is that marginal returns in all factors are positive but declining in the factor of production.

The implication is therefore that output can grow not only because of an augmentation of the physical capital stock, or the labour force available for production, or indeed because of improvements in the technology of production. Output can rise also since the human capital the economy has to dispose of has increased. Mankiw, Weil and Romer (1992) are concerned with the question of whether this proposition finds any empirical support.

In order to address the question they estimate two alternative equations. For the traditional Solow model they consider the impact of only growth in capital and growth in the labour force. In the modified Solow framework concern is with the question of whether growth in human capital stocks adds anything to our understanding of the growth process. Thus for the traditional Solow model they consider:

$$\ln\left(\frac{Y}{L}\right) = \alpha_1 \ln(s) - \alpha_2 (g_L) \tag{2}$$

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[10] Since these models have their genesis in the work of Robert Solow (see 1956 and 1957), they are also often referred to as Solow Models.

where Y/L denotes per capita output, s the savings rate S/Y, g_L the proportional growth rate of the labour force, and the α_i are two coefficients. This is contrasted with the modified Solow model:

$$\ln\left(\frac{Y}{L}\right) = \beta_1 \ln(s) + \beta_2 \ln(h) - \beta_3 \ln(g_L) \tag{3}$$

where all terms are defined as before, and h denotes the per capita stock of human capital, while the β_i are three coefficients.

The question they pose concerns the extent of the improvement in explanatory power as we move from equation (2) to equation (3).

Mankiw et al (1992) provide estimates of equation (2) for three samples of countries. The first is a sample of 98 non-oil producing countries, from which oil producers are excluded since oil entails virtually no value added in production, and the relatively high returns to the natural resource distorts the per capita income of oil producers.[11] The 98 country sample still contains a number of "small" countries, with populations of less than 1 million. Mankiw et al therefore define a second sample, excluding all countries with populations with less than 1 million inhabitants, and countries for which data quality is poor. As a third sample they separated out 22 OECD members with populations greater than 1 million inhabitants. Estimations were obtained from regressions of the log of per capita GDP in 1985, on average investment rates and labour force growth rates over the 1960-85 period. Their results are reproduced in columns 1 through 3 of **Table 5.1**.[12]

Table 5.1: The Impact of Human Capital on Output Growth. Figures in round parentheses are standard errors. Statistical significance is denoted by *.

Dependent Variable: lnGDP per working person in 1985						
	1	2	3	4	5	6
	Non-Oil n=98	Inter-mediate n=75	OECD n=22	Non-Oil n=98	Inter-mediate n=75	OECD n=22
Constant	5.48* (1.59)	5.36* (1.55)	7.97* (2.48)	6.89* (1.17)	7.81* (1.19)	8.63* (2.19)
ln(I/GDP)	1.42* (0.14)	1.31* (0.17)	0.50 (0.43)	0.69* (0.13)	0.70* (0.15)	0.28 (0.39)
$\ln g_L$	-1.97* (0.56)	-2.01* (0.53)	-0.76 (0.84)	-1.73* (0.41)	-1.50* (0.40)	-1.07 (0.75)
lnSchool				0.66* (0.07)	0.73* (0.10)	0.76* (0.29)
adj-R^2	0.59	0.59	0.01	0.78	0.77	0.24
s.e.e.	0.69	0.61	0.38	0.51	0.45	0.33

Source: Mankiw, Weil and Romer (1992).

[11] Readers should note that this incorporates essentially the entire rest of the world.

[12] For additional deliberation and extension of these results see also Andrēs, Domēnech and Molinas (1996).

The results have a number of significant features:

- Both the savings rate and labour force growth rate coefficients are of the correct sign,[13] and are statistically significant in two of the three samples, though for the OECD country sample both coefficients are insignificant.[14]

- Except for the OECD countries, differences in the savings rates, and labour force growth rates account for a large proportion (approximately 60%, on the basis of R^2 statistics) of cross country variation of end of sample period per capita GDP, and hence of the growth rate of output over time. The implication is that differences in the technology of production are not required in order to account for variations in income between countries.

The net implication for Mankiw et al is that the Solow model does not stand in need of substantial modification. The explanatory power of the model is good, and all the variables do the work that is expected of them. Yet the results are not entirely satisfactory either. First, the coefficients on the savings rate and labour force growth rate are potentially simply too high. The implication for the 75 intermediate country sample, for instance, is that a 1% increase in the savings rate, would result in a greater than 1% increase in end-of period per capita GDP. A 1% decrease in the labour force growth rate, would increase end of period output by more than 2%.

Second, the two explanatory variables account for virtually none of the cross-country variation in per capita income amongst OECD countries. This might be due to a high degree of homogeneity between countries, but does rouse at least some suspicion as to the validity of the results. Lastly, in all three samples the constant is large and significant. In a Solow-type of model, the constant would capture the augmented labour productivity gain across the estimation period. The implication is that the role of technology may be much more important in accounting cross country variation in income than Mankiw et al allow for. If so, the need for an endogenous explanation of technological change remains pertinent, and endogenous growth theory remains important.

Mankiw et al (1992) estimate equation (3) by regressing the log of per capita GDP in 1985, on average investment rates and labour force growth rates over the 1960-85 period as before, but adding the average percentage of the working-age population in secondary school for the 1960-85 period (ln School). We report the results in columns 4 through 6 of **Table 5.1**, and note that:

- The physical capital savings rate, the human capital endowment, and the labour force growth rate coefficients continue to have the correct signs throughout, and are statistically significant in the two large(r) samples. By contrast, only the human capital variable is significant for the OECD sample of countries.

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[13] Since the dependent variable is per capita output, ln(Y/L), an increase in the labour force would lower output per worker.

[14] A possible reason for this insignificance might be that the savings rates and labour force growth rates of OECD countries do not differ significantly enough to account for differences in the growth performance of OECD countries, and hence would not explain the final per capita GDP of the OECD countries.

- Differences in the physical capital savings rate, the human capital endowment, and the labour force growth rate now account for approximately 80% of the cross-country variation in per-capita income in the two large samples. For the OECD countries, differences in human capital alone account for approximately 20% of cross-country variation in per capita income - indeed the R^2 statistic shows a dramatic improvement over that of the Solow-model.

- The coefficients are now no longer of an order of magnitude which casts doubt on their validity. Returns in terms of per capita income in response to a percentage increase in each of the determining variables is now less than proportional, in contrast to the simple unmodified Solow-model case.

The implication drawn from these results by Mankiw et al is that the human capital augmented Solow-model, despite its simplicity, accounts for a significant proportion of cross-country variation in per capita output. They argue that the strength of the empirical evidence has to be accepted as forceful evidence in favour of the model, on their account – and that recourse to endogenous growth theory, given all the complexity it often introduces, may simply not be necessary.

Three doubts remain, however. First is the continued poor performance of the model for OECD countries. The obvious question has to be why this sub-grouping of countries falls outside the scope of the explanatory power of the model, while the growth performance of a strong majority of countries in the world is adequately accounted for by means of the Solow model. Does this point to the existence of a "stages of growth" phenomenon, such that different factors are important for growth at different levels of per capita GDP (given that OECD countries are at the upper end of the scale of per capita GDP)? If so, what are these stages, why do they exist, and which determining variables are significant at the various distinct stages of economic growth?

The constant term continues to play a very significant role in all three samples. As previously indicated, in Solow models this generally points to the presence of strong labour or capital augmenting technological change. The implication is thus as before that technological change may account for a significant proportion of the growth performance of countries. Again, therefore, the role of endogenous growth models that explicitly account for the growth in technology cannot be discounted.

It thus seems valid to continue to search for additional determinants of growth performance. And perhaps to allow the impact of human capital to be varied, exercising its influence both in the direct manner identified by the Mankiw et al, as well as the more indirect effects identified by endogenous growth theory.

Nevertheless, what the evidence of the present section has served to show is that there is certainly strong evidence that favours the existence of an immediate, direct effect of changes in human capital stocks on the growth rate in real per capita GDP, as *well* as the indirect effect suggested by endogenous growth theory.

5.3 Further extensions: back to endogenous growth and some additional lessons

It is worthwhile briefly to revisit contributions we might expect from human capital to economic growth through the endogenous growth framework. Partly this is in order to remind ourselves of the differences between it and the proposal put forward by Mankiw et al., but also in order to add some nuance to our understanding of the impact of human capital on growth within the endogenous growth framework.

Remember that in the Romer (1986) spill-over type of endogenous growth model human capital creation is really the *consequence* of the positive externality that is associated with the act of investment in physical capital stock. While learning-by-doing is the vehicle by which the learning effects that are attached to the act of investment in physical capital stock are transmitted amongst firms, the origin of the human capital remains rooted in physical investment. That was why the policy prescription that emerged from this approach to understanding technological progress was to recommend subsidies on physical capital, in order to counteract the fact that the social marginal rate of return lay above the private marginal rate of return to physical investment.

But in a further (though independent) extension of the spill-over approach to endogenous growth, Lucas (1988) proposed a production function for output that captures very similar ideas to those proposed by Romer, but capable of generating some important additional nuance. The production function suggested by Lucas can be represented by:

$$Y = AK^{\beta}\left[uhL\right]^{1-\beta} h_A^{\gamma} \tag{4}$$

where Y denotes output, A the state of technology, K capital, L labour, where the actual labour time at the disposal of the economy is now adjusted for the level of human capital it embodies, h, as well as the proportion of time u it devotes to the production of current output. While production is constant returns to scale,[15] the possibility of increasing returns (as in the Romer model) is introduced through the impact of the generally available human capital, h_A, to the economy. Indeed the increasing returns are present as long as the γ parameter is positive.

However two further implications make this model particularly interesting for our purposes. First, Lucas suggested that human capital growth in an economy could be represented by:

$$v = h\delta\left[1 - u\right] \tag{5}$$

where v represents the growth rate, δ the research success coefficient, and [1-u] represents the portion of time the existing stock of human capital is allocated to the creation of additional human capital rather than being employed in the production of final output. The story is really the same that we encountered in the theories of Karl Shell and of Romer (1990), that of the perfect university process, but with the explicit

[15] Note that $\beta+(1-\beta)=1$.

recognition that human capital can be either employed in the creation of final output, as well as in the creation of new human capital. The growth process comes to depend on the contribution of human capital to knowledge creation.

The reason why this formulation turns out to be interesting is that one can show that the final growth rate of the economy will be determined by v, the rate of growth of human capital creation. Moreover, the growth will turn out to be unbounded, even in the absence of increasing returns to scale. The result is analogous to the unbounded growth due to technological progress in traditional theories of economic growth, but now with an explicit recognition of the motor force behind this growth in the process of human capital formation.

The second reason for our interest is that where we also have increasing returns to scale in production ($\gamma>0$), the implication is that the usual consequence of economic theory, that the rate of return to factors of production will be highest where they are scarcest, will be reversed. Instead, the implication is that the rate of return to human capital will prove to be the highest where it is most abundant. In the presence of labour mobility, the implication is that labour well endowed with human capital will migrate to centres already intensive in human capital, simply because the rewards for doing so are large.

If this is the case for developing countries, the policy implications are profound. For it implies that if you are behind in the human capital accumulation stakes, you are likely to remain forever behind. Countries ahead of you in the growth race will steadily out-accelerate you. But worse, if you as a developing country try to rectify matters by improving investment in human capital, such human capital is simply likely to emigrate away to greener pastures. Already wealthy countries will stand to benefit from the hard investment undertaken by the poor country – and accelerate away even more rapidly thanks to the poor country's efforts.[16] The situation for poor countries is doubly perverse. They are poor because poorly endowed with human capital. But the policy intervention designed to ratify the situation, of saving in order to be able to invest in education, merely serves to benefit the already rich, enabling them to accelerate their growth yet further.

Thus if human capital maters to growth, and if increasing returns to human capital are indeed present, poor countries face the tough task of having to keep the environment for skilled people at home even more attractive than otherwise would have been the case. Policy intervention must be conscious of the need to improve the incentive for human capital to stay, rather than leave. Since the evidence we presented above on the South African manufacturing sector suggests that such increasing returns due to the generally available human capital may indeed be present in the South African economy, this is a policy implication that is particularly important in the South African instance.

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[16] On this view therefore openness of the economy may allow human capital to migrate away from developing to developed countries. Openness under this view carries serious dangers for developing countries. However, without ameliorating the danger for human capital accumulation, Barro and Sala-i-Martin (1995) demonstrate that greater openness may bring advantages to both technology innovating and imitating countries.

Since South Africa has been losing some of its best human capital over a long period of time now, we devote a specific case study, entitled "The Parable of the Sage", to some general reflections on just how costly this has proved. We reflect further on the fact that it was often the unsympathetic stance of the political and policy environment that accelerated the exodus. But to keep matters in perspective, we also add an additional case study on India, in a box entitled "India: Awakening Information Technology Giant", to illustrate that the brain drain phenomenon need not be entirely crippling. It can be reversed in the presence of the right sorts of policies and incentives to human capital, even in very poor countries such as India.

So the theory thus far has come to imply that increasing returns to scale in human capital may lead to perverse *international* allocation of human capital. But this unfortunate *international* allocation of human capital may well be exacerbated by further counterproductive *intranational* human capital allocation. Recall that the Romer (1990) conception of the interaction between growth and technology also generates a low income level trap. In this model we have a sector dedicated to the creation of knowledge, with human capital used in order to produce final output. The difficulty for developing countries is that at low levels of human capital accumulation, there may simply not be the critical mass of human capital to generate sufficient returns from the pursuit of new knowledge. As a consequence human capital will come to migrate to final goods production rather than new knowledge production, simply because the return there are higher. The consequence is that more developed nations, with their ability to create new knowledge will come to forge ever further ahead of developing nations.

Thus developing nations are potentially caught in *two* vicious cycles that result from the impact of human capital on long run economic performance. The one results in an unfavourable international allocation of human capital away from developing nations to developed nations. And the other ensures that what human capital remains in developing nations may not be allocated to where it has the most dramatic long term impact.

Either way policy makers face demanding challenges in ensuring that incentives in developing economies are such as to ensure that human capital not only remains at home, but that if it so remains, that it is most productively employed.

Two final points are worthy of emphasis in the context of endogenous growth theory and its view of human capital. *First*, if the increasing returns emphasised during the course of our discussion do indeed attach to the human capital dimension, then the implication is not only that human capital should be core to any developmental strategy. This much we have already emphasised. It also implies that potentially significant indivisibilities attach to the impact of human capital on long run growth. If returns to human capital are increasing, the return to ever higher levels of education and training should be increasing also. Again on the proviso that the increasing returns are indeed present, policy should then pay attention to its human capital creation strategy as a totality. It is no longer simply a question of sorting out primary and secondary education. Tertiary education should ideally become part and parcel of the most basic developmental human capital creation programme.

Thus the implication is that if countries concentrate only on a “partial” human capital creation strategy, the pay-off may be considerably less dramatic than if a more holistic approach is adopted. Indeed, in the limit there may be very small, perhaps even negative returns to human capital in a partial human capital creating approach, since critical mass levels of human capital are not breached.

But the second point is equally instructive. Given the presence of the two perverse traps pointed to above, care must be taken in interpreting evidence on human capital formation and its impact on economic growth. A negative association would in fact *not* serve to prove the absence of a positive impact of human capital creation on economic growth. Instead, it may simply be pointing to the presence of one or both of the two traps we have identified. That creation of human capital represents a drain of resources on poor countries, with benefits that migrate to developed nations.

The Parable of the Sage or: Keeping the Best - a Story of five Sirs and One Mathematical Genius

by Raphael de Kadt

There lived long ago, in a faraway place, a wise man. Some years back we might have called him a "thinker" or "philosopher", recalling the original meaning of the term "philosophy" – the love of wisdom, the "good and the true". Many of his compatriots thought him odd, even somewhat demented. Many were fearful of his intellect, of his effortless superiority in argument. The powerful and influential among them were especially discomfited by his uncanny knack of casting doubt on the legitimacy both of their actions and of their offices. Deep down, they feared the power of his mind, his boundless curiosity and his love of virtue. For this man often saw things in strange and unusual ways. The King, who like so many monarchs was not noted for his sharpness of mind, was disturbed by the oracular pronouncements of this sage. Even more bothered were the King's counsellors. Craven and sycophantic, as are most beneficiaries of patronage, they conspired to make the circumstances of his life uncomfortable. Subtly, and then not so subtly, they denied him the means to pursue his studies and engage in reflection. His ability to communicate his insights and his wisdom were constrained. The tools he needed to pursue his scientific enquiries were ever more difficult to get hold of. For a while he endured the deprivations and continued with his quests. But the counsellors became increasingly vengeful. Deprivation turned to harassment. Being good, but also shrewd, our sage left the land of his birth, never to return. He wandered far and wide on foot, meeting with many experiences – some dangerous and unpleasant, others enchanting. He passed through forests and deserts, through temperate grasslands and tropical jungles. Then one day he chanced upon another traveller who invited him to accompany him on his return to his own land. There, in the land of the stranger, he was bought to the court of the Regent. This Regent and his advisors were of a quite different kind. Democratically elected and accountable to their people, they were open to diversity of opinion and supportive of the life of the mind. They valued curiosity and saw virtue in dissidence. Immediately they recognised the genius of the itinerant sage. They provided him with the wherewithal to practice his scholarly craft, listened to him with attention and bestowed honours upon him. The recognition brought its own rewards. Emboldened, the sage went on to achieve ever-greater things. He was, in due course, himself elected an advisor to the Regent. The scribes began to chronicle his accomplishments in ever-larger tomes, for his contributions to his adoptive land had, indeed, been impressive. Its civilisation had flourished even more under his influence. Its science and technology became the envy of the whole world, its people prospered as no people had ever done before. They lived longer and healthier lives with marvellous amenities and magical potions to ease their aches. Within the lifetime of the exiled sage, and under his guidance, they journeyed the moon and made wonderful machines to do all their calculations.
What a lucky people they were – and so wise they were to give sanctuary to the refugee from the land of the foolish King and his paranoid courtiers.

This parable may be somewhat forced and contrived, but in it can be seen the elements of a not uncommon modern story: the story of the migration of talent from less hospitable to more hospitable places. In the very broadest terms, it is the story of the virtues of "open societies" and the vices of "closed societies". It is the story, in particular, of the loss to many modern dictatorships and authoritarian regimes of their most gifted and capacious minds; and the story, too, of the beneficiaries of these migrations. It is the story of Fascism and of Pogroms in Europe, and of the triumphs American science and technology and of the American economy. Sadly it is, too, the story of South Africa during the long, dark night of Apartheid. For South Africa lost, during the second half of the twentieth century, some of its most genuinely creative and powerful intellects. Migration, of course, is a feature of all historical epochs, and the reasons for it are many and do no always involve political repression and persecution. People leave the land of heir birth for adventure, for the pursuit of romance or to explore distant climes and cultures. Sometimes they return, sometimes not. There are, however, particular patterns of migration that should be a special cause for concern among those charged with governing a country whose economy desperately needs to grow. Commonly, this pattern is termed "the brain drain". South Africa has long suffered from it.

Of especial concern has been the story of the emigration of people of quite exceptional talent, the kinds of people who perhaps correspond to the figure of the "sage" in our parable. Just as Hitler facilitated the acquisition by the United States of people such as Einstein, Fermi, von Neumann and Harsanyi, to name just a few, so circumstances in South Africa facilitated the acquisition by Britain and the United States of far too many of its top drawer scientists. The names of Sir Raymond Hoffenberg, Sir Solly (later Lord) Zuckerman, Sir Basil Schonland and Sir Aaron Klug come to mind. So too does that of the great mathematician Seymour Papert, developer of the Logo programming language, co-founder of the MIT's famous Artificial Intelligence laboratory and a major driving force behind the computer revolution. Whether the political climate had any direct bearing on the decisions of Klug, Zuckerman or Schonland to re-locate to the United Kingdom is difficult to establish. It certainly did, however, in the cases of Hoffenberg and, probably, Papert. Hoffenberg, – regarded by many as the outstanding South African medical scientist of his generation, and who was later to become President of the Royal College of Physicians, had a banning order served on him by the National Party government. This severely interfered with his work. As Professor Peter Folb of the Department of Pharmacology at the University of Cape recently observed, not only was Sir Raymond harassed by the security police, but – much as our parable might suggest – he received scant support from the medical profession as a whole. And, as in the parable, it was only in the United Kingdom that he was to be appropriately honoured and recognised for his scientific talent. It might be that, in the case of Aaron Klug who was later to win the Nobel Prize in Chemistry and – following in Lord Zuckerman's footsteps – to become President of the Royal Society, the "logic" of a career in "big science" was the overwhelming factor. It might be that in his case, as in the cases of the post Second World War careers of Zuckerman and Schonland, South Africa simply did not offer the opportunities, resources and support requisite to scientific careers at that level. The fact of the matter, however, is that all these talents were lost to South Africa.

This story of this loss invites a study in contrast. The figure in this study is that of Sir Mark Oliphant, the great Australian physicist. The story of Sir Mark is appropriate because he, too, is of the same rank as Hoffenberg, Klug, Schonland, Zuckerman and Papert. His, however, is a story of a "prophet" who does not go without honour in his native land. Sir Mark, who during he Cold War came to be labelled a "peacenik", was one of that remarkable group of physicists based in America who helped to make the atomic bomb. While Professor of Physics at the University of Birmingham, his laboratory developed the magnetron, which was crucial to the improvement of radar. Sir Mark, who died this year, was the subject of an obituary in the *Economist* of July 22nd. The obituary, which is the principal source of the information in this box, points out that, after his return to Australia, he founded the Research School of Physical Sciences at the Australian National University in Canberra and helped to establish the Australian Academy of Sciences. Both institutions, the obituary observes, are now world-class. After he retired from science, he was appointed in 1971 as governor of South Australia. His term of office is widely regarded as remarkable for its enlightened character and for his stances on the environment and racism. His death elicited extraordinarily wide and admiring coverage in the Australian media. Knighted in 1959, he was able to make contributions to the scientific, technological and cultural life of his homeland in a measure equal to his talents. This, sadly, was not the fate of Sir Raymond Hoffenberg. To return to our parable: he was honoured in "the land of the stranger". What contributions, one is prompted to ask, were lost to South Africa though the exodus of so much extraordinary talent? And how, in future, might South Africa succeed in retaining a larger share of its finest intellects? What incentives, what facilities and what rewards are needed? How do we learn to honour those whom we so desperately need to keep?

India: Awakening Information Technology Giant

by John Luiz

Source: Adapted from Akshay Joshi. Information Technology – Advantage India. www.idsa-india.org

India, after having missed the industrial revolution, is on the threshold of the information revolution due to a combination of factors, some global and some of her own doing. India concentrated on developing skilled scientific manpower by opening government-funded 'centres of excellence' and public sector industries. The urge for self-sufficiency and the encouragement for research fuelled the scientific temper of this nation. Till the late 1980s, there was a steady growth in the Indian IT industry accompanied by a brain drain to the West. In 1988, an autonomous organisation called the National Association for Software and Services Companies (NASSCOM) was formed and it started working closely with the Indian government for the development of the IT sector.

1991 saw the opening up of the Indian economy. In 1991-92 a World Bank funded study by the Department of Electronics (DOE) in India visualised a $ 1 billion a year potential for software exports from India by the year 2000. This was the first benchmarking exercise carried out by India. It achieved the target of $1 billion a year well ahead of time. Since 1991, the Indian software industry has grown at over 50 percent every year and will be a $5.7 billion industry in 1999-2000. Due to the 'offshore software development revolution' in the 1990s, almost 273 of the 'Fortune 1000' companies are outsourcing their software requirements to India. The market capitalisation of Indian software shares stood at $27.3 billion in December 1999. In 1998, the BJP government formed the Prime Minister's (PMs) IT Task Force in which eminent people from the government, industry, defence forces and the research community were taken. This task force appreciated that the challenge was to develop an information infrastructure in India which constitutes addressing problems like the cost of the personal computer (PC), the cost of connectivity and IT literacy. The report has suggested a new IT organisational structure in the government, like appointing an advisor to the PM on the lines of the set up in the US, setting up a separate IT division in the Planning Commission and forming a high level committee at the centre and state levels constituting several task forces on the lines of the National Computer Board in Singapore. The report calls for setting up 'tool rooms' throughout the country for the purpose of offering a wide range of services like design and development, training, consultancy, software-housing and the like. The report aims at making India a $100 billion player in the IT world.

1999 also saw the approval for the National Telecom Policy (NTP-1999), formation of the IT Ministry and the passage of the IT Bill – all steps in a positive direction. The second benchmarking exercise in India was initiated by the government when NASSCOM commissioned McKinsey and Company, the pre-eminent management consulting firm, to help develop a vision and strategy to capture the opportunities thrown up by the digital revolution and generate rapid growth for India's IT industry and, thereby its economy. The report predicts that India has the potential to become a global superpower in the knowledge economy. Some of the key findings of this report are that by the year 2008:

- Software and Services will contribute over 7.5 per cent of the overall Gross Domestic Product (GDP) growth of India.
- Exports in the IT sector will account for 35 per cent of the total exports from India.
- There are a potential 2.2 million jobs in IT by 2008.
- The overall revenues from the IT sector will be nearly $90 billion including $50 billion in exports, and the minimum market capitalisation of IT shares will be $225 billion.

According to this report, technology, economy and market drivers are reshaping the global information technology landscape which offer Indian and India-centric companies unique opportunities in four broad areas: value-added IT services, software products, IT-enabled services and e-business.

Why does Information Technology suit India? Information Technology by its very nature needs and breeds democracy, freedom and democratic institutions. India is the largest and most vibrant democracy which encourages the free flow of information and ideas. English, which is fast becoming the international business language, thanks to the Internet, is used extensively in India. India also has a well educated human resource pool who have a good grounding in mathematics. Add to this the confidence of successful young entrepreneurs, who are now in decision-making positions all over the world. The brain drain which took place since independence is now changing to a reverse brain drain, with successful IT savvy Indians pouring money and resources into India. These whiz kids are also networking with each other to ensure success to more people. Many successful entrepreneurs are now returning to India to exploit the opportunities in this market. Indian Institutes of Technology (IITs), were recently categorised as among the world's pre-eminent technical finishing schools. Today there are more than 20000 Indian millionaires in the Silicon Valley. Most of them started off with little more than an engineering degree.

Another major global paradigm shift, which is benefiting India, is the falling costs and importance of hardware and the increasing costs of software. Today hardware costs only 10 percent while the software component costs 90 percent of the computer system. Since hardware is losing importance, countries like Korea are losing market share in the IT industry, while countries like India are benefiting because of software. Countries like India, which have a strong intellectual and human capital in the field of software stand to benefit by the increasing importance of software in the information technology industry.

An important ingredient of India's IT strategy in the 21st century will be to "Anchor Indian IT MNCs" abroad, that is, encourage top Indian IT companies to become global MNCs. In Europe, Nokia is worth almost 2 per cent of Finland’s GDP. Sweden is called the 'Silicon Valley of Mobile Phones' because of Ericsson, while SAP has played an `Anchor MNC' role for Germany. Silicon Valley in the USA serves as a regional development model which has an economic leverage of its own in the world. Companies like Hewlett Packard (HP) and Cisco played a critical anchor role in the Silicon Valley. All these MNCs encouraged innovation within their country and created a global brand equity for their products.

5.4 Some international evidence on the impact of human capital on economic growth

The impact of human capital has by now been extensively researched. Our discussion here cannot hope to cover all of the studies that have been published. However, we do hope to point out some of the most important findings that have emerged from the literature.

The first piece of international evidence has already been addressed in the section dealing with the approach advocated by Mankiw, Weil and Romer (1992). Inclusion of human capital variables has by now become standard in cross country growth regressions. Given the wealth of such studies now available in the literature, we cannot hope to cover all of the evidence that has now accumulated. Instead we focus on just a few studies that prove instructive in their findings. We present some of the central papers together with their findings in Table 5.2.

The central points to emerge from the empirical studies can be summarised as follows:

1. Human capital variables generally are found to be positively related to long run growth performance of countries.
2. This positive relation is not found to be robust, in either cross sectional or panel data contexts.
3. This may well be due to the "webs of association" that exist between educational and other economic and social indicators, rendering human capital coefficients subject to potential spuriosity.
4. Quality may be more important than the quantity of education.
5. Time series evidence in favour of endogenous growth theory is mixed. Controlling for different types of innovative activity and structural breaks is likely to be crucial.
6. The international human capital migration predicted by Lucas finds confirmation.
7. The potential for domestic misallocation of human capital finds some support.
8. Microeconomic evidence from Africa also reports both internal and external productivity improvements from education.

Finally, we supplement to econometric and statistical evidence on he impact of human capital on growth with a number of case studies. In a box entitled "Small Countries, Big Achievements" we detail some of the qualitative lessons that emerge from considering case study evidence from a number of success story countries: Ireland, Finland and New Zealand. Again, it appears as if the process of human capital investment carries positive benefits for long run economic growth, though on occasion the pay-off to such investment is a long time in materialising.

Table 5.2: Summary results from central studies with a bearing on the impact of human capital on long run economic growth.

Study	Findings
Barro (1991)	The seminal cross country growth regression paper. The sample includes a maximum of 118 countries – though the study also considers subsamples along the lines of Mankiw et al. Both primary and secondary school enrolment rates are found to consistently have a positive impact on growth in real per capita GDP.[17]
Levine and Renelt (1992)	The seminal paper testing for the robustness of cross country growth regressions. The sample is the same as that employed by Barro (1991). Again both primary and secondary school enrolment rates are found to be positively associated with economic growth. However, the finding is not robust, in the sense that both human capital variables are found to be statistically insignificant for some specifications.[18]
Fedderke and Klitgaard (1998)	The paper again reports results for the Barro-type cross country growth regressions, and again on the same sample. Both primary and secondary school enrolment rates are employed in estimation. While the paper reports a positive impact of human capital on growth, it points to a possible reason for the Levine & Renelt lack of robustness finding. Numerous and strong statistical associations between human capital and other economic and social indicators of development are identified. Inclusion of human capital variables in growth equations may thus lead to spurious results.
Hanushek and Kim (1995)	The paper controls for both the quantity and the quality of human capital. Results establish that improvements in cognitive skills as measured by maths & science attainments translates into far stronger and more robust impacts on growth than average years of schooling. See Table 8 of the paper.
McDonald and Roberts (1997)	One extension amongst many of testing growth equations in a panel data context. Findings on the human capital variables is mixed, confirming the lack of robustness findings of Levine & Renelt on panel data.
Jones (1995)	One of very few time series studies in growth theory. Data is for the OECD. The test is not for a direct impact of human capital on output growth, but a test for an impact of various R&D and human capital indicators on TFP growth. The empirical findings reject the endogenous growth proposition of increasing technological innovation with rising R&D and human capital indicators.

[17] Many other papers have since followed in these footsteps.
[18] Again, a number of other studies have since reported similar lack of robustness.

Crafts (1996)	A cliometric approach to the impact of human capital on long run growth. Thus comes to add perspectives from economic history, and extends the time series approach. Finds confirmation of endogenous growth theory in various OECD countries. However, the study points to the importance of considering measures of innovation-enabling mechanisms beyond the standard ones mostly used in growth models: such as R&D expenditure and scientists. Also identifies the significance and importance of structural breaks in time series modelling of technological innovation.
Dolado, Goria & Ichino (1993)	Examine the impact of immigrants to 23 OECD countries on ECD country growth rates. Establishes that the human capital endowment of immigrants from less developed nations is close to that of OECD natives. See Table 5 of the paper. Confirms that the human capital content of immigrants has a positive impact on receptor country growth. Thus confirms the international human capital migration hypothesis of Lucas (1988).
Bigsten et al (1998)	Examines the rates of return on human and physical capital in a panel of 5 African countries. Rate of return on physical capital in a production function context exceeds the rate of return on human capital in a ratio of 4:1. Potential confirmation of the Romer (1990) point that low human capital endowments may lead to low rates of return on human capital.
Weir (1999)	Application of human capital theory to microeconomic context. Examines the effects of education on farming productivity in Ethiopia. Reports substantial internal (private) benefits of schooling for farmer productivity in the form of efficiency gains. Subject to a threshold effect however (at 4 years of schooling). Also reports substantial external (spill-over) benefits from schooling. There are increases in farm productivity if school enrolments in rural areas increase.

Small Countries, Big Achievements.

by Raphael de Kadt

In 1999, The Irish Council for Science, Technology and Innovation (ICSTI), with the assistance of the National Council for Curriculum and Assessment (NCCA) published a benchmarking study of school science, technology and mathematics (STM) education in Ireland against Scotland, Finland, Malaysia and New Zealand.

The five countries "were identified as open, knowledge-based societies, generally on the periphery of major trading areas". The study was informed by the recognition that "in order to meet economic and social challenges, there is an increasing need for the citizens of these countries to create and use new and existing knowledge, much of which will be *scientific and technologically based*". (Emphasis added) It is important to note that in the decade 1991-2000, all the societies benchmarked achieved solid real per capita growth rates. This is especially significant given that some of them (Ireland, Scotland, Finland and New Zealand) were growing off relatively high GDP bases. Especially notable for our purposes has been the extraordinary performance of the Irish and Finnish economies in terms both of economic growth performance and the creative embrace of product innovation and entrepreneurial flair. Both Ireland and Finland have, in their distinctive ways, become major global players in the domain of the so-called "new economy".

Ireland

The Irish case is remarkable in a number of respects. First, apart from a relatively poor real GDP growth rate in 1991 of 1.9% (it's real GNP growth for that year was 2.5%), for the remainder of the decade its real GDP growth rate was 3.3% , 2.6%, 5.8%, 9.5%, 7.7%, 10.75, 8.9%, 6.7% and 6.4% respectively (Source: *IMF World Economic Outlook, May 1999*). This growth took place against a background of steadily declining unemployment levels (from 14.7% in 1991 to 6.2 % in 2000) and low rates of inflation (ranging from a high of 3.2% to a low of 1.4%) One distinctive feature of the Irish economy is that, along with Malaysia, it is one of the most open in the world. Its total openness, covering both exports and imports was estimated for 1997 at 148% of GNP. (*IMF Financial Statistics Yearbook, 1998*) This trade openness increased to 165% in 1998, placing Ireland second in the OECD behind Luxembourg. (*Benchmarking STME in Ireland Against International Good Practice, p 57)* In addition to trade openness, factors that the study identified as having had a significant effect are a "significant amount of FDI", a "well-educated, relatively cost-competitive workforce", fiscal prudence and a national wage-agreement process. Especially notable is that, notwithstanding the fact that Ireland's small economy accounted for only 0.3% of the world weight, it received the fifth largest amount of US direct investment abroad in 1997(*OECD Survey, Ireland May 1999* cited in *BSTM p 55)* The rate of return for US FDI in Ireland is "almost double that of Europe or the world average".(p55)

In terms of sectoral trade, Ireland along with the other benchmarked countries experienced a move from traditional sector dependency to dependency "on more high-tech, high-value-added, capital-intensive sectors" (p58) This could only have occurred in consequence of appropriate human capital formation policies. However, the Irish authorities are themselves concerned that Ireland has depended too much on the importation of both capital and technologies from abroad and that is has not yet developed a sufficiently vital endogenous capacity to innovate.

Finland

Reference to Finland nowadays conjures up an image of a cell-phone economy associated with the successful brand name “Nokia”. Notwithstanding the buffeting it received in the aftermath of the disintegration of its erstwhile state-socialist neighbour, the Soviet Union, the Finnish economy rebounded impressively through the course of the 1990’s. Again, what is notable about the Finnish success story is that it coincides with a **substantial increase in investment in education at university and polytechnic level**. Especially notable are a) the substantial size of the investment in R&D in the universities and b) the general increase in expenditure on polytechnic and university education. The R&D expenditure in universities amounted to one fifth of the total R &D expenditure in Finland. Further, R&D expenditure in Finland, in 1997, was 2.8% of its GDP – which was higher than the average for the OECD. From 1985 to 1997, the proportion of GDP spent on R&D in Finland rose steadily as did the proportions of R&D expenditure by both universities and business. (Source:*Statistics Finland*) So the importance of the public financing of R&D, and its synergistic connection with private sector vitality and innovations, appears also to be borne out in the case of Finland.

There are several general properties of the Finnish educational system that warrant special mention. The first is the high level of spending on education as a whole. Finland, by OECD standards, spends a high percentage of its GDP on education (6.6%in 1995- *Source: Education at a Glance, OECD Indicators,1998, cited in Education in Finland, Statistics Finland*). Second, notable is the breadth of education in Finland conjoined, as it is, with a specific pattern of prioritisation.

Three more specific features seem to invite special mention. First, at the tertiary level, Finland - as we have already noted - has chosen to invest heavily in the development of polytechnics. The total number of students enrolled in polytechnics has increased from 148 at the time of their foundation in 1991/2 to 82,211 in 1998/1999. That is an increase of over 5,500%! First year enrolments have increased from148 to 29,337 or almost 200 times. This compares with respective increases in university student enrolments over the same period from 112,921 to 142,962 and 15,329 to 7,985. Thus the increase in polytechnic enrolments has substantially outstripped that in university enrolments. However, judging by the increases in university expenditure, the growth in university R&D activity and the increase in the number of students earning higher qualifications, a *prima facie* case can be made that the **quality** of university education has improved.

Second, there is an interesting pattern in terms of field of study at the tertiary level. The biggest field of study in 1997/8 was engineering followed by the humanities, the natural sciences, the social sciences and economics and the educational sciences in that order. Bringing up the rear were, in descending order of enrolments, veterinary medicine, theatre and dance and fine arts. This suggests a higher educational system characterised by both breadth and balance and, by extension, a population characterised by educational breadth. The high rank enjoyed by Finland in “innovation” and “creativity” ratings may well be connected with this breadth. This balance and breadth seems, in some measure, to correlate with the evolution of a system with a significant degree of functional differentiation among types of institution.

Third, a feature of the education system as a whole is the emphasis that is placed on the acquisition of foreign languages – especially English. This phenomenon is not uncommon in the case of small countries with large neighbours and trading partners who speak different languages. The Netherlands is a famous case in point and its deliberate cultivation of multilingualism has almost certainly brought commercial benefits. In the case of Finland, pupils at the lower secondary level read at least two foreign languages. Depending on mother tongue, one of English, Finnish or Swedish is a compulsory second language. The other is elective. Leaving aside Finnish and Swedish, the most popular second language is English (93% of pupils) followed by German, French and Russian. Other languages are also taught. This practice has undoubtedly contributed to the openness of the economy and to the effectiveness with which Finns have been able to enter the highly competitive global telecommunications and electronics markets.

In conclusion, a few summary points may be made about the Finnish education system.

- Through the 1990's Finland's rate of expenditure on Education increased at least as much as, and usually more than the increase in the rate of growth of GDP. (*Statistics Finland*)
- There are nine years of compulsory schooling for children aged 7-16
- Learning at least two foreign languages is compulsory
- Expenditure on education, as a percentage of GDP, is high by OECD standards
- There has been a substantial growth in expenditure on universities and polytechnics
- 50% of Finns who are now 20 years of age can expect to earn a degree
- Participation in university education is higher in Finland than in other EU states
- Finland has twenty universities for its population of five million people.
- Mathematics education is compulsory at post-primary level for all pupils from ages 13 through to 15/16

New Zealand

New Zealand, along with the other benchmark countries, has evolved into one of the most open and lightly regulated economies in the OECD. Except for 1991 and 1998 (the year of the Asian economic crisis), it has experienced positive economic growth rates, coming off a relatively low base in the early 1990's to reach highs of 5.1%, 6% and 4.0% in 1993, 1994 and 1995 respectively. By 2000, is real GDP growth rate had rebounded to a respectable 3.3%. The basic trend of it unemployment rate has been downwards as has the broad trend of its inflation rate.

One aspect of the educational practices in the countries in the benchmarking study is that teachers from all subject areas tend to be treated the same in terms of incentives. In only two of the countries – Malaysia and New Zealand – are dedicated incentives to attract and retain STM teachers used. New Zealand offers a scholarship of US$5,000.00 to people with academic qualifications to teach mathematics, physics and technology. Its immigration policy also favours teachers of science, mathematics and technology from other countries (p30).

General Features of the Education Systems of the three Benchmarked Countries

- Incentives are used/advocated to reward good teaching and to recruit and retain well-qualified people in the teaching profession. These range from good pay to awards such as the Malaysian "Master Teacher" awards. (Although Malaysia is not one of our three countries, it is included in both the Irish benchmarking study and in the OEC *Education at a Glance* data).
- It is acknowledged that steps have to be taken to improve the attractiveness of teaching as a career, not least in the field of STM teaching. However, in only two systems out of the five – and those are the two in which teachers are least well paid in general – are special incentives offered to STM teachers.
- In all the systems, and especially in Ireland, teachers are well paid at all levels in the educational system. In 1996, the pay of Irish teachers after 15 years experience ranged from US$ 35,061 to US$ 37,154. This was second only to Germany with an equivalent range of US$35,885- US$41,081. This, when converted into Rands, is the kind of attractive pay that private sector accountants, some IT specialists or financial analysts might expect to earn in South Africa.
- In the OECD countries in1996, the number of teaching hours per year ranged from a low of 629 (parts of the Greek system) to a high of 964 hours in the lower secondary sector in the United States. The Irish system posted a relatively high figure for 1996. The OECD mean for 1996 at primary level was 791 hours; the Irish primary figure was 915 hours. All countries show a decline in the number of teaching hours as one progresses upwards through the system from primary to upper-secondary.*(Source: Education at a Glance: OECD Indicators 1998)*

- It would seem that, by comparison with the United States, our three "small countries" get good value from money spent on education when measured on an expenditure per pupil basis in US dollar terms This is especially so for Ireland.
- All the OECD countries listed in the 1998 *Education at a Glance: OECD Indicators* report had low pupil : teacher ratios in all parts of their education system. These ranged from an Irish high of 22.6 in the primary school system to a Finnish low of 12.4 at the lower secondary level. (The Greek "all secondary figure for 1996, the year under consideration, was 11.3).
- The amount of study time in our three selected countries (as well as for the OECD more generally) spent on mathematics and science education ranged from between less than one third to more than one fifth.
- All three of the selected small countries can now be regarded as "well educated" if measured by the ratio of upper-secondary graduates to the population at the typical age of graduation. The percentages for 1996, in descending order, are: Finland, 98%, New Zealand 93% and Ireland 79%.
- All three countries combine breadth of education with a commitment to improving the quality of education in STM.
- Pupils in Ireland and New Zealand performed close to the international average in both the 1995 TIMSS Mathematics and Science assessments, both at the fourth and eighth grade levels. Finland did not take part in the study.

5.5 The South African evidence

We have seen that theoretically human capital creation should make a difference to economic growth. In addition international empirical evidence on balance confirms this prior theoretical expectation.

In this section we now face two questions.

The first concerns the legacy of South Africa's human capital creation. Just how good has it been – or perhaps more appropriately, just how bad?

The second question then concerns the issue of whether the nature of South Africa's human capital creation has been such as to influence its growth path, for better or for worse.

5.5.1 South Africa's legacy of human capital creation

Needless to say the issue of South Africa's legacy of human capital creation is a vexed one. It was one of the principal vehicles through which the policy of apartheid significantly skewed the opportunities facing its citizens, and thereby seriously damaged the long term developmental capacity of the economy. It is here perhaps more than anywhere else in the present study that the legacy of apartheid is not only evident historically, but continues to exercise its influence to the present day.

Human capital creation can be viewed in a number of distinct dimensions. In the theoretical discussion of human capital above we have already seen that we can distinguish at least between the pure skills, the entrepreneurial and the knowledge stock dimensions of human capital. And the pure skills dimension itself can be further broken down into educational and vocational subcomponents. In the discussion that follows we focus on the educational system in South Africa, and its performance. This is not to say that the other dimensions of human capital are less significant. The focus is merely determined by data availability considerations.

The discussion that follows draws substantially on earlier published findings on the South African educational system.[19] In the earlier work we addressed the performance both of South Africa's schooling system, as well as various components of its tertiary educational system. In the discussion that follows we simply highlight some of the more salient features that emerge from the data.

5.5.1.1 A characterization of the performance of South Africa's schooling system

That all is not well with South Africa's schooling system is not news. The performance or lack of it in various parts of the schooling system forms the focus of much anecdotal evidence, and debate surrounding the issue intensifies annually on publication of matriculation pass rates.

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[19] See Fedderke, De Kadt and Luiz (2000a,b).

But it is possible to be precise about the nature of the schooling system's performance.[20] In **Figure 5.2** we report the matriculation pass rates in the South African schooling system, distinguishing between "white" and "black" matriculation pass rates.[21]

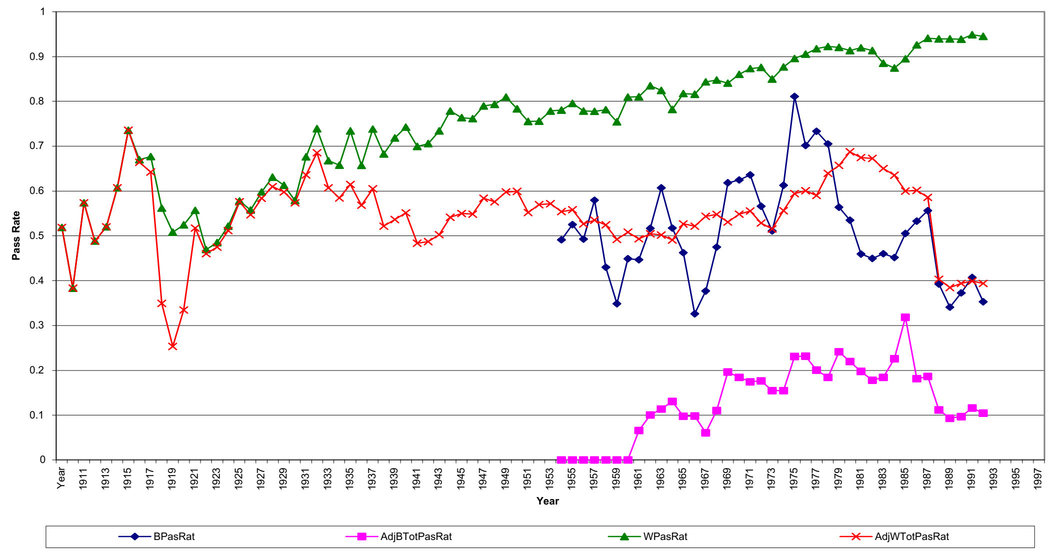

Figure 5.2: Matric Pass Rates. Source: Fedderke, De Kadt and Luiz (2000a).

While the white matriculation pass rate (**WPasRat**) shows an unambiguous trend improvement over the entire 1911-93 sample period, for black matriculation the evidence is far more mixed. While black pass rates (**BPasRat**) increase from 1955 through to 1976, they then decline steadily through 1993. In the period for which we have separate figures for both black and white pass rates (1963 - 1993), with the singular exception of 1976 when the black matriculation pass rate approaches the white, the black rate consistently falls below the white rate by a very considerable degree. During this period the white pass rate stays within the 75% -95% range, while the black pass rate - with few exceptions - falls below 60%. The difference, in the worst years for black education, lies in the region of 60 percentage points.

A further distinguishing feature of the two pass rates is that the black pass rate fluctuates wildly. By contrast, the white pass rate fluctuates in an almost equivalently wild fashion only during the very early period of political and societal consolidation after Union (1910 -1923).[22]

[20] For a fuller discussion of these results see Fedderke, De Kadt and Luiz (2000a).
[21] For purposes of precision and consistency we have followed the classificatory conventions deployed by the South African authorities during both the pre-Apartheid and Apartheid periods. We consider it important to record the information under these contrived rubrics since the system of racial estates and statutory race classification had profound implications for the administration of educational matters and for the distribution of educational resources and opportunities. Hence the use of the racial classificatory conventions employed under apartheid.
[22] The distinction becomes evident from a comparison of the standard deviation which attaches to the percentage change in matriculation pass rates for whites and blacks: 8.85 and 16.57 respectively.

The black schooling system thus not only produced pass rates which prove to lie considerably below those of the white system, but the black system also appears to have been far more prone to either a series of shocks, or did not serve as a consistent screening mechanism - or both. Either reason for the fluctuations in pass rates is likely to have proved damaging for any positive incentive mechanisms present for black pupils - lowering the likelihood that what human capital accumulation was on offer to pupils in the black schooling system would be absorbed.

Raw matriculation pass rates form a legitimate standard of comparison of the alternative schooling systems only if the two examination standards are comparable. Anecdotal evidence if nothing else makes this assertion questionable. We therefore weight the matriculation pass rates of white and blacks by the proportion of total matriculation candidates sitting mathematics (in either higher or standard grade).[23] In **Figure 5.3** we report the results as **AdjWTotPasRat** and **AdjBTotPasRat** for white and black candidates respectively. The implication of weighting the pass rates is that the divergence between the measures of white and black schooling system output is further exacerbated. At no point in time does the weighted black pass rate approach the weighted white pass rates – with the minimum differential at approximately 30 percentage points.

The weighted pass rates for whites further suggests that the improvement in the white schooling system has been considerably less dramatic than implied by the unweighted rate. Indeed, while there is some improvement in the weighted pass rate post-1975, the 1930-75 period does not manifest any consistent trend. Moreover, weighted black pass rates also manifest somewhat different trend patterns from the unweighted series. The improvement in weighted pass rates runs through the late 1980's, declining thereafter to the end of the sample period. Thus the decline sets in a decade later than implied by the unweighted pass rates.

The maths-weighted matriculation pass rates further prove to manifest considerably higher volatility for both whites and blacks. In the case of blacks the standard deviation of the percentage change of the pass rate increases from 16.57 to 30.37, while for whites the increase is from 8.85 to 13.09.

In terms of weighted pass rates even the best schooling system in South Africa is thus subject to severe quality constraints. Indeed, a consideration of the proportion of black and white pupils taking mathematics in either higher or standard grade reinforces the point. For whites the proportion of total matriculation candidates sitting mathematics has been in steady decline since the 1930's - accelerating during the course of the 1980's, to reach a low of 40% of all white matriculation candidates - see **Figure 5.3**. By contrast the proportion of black candidates writing maths rose until the late 1980's,

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[23] We choose mathematics for the following reasons: mathematics has as clearly identifiable objective performance standards as any subject available to matriculation candidates. Application of subjective standards of assessments are therefore minimized. Moreover, we consider mathematics to be foundational to a wide range of cognitive activities and vocational skills. Lastly, mathematics (and science) was used as the central indicator of the quality of the educational system in the Hanushek and Kim (1995) growth study - and proved a more significant predictor of long run economic performance than the quantity of education.

though the trend has been reversed since, and has come to lie at the 30% level in 1993.

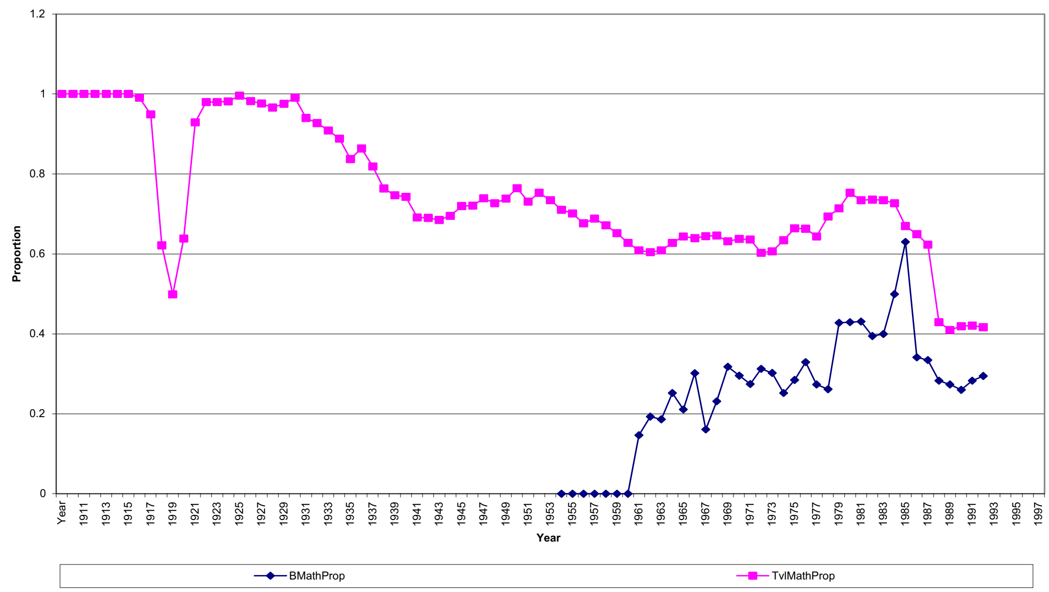

Figure 5.3: Proportion of Matric Candidates with Maths. Source: Fedderke, De Kadt and Luiz (2000a).

So the performance of the schooling system in South Africa is poorer than we might wish for. But can we provide some insight as to why this might be the case?

Part of the answer lies with the nature of the inputs into the schooling system. Where inputs into the human capital creation process are poor, it is hardly surprising that the output will suffer in terms of its quality also.

Evidence that inputs into the schooling process have suffered from poor quality emerges in at least three distinct dimensions.

First, a comparison between pupil-teacher ratios in white and black schooling suggests that the educational opportunities in the two schooling systems were not equal. **Figure 5.4** reports the pupil teacher ratios for both public and private schools for whites and blacks.[24] The most salient point to emerge from an examination of the data is that white educational opportunity, regardless of whether the opportunity arose in public or private schools, is consistently and considerably better than black educational opportunity. White public school pupil-teacher ratios (**WPubPupTch**) never rise above the mid-20 level (the very highest ratio is 24.06 in 1952), while the best black pupil-teacher ratio is provided by the private schooling system (**BPvtPupTch**) in 1941 at a ratio of 31.61. Case and Deaton (1998), on the basis of cross sectional survey evidence from South Africa, note that while differences in

[24] Again, for a fuller discussion of these results see Fedderke, De Kadt and Luiz (2000a).

pupil-teacher ratios in the 10:1 to 40:1 range may not significantly determine the educational performance of pupils, an increase in pupil-teacher ratios from 30:1 to 60:1 is a statistically significant determinant of educational performance. In this context it is noteworthy that the pupil-teacher ratio for black public schooling (**BPubPupTch**) remained in the range from 50:1 to 70:1 for a protracted period from 1957 to 1993, while black private schooling over the same period did not do significantly better.

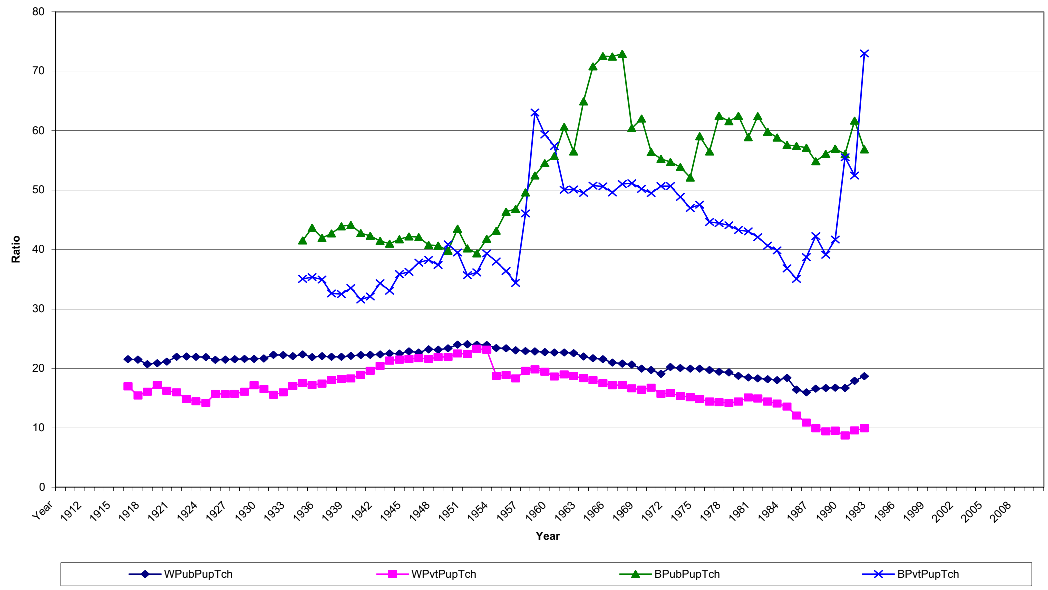

Figure 5.4: Pupil Teacher Ratios for Black and White Public and Private Schools. Source: Fedderke, De Kadt and Luiz (2000a).

Second, real expenditure per pupil showed wide disparities between the racially defined schooling systems. In **Figure 5.5** we report the per capita expenditure figures by racial grouping. While in absolute terms real expenditure on black schooling increased dramatically throughout the 1980's, this did not translate into a strong increase in real per capita expenditure per pupil.[25] On these figures white per pupil expenditure (**RealWperCap)** remains at least at seven times the level of that for blacks (**RealBPerCap**), and almost twice that for Coloureds and Asians (**RealC&APerCap**). Thus the rapid increase in real expenditure on black education has not allowed black schooling to eliminate the backlog with white education. Moreover, a closer examination of black per pupil expenditure suggests that over the 1983-93 period per pupil expenditure remained virtually stagnant in real terms. The implication of the present section is thus that the divergence of quality between the white and black schooling systems is potentially even more dramatic than suggested by the pupil teacher ratios examined above. The ratio of seven to one on

[25] It should be noted that there exists some controversy concerning the appropriate expenditure figures on black schooling. For a fuller discussion and a consideration of alternative evidence see Fedderke, De Kadt and Luiz (2000a).

real per pupil expenditure is several orders of magnitude greater than the ratio of two to one we reported with respect to pupil-teacher ratios.

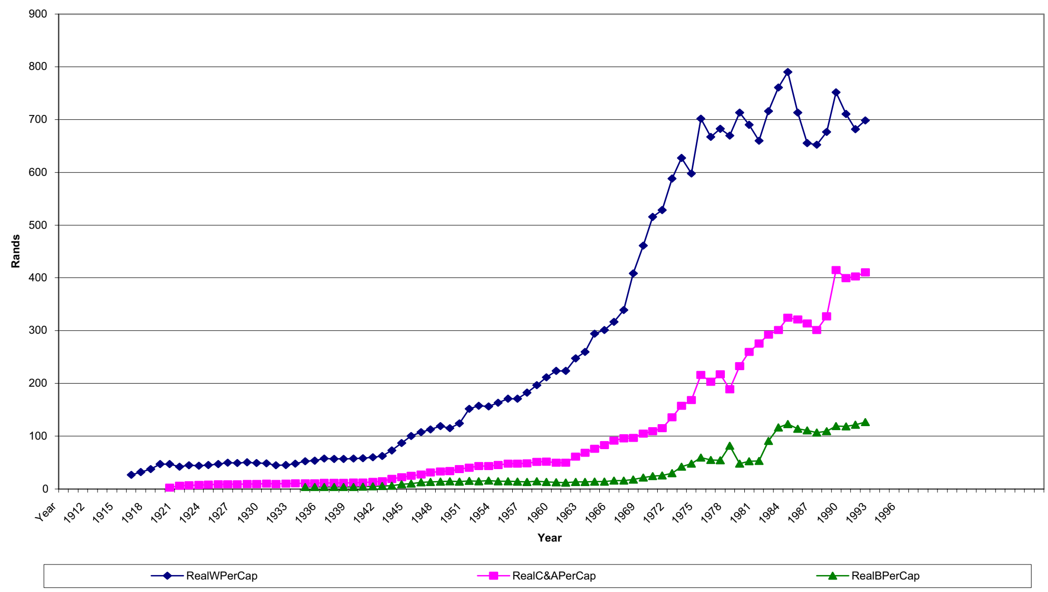

Figure 5.5: Real Per Pupil Expenditure by Race. Source: Fedderke, De Kadt and Luiz (2000a).

Third, differentials in teacher qualifications similarly point to the presence of large disparities in the quality of inputs into the schooling process between black and white schooling. We consider the percentage of teachers in public schools who fall into one of two limiting categories. The first, which we label **iUNQLRAT**, denotes the proportion of the total teacher body for the racial category **i** which holds a Matric qualification or less. The second, which we label **iSPUQLRAT**, denotes the proportion of the total teacher body for the racial category i which holds a tertiary qualification.[26] They represent respectively “under”-qualified and “super”-qualified teachers. **Figure 5.6** reports both categories of teachers for both white and black racial groups. Surprisingly the **iUNQLRAT** category of teachers is fairly similar between the white and black schooling systems, with approximately 20% of teachers proving to be unqualified. The only significant difference to emerge is that the proportion falls to approximately 10% for the white schooling system almost a decade earlier than it does for the black schooling system.

Thus in a number of crucial dimensions we find that the quality of inputs into the educational process in white and black schooling are sufficiently large to serve as plausible explanations of the differential performance we observe in the white and black schooling systems.

In a more detailed econometric exploration, Fedderke and Luiz (2000) confirm that the inputs into education matter for educational attainment. The findings rest on the

[26] “Tertiary” education denotes either a degree or a diploma.

specification of an educational production function linking inputs to outputs in the two South African schooling systems. The specification estimated is given by:

$$iPRAT = F(iPUBPTR, iRPPEXP, REPR) \tag{6}$$

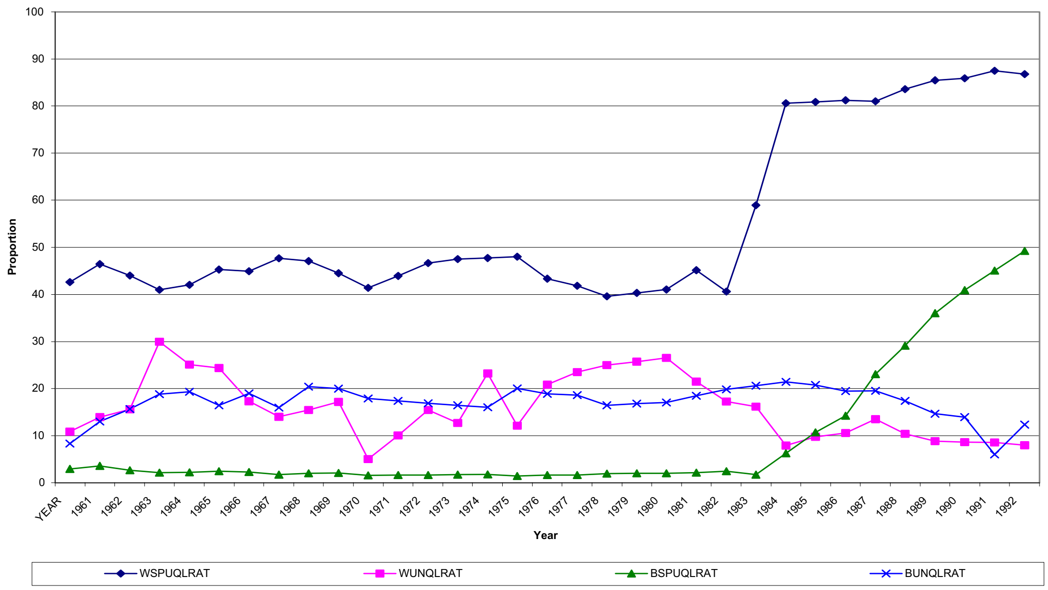

Figure 5.6: Teacher Qualifications. Source: Fedderke, De Kadt and Luiz (2000a).

where iPRAT denotes the pass rate[27] of racial grouping i,[28] RPPEXP real per capita expenditure, and REPR denotes a political instability variable. [29] The salient results are presented in **Table 5.2**.[30]

The implication of the econometric findings is that the inputs into schooling have a strong, statistically significant and benevolent impact on pass rates in white schooling, while for black schooling the impact of political instability dominated all other factors, lowering matriculation pass rates.[31]

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[27] Defined as a log-odds ratio.
[28] Again defined as black (B) or white (W).
[29] On the definition and construction of this variable see Fedderke, De Kadt and Luiz (1999a).
[30] Given the nonstationary time series character of the data, we employed the ARDL cointegration technique due to Pesaran and Shin (1995a,b), Pesaran, Shin and Smith (1996). For a fuller discussion see Appendix 1 to the present chapter.
[31] We report only long run equilibrium coefficients, not the full dynamics. The error correction terms confirm the presence of a stable equilibrium relationship between variables. Full results are available in Fedderke & Luiz (2000).

Table 5.2: ARDL Cointegration Estimation Results.

White Schooling ARDL (6,6,3,2) 1944-50 n=50		Black Schooling ARDL (2,1,2,4) 1968-93 n=28	
	WPRAT		BPRAT
Constant (t-ratio)	9.01* (7.97)	Constant (t-ratio)	7.33 (1.20)
WPUBPTR (t-ratio)	-2.86* (9.40)	WPUBPTR (t-ratio)	-0.97 (0.66)
WRPPEXP (t-ratio)	0.24* (5.20)	WRPPEXP (t-ratio)	-0.18 (1.17)
REPR (t-ratio)	0.02 (1.49)	REPR (t-ratio)	-0.32* (3.47)
ecm(-1) (t-ratio)	-0.997 (6.22)	ecm(-1) (t-ratio)	-0.65 (5.16)
ARDL Diagnostics		ARDL Diagnostics	
$R^2 = 0.98$	adj-$R^2 = 0.97$	$R^2 = 0.91$	adj-$R^2 = 0.83$
$\sigma = 0.10$	DW = 1.97	$\sigma = 0.23$	DW = 1.90
AR = 0.03	RESET = 2.08	AR = 0.02	RESET = 1.51
NORMAL = 7.29*	HETERO=0.94	NORMAL = 0.14	HETERO=0.14

Source: Fedderke and Luiz (2000).

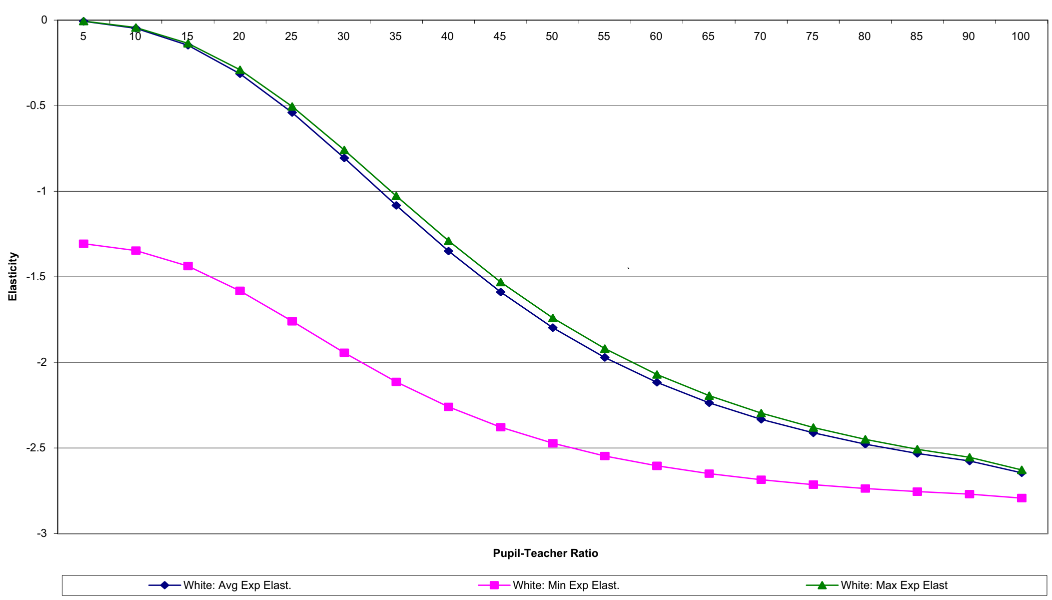

Figure 5.7: White Schooling: imputed elasticity of matriculation pass rates with respect to the pupil-teacher ratio.

Given the variable elasticity of pass rates with respect to pupil teacher ratios implied by the specification estimated, in **Figure 5.7** we provide an indication of the magnitude of the elasticity of pass rates for white schooling over a range of pupil-teacher ratios. What is startling about the evidence is the strength of the implied elasticity, confirming that inputs matter, and matter substantially. This is all the more important since this evidence emerges on ranges of inputs which are comparable to those for which many studies did not find statistical significance for the USA.[32]

The question here must of course be why statistically the inputs matter in the white schooling system, and not in the black. But in fact the difference between the two production functions is readily interpretable. Over the sample period under consideration, whites in South Africa had access to institutions that allowed them to exercise at least some control over the educational production process. Certainly provincial educational administrators could be accessed through political representation in order to address any inefficiencies in the educational process. By contrast, blacks had access to no such institutions – and certainly the officials responsible for the delivery of educational services had no incentive to respond to delivery failure reported by parental complaints. Thus the distinct institutional background that distinguishes the two schooling systems appears to have carried profound implications not only for educational attainment by pupils, but implicitly for the efficiency with which resources were being employed within the schooling structures also.

The institutional structures that govern policy formation in the schooling system, as well as the inputs into the educational process appear to be crucial in determining educational attainment of pupils. Where parents have the capacity to influence policy, the use of inputs in education has proven to be more efficient than where they do not. The labour market gives individuals a stake in the educational process. What governance structures of schooling should reflect are adequate means for allowing agents to realize such stakes in their own best interests.

Thus for South Africa's schooling system the evidence is of large quality differentials in the output of the schooling system attributable to poor inputs into the schooling process, and to inappropriate governance structures.

And recall that the evidence suggests that even the best parts of the system could be doing better.

On the upside of the evidence, at least we know what is going wrong (though we need even more information), and therefore what the appropriate forms of policy intervention should be if we wish to improve schooling performance.[33]

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[32] This applies particularly to pupil-teacher ratios. White pupil-teacher ratios are in ranges similar to those found in the US, where they appear to be insignificant. The difference lies in the fact that US studies have tended to use cross-sectional data (see for instance Hanushek 1995, 1996), rather than time series, due to the absence of time series data. Yet since the impact of changing inputs is likely to take time to emerge, time series is clearly the way to go here.

[33] For an elaboration on the policy issues that arise out of the schooling education data, see Fedderke (2000b).

5.5.1.2 A characterization of the performance of South Africa's tertiary educational system

The next question to ask is whether the poor schooling system in South Africa has translated into a poor tertiary educational system, and whether the patterns that were evident at the schooling level have been reproduced for tertiary institutions?

The data to be presented in this section covers the university system in South Africa.[34]

In tertiary education we find the patterns of performance to be somewhat different from those we found for schooling. For universities the distinction between the historically white universities, and universities historically designated for other race groups, is not in terms of the quality of inputs as measured by student-lecturer ratios, or by expenditure per student.[35] Indeed, real expenditure per student for universities was higher in the black universities than it was for whites. Nevertheless, our findings show that the quality of output of black universities in terms of both the degrees they issued and their research output lay considerably below that of the universities designated white.

Only the teacher training college system emulates the results we found for South African schooling. Here again, inputs as well as outputs of the teacher colleges prove to be of considerably lower quality for blacks than for whites.[36]

In technical training, the differential between whites and blacks emerges primarily in the form of poor access to such training by blacks, rather than in the form of poor inputs into black technical training as measured by student -lecturer ratios and real per student expenditure. A more general finding to emerge from our data on technical education in South Africa is that significant under-investment in technical forms of human capital has been maintained over the sample period, and for all population groups.[37]

In the university system student-staff ratios show relatively little variation across race groups – see the evidence of **Figure 5.8**.[38] Indeed, during the course of the 1960's and 1970's the student-staff ratios at the black, coloured and Asian (BCA) institutions lay

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[34] Again this section draws substantially from Fedderke, De Kadt and Luiz (2000b), which is also concerned with the technikon, teacher college, and apprenticeship contract data for South Africa. The restriction to the university sector in the current context is because it is the most significant tertiary educational sector both in terms of student numbers, and in terms of its anticipated innovative capacity. Since it is the supposed pinnacle of the tertiary system, it is also held to be indicative of the health of the sector as a whole. Fedderke, De Kadt and Luiz (2000b) note some crucial differences between the various parts of the tertiary system, however.

[35] We note at the outset that for universities the distinction between "white" and "black" makes less sense than elsewhere in the educational system. Since student bodies always tended to be mixed, the designation cannot be taken to reflect the racial composition of the institutions being referred to so much as a series of historically determined labels. For reasons that will become clear from the ensuing discussion, "historically advantaged" and "historically disadvantaged" is also misleading. All labels in the current context are thus misleading, and we therefore stick to the historical ones. At least these give a sense of continuity and contiguity with past usage.

[36] The full results are available in Fedderke, De Kadt and Luiz (2000b).

[37] The full results are available in Fedderke, De Kadt and Luiz (2000b).

[38] A fuller discussion of the issues touched on here is contained in Fedderke, De Kadt and Luiz (2000b).

below that maintained in the white university system.[39] This pattern only changes after 1980, when the student-staff ratio of all parts of the university system begins to demonstrate an upward trend. During the course of the 1980's the student-staff ratio of both the Coloured and Asian universities is of essentially the same order as of the white universities, though there also appears to be greater cyclical variability in Asian and Coloured student-lecturer ratios. However, the strongest change during the course of the 1980's, concerns the student-staff ratio in black universities, which rises dramatically during the 1980's, to approximately double that which prevails in the white university system.

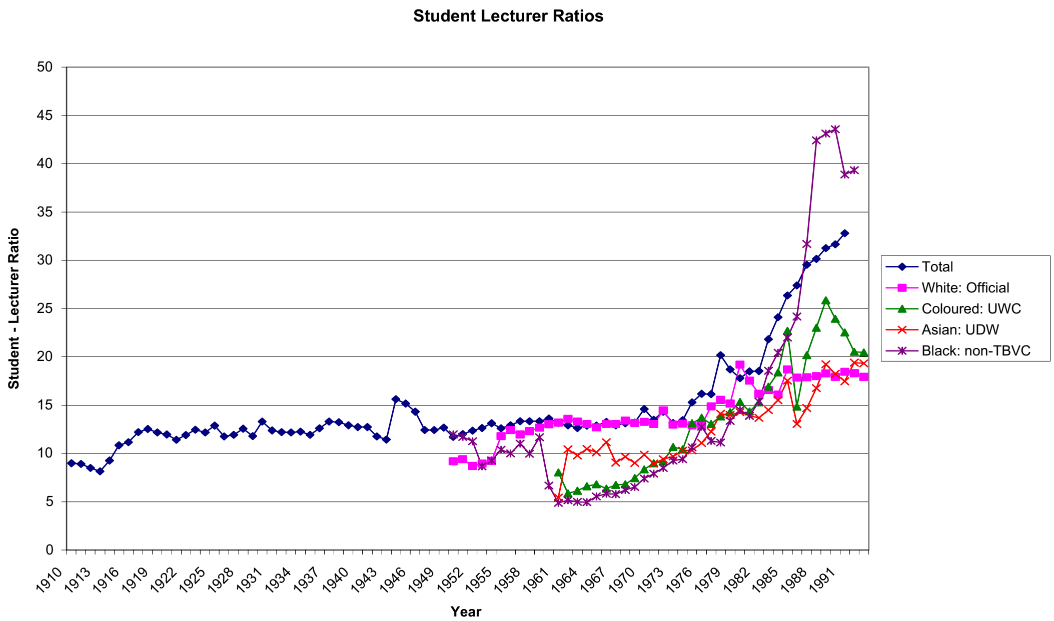

Figure 5.8: Student Lecturer Ratios: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

There are three immediate and important implications that emerge from the evidence provided by student-lecturer ratios. First, the low student-lecturer ratios in BCA-universities during the pre-1980 sample is likely to be influenced by the poor performance of the BCA-schooling systems, detailed above. Thus the ability of the BCA-tertiary education system to attract sufficient student intake is likely to have suffered from a supply-side constraint, making it difficult to attract students in sufficient numbers.

Second, it becomes likely that student-staff ratios for universities may well not be a reliable indicator of quality of learning environment,[40] particularly since we know the

[39] This is true even where (as in Figure 5.8) we employ the white university student enrolment figures which do not count the students of other races attending these universities. Where the adjusted student enrolments for white universities are employed, there is a further though marginal upward adjustment in the student-lecturer ratio at white universities.

[40] The ratio of students to lecturers does not control in any way for the quality of the lecturing staff employed in the respective sets of institutions. Ideally, the ratio should be appropriately weighted for

student intake to have been poorly prepared for tertiary education. This is thus quite unlike the case for the South African schooling system, where pupil teacher ratios were found to show strong variation across the racially defined schooling systems, and this variation was found to exert strong influence on educational attainment.

A third implication of this evidence is that the development of separate university systems for the distinct ethnic groupings of South Africa's population was an extraordinarily inefficient use of scarce resources. Universities are notoriously expensive in terms of start up costs. To develop entirely new universities with a student body generally poorly prepared, and with low student-staff ratios, may well have prevented the already existent universities from improving their quality. A more rational approach to the development of the tertiary educational system would have been to take advantage of economies of scale in incorporating BCA students into their historic student body.[41]

The real expenditure per student data further strengthens the patterns observed in **Figure 5.8**. We present the data in **Figure 5.9**.[42] For historically white universities, real per student expenditure has remained essentially constant over the full 1910 to 1993 period, though the 1980's and early 1990's have seen some decline from the height of per student expenditure achieved during the course of the 1970's. For all other racial groupings in the university system, per student expenditure during the course of the 1960's and 1970's was higher than for the white university system, though the 1980's has seen convergence between the expenditure figures for the various sections of the university system. The black university system did not differ from Coloured and Asian universities in this respect. For black universities real per student expenditure consistently lay above that for the white university system during the 1960's and 1970's, and it is only the sharp increase in student numbers at black universities during the 1980's that drives down per student expenditure below that of other parts of the university system.

A number of explanations account for these data patterns - and a number of implications follow. First, the high per student expenditure figures in the BCA-universities can be accounted for in terms of the start-up costs of any new university system. Again, consistent with our suggestions emerging under the discussion of the student-lecturer ratio, the difficulty likely to have been experienced by the BCA universities is the recruitment of a suitable student body. Thus, the investment in infrastructure and in the high level human capital required to start up a new set of universities was for a small student body, who were in consequence funded to a disproportionately high level on a per capita basis. Only during the course of the 1980's does a quality differential come to be indicated in per student expenditure levels at universities.

This evidence is once again corroborates that the educational system imposed by the apartheid ideology was wasteful of scarce resources.

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the quality of lecturing input. Unfortunately, no ready statistics were available to enable such a quality adjustment.

[41] This is a point that generalises across the tertiary educational system in the Apartheid era in South Africa.

[42] Again, a fuller discussion of the data and its characteristics can be found in Fedderke, De Kadt and Luiz (2000b).

The resources expended in developing an entirely new university sector in parallel with an already existing system might have been far more efficiently employed in expanding the capacity of the existing system, with the associated economies of scale that might have been realized in the process. As it was, the educational system was starved of a large body of resources, that might have been more appropriately employed in improving the quality of the primary and secondary schooling system feeding the universities, or in expanding existing universities.

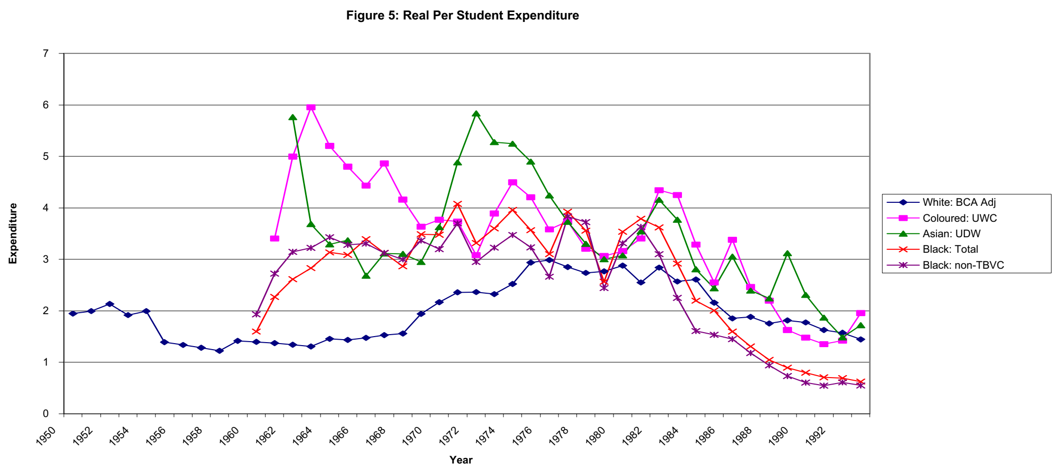

Figure 5.9: Real Per Student Expenditure: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

So the evidence on inputs into the university system suggests that the patterns of inequality that characterised schooling in South Africa, and which in turn issued in large differentials in performance by pupils in schools, are not repeated for the university system in South Africa. The question now must be whether the more equal allocation of resourcing in the university system managed to produce a university system of an undifferentiated level of excellence throughout.

Anecdotal evidence suggests that this was not the case, but what does the hard data tell us?

Figure 5.10 reports the absolute output of university degrees in South Africa. Absolute output measures of the university system suggest a steady and, since 1960, sometimes steep increase in the total degrees granted by universities. The evidence suggests that the white universities dominate the university system as a whole in output terms, despite the growing degree output of black universities particularly during the course of the 1980's.

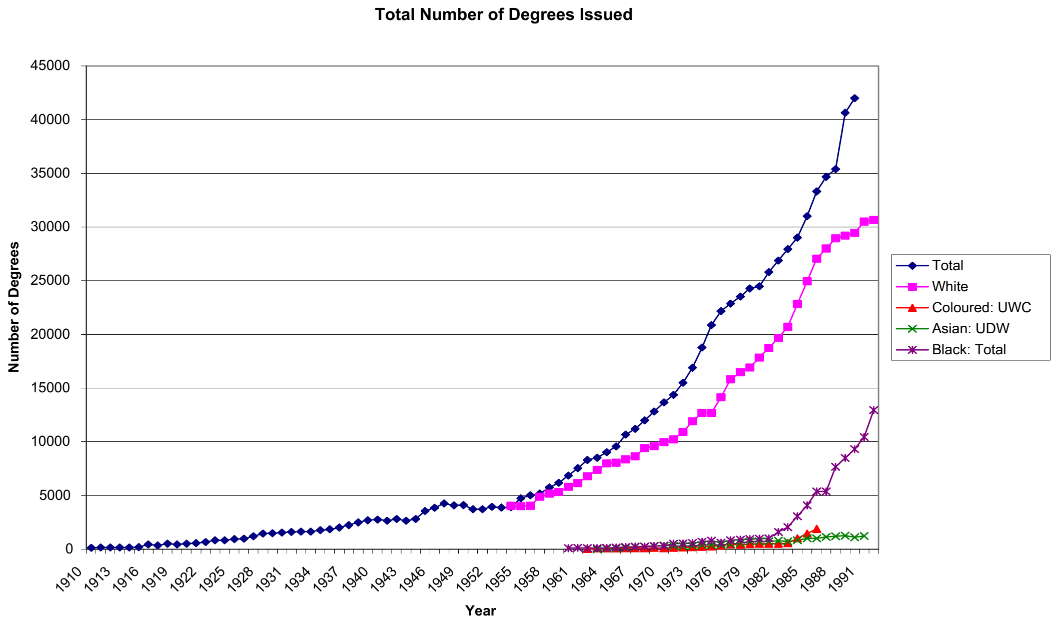

Figure 5.10: Total Number of Degrees Issued: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

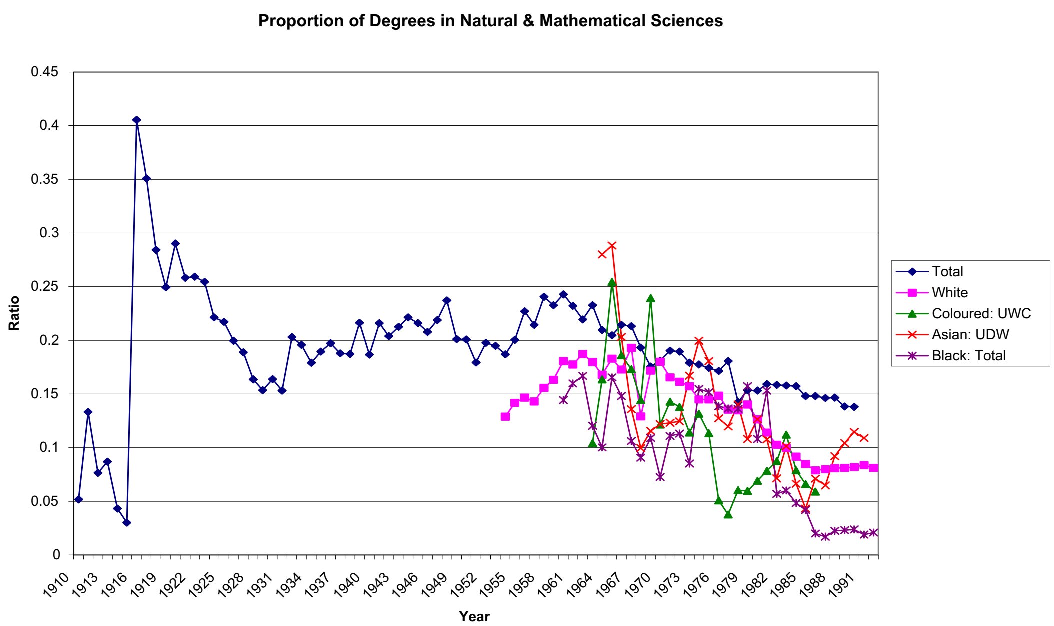

Figure 5.11: Proportion of Degrees in Natural and Mathematical Sciences: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

While the absolute output of degrees suggests that black universities were expanding their output as the number of students entering the system increased during the 1980's, absolute numbers of degrees do not yet control for the quality of the output being generated.

In **Figure 5.11** we report the proportion of total degrees issued by the various university systems that emerge in the natural and engineering sciences (NES).[43] For the white and Asian university systems, the proportion of NES degrees falls from a high point of 20% in the mid 1960's, to a little under 10% in the early 1990's.[44] While the black university system initially had a similar proportion of NES degrees conferred, during the course of the 1980's at precisely the time when student enrolments were expanding rapidly, the NES proportion fell rapidly, and by 1993 had reached a low of 2%. While the trend for both systems has been downward, the performance of the black universities in producing science graduates is far poorer than that of the white university system. Moreover, while the strong increase in student numbers in the black university system in the early 1980's was matched by an increasing conferral of degrees this was clearly achieved by an expansion of students reading toward "soft" rather than science degrees. **Figure 5.11** demonstrates a sharp decline in the proportion of science graduates precisely at the point at which both student numbers and total degrees conferred were experiencing sharp growth.

This evidence carries the implication that the black university system, while beginning to absorb increasing numbers of black students emerging from the black schooling system, was unable to translate the increased enrolment into NES graduates with the same facility as the rest of the university system. While this may point to the poorly prepared student intake that the black university system had to contend with, it is also indicative of a low capacity within the black university system to generate NES graduates.

Similar implications emerge from student throughput rates,[45] and real expenditure per degree data. All sections of the university system saw an increase in the cost per degree produced over the course of the 1980's. However, the increase has been the most dramatic in the black university system, to the extent that the cost per degree in the black university system in 1993 had reached 1.5 the level maintained in the white universities.

White and black university systems also have significantly different throughput rates. For white universities approximately 17% of the total student body in 1993 was

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[43] We choose NES degrees for the following reasons: the mathematical sciences have as clearly identifiable objective performance standards as any subject available to university students. Application of subjective standards of assessments are therefore minimized. Moreover, we consider the mathematical sciences to be foundational to a wide range of cognitive activities and vocational skills. Lastly, mathematics (and science) was used as the central indicator of the quality of the educational system in the Hanushek and Kim (1995) growth study - and proved a more significant predictor of long run economic performance than the quantity of education. We have also already seen from the evidence of Chapter 4 that the impact of science degrees on output growth in manufacturing is positive both for South Africa, and internationally.

[44] The higher proportion of NES degrees in the total student body is attributable to the impact of Coloured and Asian students present in the white university system, but classified in terms of their racial categories. In this instance the bias could not be corrected for.

[45] Defined as the ratio of degrees conferred to the total student body.

receiving a degree, and the trend for the white university system was upward. By contrast, black universities while sharing an upward trend in the total degree throughput rate since the early 1980's, had reached a throughput rate of only 10% in 1993, significantly below that of white universities. In the case of the throughput of NES degrees black universities reported close to 0.002 in 1992, while white universities reported 0.01. While particularly the NES throughput rate is poor for both university systems therefore, it is evident that matters have been far worse in the BCA university system. The sharp uptake in additional students through the 1980's has not been translated into an improved university sector performance.

There is a final but perhaps also most important indicator of the differential quality of South African universities. Universities are distinguished from other forms of tertiary educational institutions by virtue of the expectation that they be engaged not purely in teaching activity, but that they contribute to the advancement of knowledge through the publication of original research. And given our discussion of endogenous growth theory, and the empirical findings we have already shown on the growth impact of R&D, this feature of the university system attains additional significance. In **Figure 5.12** we report both the absolute level of research unit output of the racially categorized universities, as well as their per lecturer research unit output.[46] The evidence confirms the suggested quality differential that we have already established as existing between the "white" universities and BCA universities. Not only is the absolute level of research output in white universities considerably higher than in BCA universities, but this is translated into considerably higher per capita research output also.

But again, while BCA universities essentially produce no research output to speak of at all, note that even the white university system produces less than one publication per lecturer per annum. Something is amiss even in the "good" part of the system.

Moreover, we note that even the best part of the university system in South Africa has at the very least manifested declining quality over time. First, the white university research output has ceased to increase in absolute terms from the late 1980's, and in per lecturer output terms the output declined through to the early 1990's, though it has since stabilised. Also – most research in South Africa is done in a very small number of universities. See **Tables 5.3** and **5.4**.

The declining per lecturer and static absolute levels of research output during the late 1980's and 1990's may well be attributable to the increased resources devoted to the development of the BCA university system. In the preceding discussion, we have already suggested that the expenditure on BCA universities proved to be an expensive way of obtaining relatively low quality degree output. The evidence on research output, suggests that an additional cost may well have been a declining capacity of the front ranking research universities in South Africa to continue to fulfil their vital

[46] Publication units are not quality adjusted. This is particularly serious since a publication of an article in a South African journal with very low impact factor would be ranked as equivalent to an article in a leading international journal with maximal impact rating. Moreover, research collaboration is penalized on a pro rata basis by the national publication unit system. Collaboration with Nobel Prize winning scientists therefore comes to be ranked below single-handed review articles of secondary material. Finally, the national register of approved journals excludes a number of leading journals, while rating obscure South African magazines as legitimate fora for research. Bizarre incentive mechanisms.

research function. The reallocation of funds to the development of the BCA university system therefore had opportunity costs not only in terms of foregone development opportunities in the already existent university system, but potentially also in preventing the resourcing of growing research capacity in the South African university system.

Again in the light of the wider evidence on the importance of R&D on growth, this finding is of particular concern for South Africa.

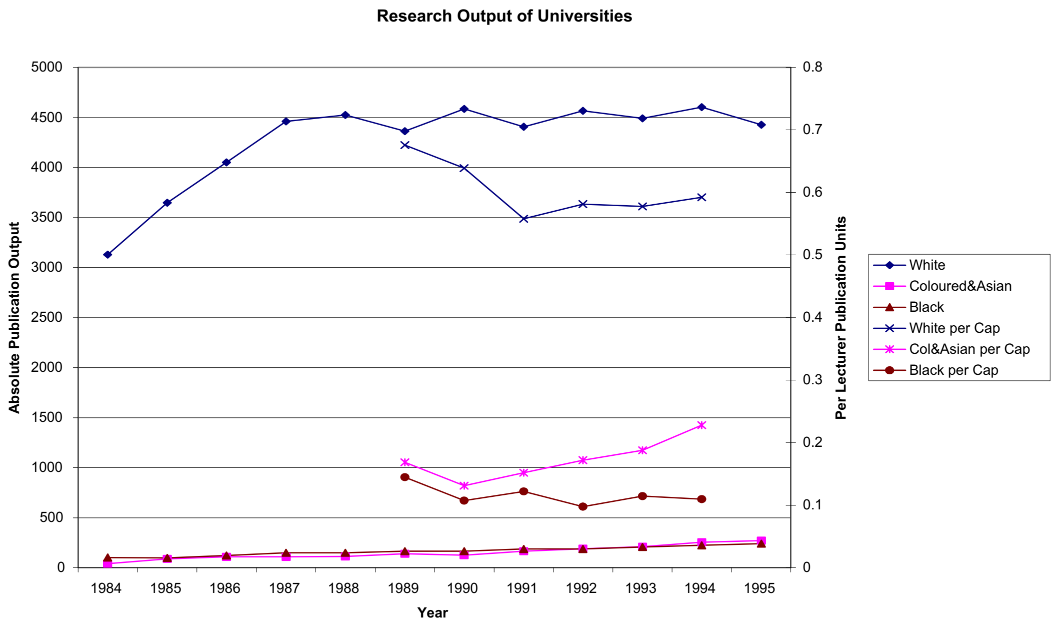

Figure 5.12: Research Output of Universities. Source: Fedderke, De Kadt and Luiz (2000b).

In a broader developmental context, it raises the important question of whether it is desirable for a society to concentrate solely on devoting resources to a broad based mass tertiary educational system premised on the lowest common quality denominator. Or whether it is not desirable to have at least some tertiary education devoted to the production of both high quality degrees, as well as world quality research. If the latter route is chosen (and the experience of the East Asian countries may be taken to at least suggest that it is not entirely unfruitful - as long as the right type of educational output is emphasized), the implication would be for the identification of a small number of core institutions, properly funded, and with appropriate incentive structures designed to encourage greater attention to research activity.

Finally, in this regard it is possible to identify a strong inter-institutional difference in terms of research output between white universities. The evidence suggests the presence of a three tier structure to the university system, as suggested in **Table 5.4.**

Table 5.3: Per Capita Publication Unit Output by University, 1989-94

	1989	1990	1991	1992	1993	1994	Rank1989	Rank1994
Wits	1.17	1.09	0.78	0.83	0.74	0.84	1	3
Cape Town	1.04	0.98	0.93	0.93	0.89	0.91	2	1
RAU	0.92	0.82	0.71	1.03	1.00	0.89	3	2
Natal	0.68	0.59	0.58	0.49	0.65	0.56	4	5
Rhodes	0.59	0.56	0.49	0.47	0.43	0.47	5	6
Stellenbosch	0.55	0.49	0.45	0.51	0.50	0.65	6	4
Pretoria	0.51	0.50	0.43	0.47	0.48	0.45	7	7
Free State	0.41	0.43	0.41	0.37	0.40	0.39	8	8
Potch	0.40	0.45	0.35	0.41	0.36	0.36	9	9
UPE	0.38	0.29	0.34	0.33	0.22	0.28	10	10
Medunsa	0.26	0.14	0.23	0.07	0.16	0.12	11	15
UNISA	0.24	0.25	0.24	0.25	0.23	0.25	12	11
UDW	0.20	0.19	0.21	0.22	0.18	0.24	13	12
Vista	0.15	0.10	0.11	0.11	0.09	0.09	14	17
UWC	0.14	0.09	0.11	0.13	0.20	0.22	15	13
Zululand	0.14	0.08	0.12	0.14	0.12	0.16	16	14
North	0.10	0.11	0.08	0.08	0.11	0.10	17	16

Table 5.4: Ranking of Universities in Terms of Research Output

Top Ranked: Per Lecturer	Mid Ranked: Per Lecturer	Bottom Ranked: Per Lecturer
Cape Town	Stellenbosch	Port Elizabeth
RAU	Natal	UNISA
Wits	Rhodes	Durban-Westville
	Pretoria	Western Cape
	Free State	Zululand
	Potchefstroom	Vista
Top Ranked: Absolute Output	**Mid Ranked: Absolute Output**	**Bottom Ranked: Absolute Output**
Wits	Stellenbosch	Rhodes
Pretoria	Natal	Potchefstroom
Cape Town	UNISA	Western Cape
	RAU	Durban-Westville
	Free State	Port Elizabeth
		North
		MEDUNSA
		Vista
		Zululand
		Fort Hare

Such a structure might provide some guidance as to how a functional differentiation between universities might come to be structured. The three-tier system might be identified with "ivy league" research universities, state universities or liberal arts colleges, and finally community colleges. Our concern here is not to identify which university should fulfil which of these functions. Nor is it to denigrate any one of the three functions. We are arguing instead that the existing capacity within the university system is not such as to place all universities on an equal footing, and that it may therefore be sensible to develop the existing structures into institutions that fulfil different pedagogical functions, all of which are important. As the evidence makes clear, the system as it is in any event has strong functional differences – we might as well recognise them, and reward them appropriately.

In concert with the earlier evidence presented on the South African university system, therefore, the implication of the present section is that the black university system proved not only to generate output that was of poor quality, but that it proved to be poor output that was expensive. While the poor preparation of pupils passing through the black schooling system is sure to have played its role, the poor design and implementation of a duplicate black university system intended to run in parallel with the white, is likely to have contributed not insignificantly in its own right.

What is more the suggestion above has been that the development of the human capital creating institutions in South Africa has been such as to inhibit the development of a strong capacity to stimulate the R&D activity so vital to long run economic growth.

5.5.2 Testing for the impact of human capital creation on long run economic growth in South Africa

So much for the descriptive account of South Africa's human capital creating institutions. But while we have seen that matters are not as sound as we might like, the question must be whether there is evidence to suggest that this really matters in hard growth terms?

In this final section we examine the impact of the human capital dimension on the long run economic performance of South Africa.

In the preceding chapter we have already established that at least for the manufacturing sector, investment in human capital in a number of distinct dimensions does appear to be adding to the presence of technology spillover effects.

The analysis in the current chapter adds to this analysis of spillover effects. In the current context our focus is on the impact of human capital on long run growth performance in the economy directly, and for the economy in aggregate.

In order to examine this question we employ a standard growth equation, incorporating investment in both physical and human capital as potential determinants of economic growth.

The data employed are determined by the long time series available from the above mentioned studies collecting the evidence on the South African human capital accumulation track record over 1910-93.

As empirical methodology we employ the vector error correction methodology of Johansen, incorporating the cointegration techniques appropriate to nonstationary time series data. Appendix 2 to the present chapter outlines the technique in greater detail.

The specification employed is given by:[47]

$$\ln Y = F\left(\frac{I}{Y}, H\right) \tag{1}$$

where lnY denotes the natural log of real per capita output (GDP) of the economy, I/Y denotes the investment rate given by the ratio of real gross domestic fixed investment to real GDP, and H denotes a vector of human capital variables, incorporating:

- the "white" school enrolment rate. The schooling variables are all specified as the enrolment rate of the relevant age cohort, obtained from census data. For whites, since the schooling pupil data covers both primary and secondary schooling, the age cohort is the 5-19 age group. Readers should note that the variable is likely to result in downward bias, since a significant proportion of pupils in the "white" schooling system are likely to complete schooling no later than at age 17. **Figure 5.13** illustrates the enrolment rate as WENROL. Enrolment rates are chosen in line with international convention in growth studies.
- the "black" school enrolment rate. The relevant age cohort, given the findings of Wittenberg (1999),[48] is given by the 5-24 age group. **Figure 5.13** illustrates the enrolment rate as BENROL.
- the total number of degrees issued by South African universities. The variable is denotes by DEGREES. **Figure 5.14** illustrates.
- the total number of degrees in the natural and engineering sciences issued by South African universities. The variable is denoted NSDEGREES.

Since all variables employed are nonstationary, the appropriate estimation technique is that provided by Johansen VECM. Appendix 3 to the chapter provides the relevant augmented Dickey-Fuller test statistics, confirming all variables to be I(1). See Table A3.2.

We examine two specifications, employing the two alternative tertiary education variables, DEGREES and NSDEGREES, and we report the results of estimation in **Table 5.5**.

The quality of the two sets of results is strongly differentiated. First, note that the long run relationship that included *total* degrees issued (DEGREES) has none of the human capital variables to be statistically significant. The only significant determinant of the output variable is the investment rate. Thus on this specification there would appear to be little more to be said on the impact of human capital creation on long run growth.[49]

[47] Readers will recall that this mirrors the specification employed by Mankiw et al (1992).

[48] Completion of schooling takes longer in South Africa's black population groups. The discussion of the time series data and the inequalities in resourcing implied by the data suggests many reasons why this might be the case – none of which implies fault on the part of the pupils themselves. But this is not our current concern.

[49] In fact, the maximal eigenvalue and trace statistics also indicate that there may be problems with this specification, since there is evidence of a number of cointegrating vectors present in the data. See Table A3.5 of Appendix 3. Thus imposing a single cointegrating vector on the data may produce misleading results, with estimated coefficients being linear combinations of the cointegrating vectors that are

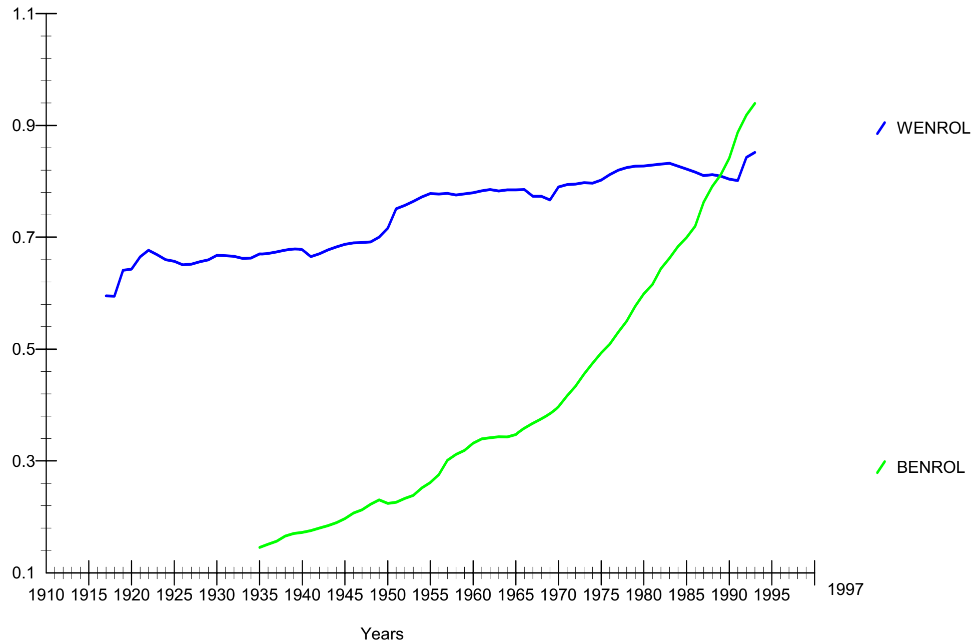

Figure 5.13: White and black schooling enrolment rates.

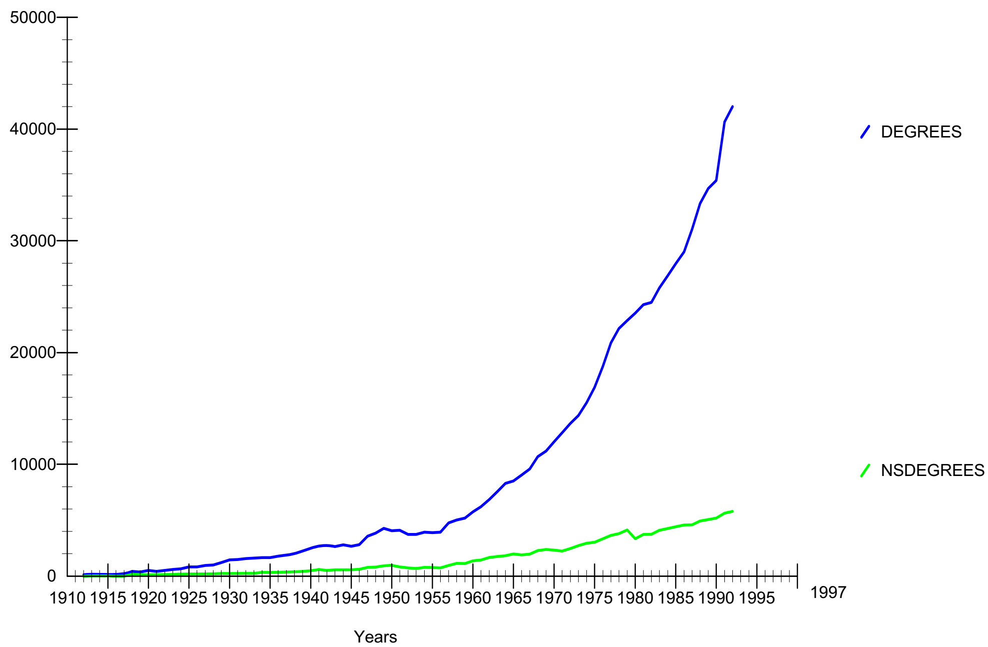

Figure 5.14: Total degrees, and Natural and Engineering Science degrees issued.

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present. While we examined a number of alternative just identifying restrictions on a system of equations, none produced theoretically or statistically congruent results.

By contrast, the specification that loads on the natural and engineering science degrees, generates results that are both statistically and theoretically sound. In particular we note that the estimation:

- Unambiguously has a unique cointegrating vector present in the data.[50]

- All of the human capital variables are now statistically significant in addition to the investment rate. The implication is that investment in both physical and human capital is a significant determinant of long run output values in the South African economy.[51]

- The error correction mechanism confirms the presence of a long run equilibrium relationship in the data, as implied by the cointegrating vector.

What is particularly startling about the estimation results is that once the estimated coefficients are standardized, the impact of the human capital variables come to demonstrate a very strong impact on output.

The implication of these findings is that the human capital variables carry their significance jointly, rather than singly.[52] The implication of this finding is that it provides confirmation of the Romer (1990) or Lucas (1988) implication of increasing returns to human capital. The impact of human capital emerges once the synergies between primary and secondary, and tertiary education come to be recognised. It is not enough to have only some parts of the educational system contributing to output – one needs to recognize the contribution of all components of the educational process to the generation of output. It is the educational system *as a vertically integrated whole*, and not just components of its that are important for economic growth.

The finding is thus a confirmation of the view that human capital creation in South Africa comes to contribute to output creation *directly*, and in aggregate, as well as through its contribution to technological innovation already discussed in the previous chapter.

But a number of the features of the preferred specification below demand further comment, and in turn carry significant policy implications.

The first point to note is that it is the natural and engineering science degrees that appear to generate the strong impact on economic output, rather than degrees in general. This finding accords well with that of Hanushek and Kim (1995) on an international sample of countries, in which schooling in mathematics and science had a growth impact eight times the magnitude of general education. Thus the implication is that while education in general helps, it also matters what sort of training is being

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[50] See Table A3.3 of Appendix 3.
[51] See Table A3.4 of Appendix 3.
[52] A zero restriction on the human capital variables jointly is rejected at the 1% level. The Chi square statistic is 10.72 for 3 degrees of freedom. We also estimated the specification with only the school enrolment variables included in the estimation, and found the school enrolment rate on its own to be insignificant. Again, the implication is that the human capital variables appear to be significant only in concert.

undertaking. The growth payoff from training in science and engineering appears to exceed that of general training.

Table 5.5: Two alternative long run specifications. Figures in round parentheses are chi-squared statistics on the appropriate overidentifying restrictions on the cointegrating space for statistical significance. Figures in square parentheses are standardized coefficients. Figures in curly parentheses are standard errors. Significance is denoted by *.

	LNY	LNY
INVRAT	2.59*	0.23*
	(35.11)	(32.71)
	[0.22]	**[0.02]**
WENROL	-0.27	11.06*
	(.03)	(10.69)
	[-0.05]	**[1.96]**
LNBENROL	0.34	-3.14*
	(.36)	(7.02)
	[0.47]	**[-4.34]**
DEGREES	-0.00001	
	(.69)	
	[- 0.28]	
NSDEGREES		0.001*
		(.0004)
		[4.15]
ECM(-1)	-0.10	-0.05*
	{0.06}	{.02}
adj-R^2	.030	0.35

This finding also strengthens the conclusion we had already noted in the descriptive part of the human capital discussion on South Africa. The expenditure of large resources on developing a university system that emphasised quantity over quality, and at the same time neglected the research dimension, has been costly at least in growth terms. It has not been the general increase in degree output that has contributed significantly to South Africa's economic growth. Instead it has been the natural and engineering science degrees that have so contributed. As a consequence, the policy choice to develop a costly and for the most part frankly mediocre to poor widely-based university system has been foolhardy as a development strategy. It has meant that that part of the university system which has most actively contributed to knowledge-creation and economic growth, has gone into stasis, and has been increasingly hampered from contributing to South Africa's long run economic development. In short, the university sector has been hindered from making its full contribution to the creation of a learning society.

The second point carries much the same import as the preceding: that it matters where and how resources are deployed. At first sight the strong negative impact of the enrolment rate in black schooling seems utterly counterintuitive, and therefore deeply questionable. But this is so only at first sight. In the descriptive evidence we have presented above and in our discussion of the schooling production function for South Africa we have pointed out two fundamental insights with regard to South Africa's black schooling system.

First, we noted that the quality of inputs into black schooling over the 1910-93 period was far inferior to the inputs into white schooling. And our estimated production function showed us that the quality of inputs matter in determining the quality of output from schooling. In addition, the educational production function evidence showed that over and above the poor quality of inputs given to black schooling, the institutions governing black schooling in South Africa precluded the users of the black schooling system from ensuring that what resources were deployed to black schooling, were at least used productively. The consequence was that not only were poor inputs provided to black schooling, but such inputs were also frequently used inefficiently.

The consequence of this combination of factors is quite simply that while black enrolment rates rose sharply in South Africa, unfortunately this quantitative increase in schooling did not reflect a qualitative improvement in the schooling that was taking place – and through no fault of the black pupils using the schooling system. It is particularly instructive to see that just as the sharp increase in black enrolment rates is taking place as of the mid-1970's the black matriculation pass rate begins to decline sharply. Unfortunately South Africa's black population was being sluiced through an educational system that was simply not preparing them adequately for the future.

This provides us with a sensible interpretation of the evidence we are obtaining from our estimation. The implication of the results is not that rising enrolment of black pupils lowers long run output in South Africa *per se*. Rather, the implication is that a mere quantitative expansion of educational opportunities, which does not pay any attention to the quality of the education that is taking place, is not particularly helpful for purposes of generating output growth.

And it is not difficult to understand why this is so. Education is an expensive activity. South Africa, in expanding its educational system, now spends far more than comparable developing or middle income countries as a percentage of GDP on education – see **Table 5.6.** Yet educational achievements in South Africa on many international comparator test scores lie below those of the competitor nations. Thus we are spending much on education, without getting bang for our buck. And whatever is spent inefficiently on education, without generating much by way of quality output, will cease to be available for other uses –such as investment in physical capital stock, for instance.

Table 5.6: Public Expenditure on Education: % of GNP

Public Expenditure on Education: % of GNP	
	1997
Argentina	3.5
Botswana	8.6
Brazil	5.1
Chile	3.6
Hong Kong	2.9
India	3.2
Korea	3.7
Malaysia	4.9
Mexico	4.9
Singapore	3.0
South Africa	7.9
Thailand	4.8
Turkey	2.2
Uruguay	3.3

Really, this is the same point we advanced in interpreting the contribution of the NSDEGREES variable above. What matters is not so much throwing resources at the problem, or making sure that large numbers of students find themselves with paper qualifications. What matters crucially is the *quality* of the education that they receive – and how consonant such education is with the demands of employment in an information and knowledge intensive modern economy. In this our results confirm the finding of Hanushek and Kim (1995).

Our evidence thus tells us that human capital matters directly for growth. But it does so only if deployed wisely. Not all education and training delivers the same rate of return – and tertiary level science and engineering appears to offer particularly strong returns (see the standardized coefficient). But even for the generalized education offered by schooling quality matters. The South African legacy of apartheid, with its strong investment in the human capital of one part of its population, and the systematic under investment in the rest of its population, provides a useful if unfortunate natural experiment. Schooling matters, but the quality of the schooling offered matters even more.

At one level the evidence is thus reassuring. Investment in human capital offers a means of improving the growth performance of the South African economy in the long run. On the other hand, this is likely to be a long run impact, playing itself out over the next generations. And in the meantime we sit with the legacy of the apartheid developmental strategy which wilfully and systematically under invested in one of the central engines of long run growth: the human capital of its population. Given the *au contraire* behaviour of countries such as Singapore and Korea, it is little wonder that we have such a strong growth differential between South Africa and the Far East.

5.6 Conclusions

It has been a long haul through the human capital sections, and we will be brief in summary.

But the findings that have emerged from this chapter are of vital importance.

First, we have seen that human capital is found to have both a direct as well as an indirect impact on economic growth. Moreover, in identifying this impact we have to take account both the quantity and the quality of education that is offered. The impact of human capital creation in South Africa emerges when the full vertical integration of the human capital creation process is recognised.

While human capital creation has exercised a positive impact on South African growth, we also have to recognise the strong failings of the South African educational system. Both the schools and the tertiary educational sectors are subject to failure – though of different sorts. The one is cheap and nasty, the other expensive and nasty.

Given that R&D is crucial to long run growth, it is vital that South Africa identify at least a few institutions capable of generating the requisite research output and research scientists in sufficient numbers. It is time we took seriously the need to concentrate resources in producing excellence, rather than spreading them thinly in the pursuit of mediocrity.

Appendix 1: ARDL Cointegration Estimation

Hsiao (1997) lays the foundations for the use of conventional estimation techniques where the forcing variables are strictly exogenous, regardless of whether the variables are I(0) or I(1). Hsiao demonstrates that where forcing variables are strictly exogenous, conventional Wald statistics are asymptotically distributed (under the null of reduced rank cointegration). This allows for the restriction of the parameter space at the most general stage, economizing on degrees of freedom. Pesaran and Shin (1995b) advocate the use of autoregressive distributed lag models for the estimation of long run relations, suggesting that once the order of the ARDL has been established, estimation and identification can proceed by OLS. While the presence of a long run relationship between variables remains critical to valid estimation and inference, Pesaran and Shin (1995b) demonstrate that valid asymptotic inferences on short- and long-run parameters can be made under least squares estimates of an ARDL model, provided the order of the ARDL model is appropriately augmented to allow for contemporaneous correlations between the stochastic components of the data generating processes included in estimation. Hence ARDL estimation is applicable even where the explanatory variables are endogenous, and, since the existence of a long run relationship is independent of whether the explanatory variables are I(0) or I(1), ARDL remains valid irrespective of the order of integration of the explanatory variables. The ARDL methodology thus has the advantage of not requiring a precise identification of the order of integration of the underlying data. Pesaran (1997) provides a useful discussion.

The PSS approach begins by estimating the error correction model given by:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=1}^{k} \sum_{i=1}^{p} \gamma_{ji} \Delta x_{j,t-i} + \left(\delta_1 y_{t-1} + \sum_{j=1}^{k} \delta_{j+1} x_j \right) + u_t \qquad \text{A1}$$

and estimating by means of an F-test (henceforth referred to as PSS F-tests) the significance of a joint zero restriction on the δ's of the error correction model. The distribution of the F-test is non-standard, and critical values are provided by Pesaran, Shin and Smith (1996). The test is further subject to potential ambiguity, in the sense that the test has an upper and lower critical bound value. As long as the computed statistic exceeds the upper bound, the null of no association can be unambiguously rejected. Similarly, as long as the computed statistic falls below the lower bound, the null of no association cannot be rejected. However, where the test statistic falls between the upper and lower bounds, it is indeterminate.

What remains critical, is the need to establish the existence of a unique long run relationship (i.e. that the F-tests confirm only one of the variables included in estimation as an outcome variable, and that all other variables act as forcing variables), and that an appropriate order to the ARDL is selected. We follow Pesaran and Shin (1995b) in a two step strategy, selecting the ARDL orders on the basis of the Akaike Information criterion (AIC), then estimating the long and short run coefficients on the basis of the selected model. Estimation can be shown to be feasible on the basis of the "Bewley regression":

$$y_t = \varsigma + \eta t + \sum_{i=1}^{k} \theta_i x_i + \sum_{j=0}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{m=0}^{q-1} \delta_m \Delta x_{t-m} + u_t \qquad \text{A2}$$

by the instrumental variables method, where:
$1, t, \sum x, \sum \Delta y, \sum \Delta x$
serve as instruments.

The methodology presumes that the x and u are uncorrelated. Where they are correlated, the methodology remains valid, but the “Bewley regression” requires augmentation.

Appendix 2: The Johansen VECM methodology.

Johansen[53] techniques of estimation employ a vector error-correction (VECM) framework, for which in the case of a set of k variables, we may have cointegrating relationships denoted r, such that 0≤r≤k-1. This gives us a k-dimensional VAR:

$$z_t = A_1 z_{t-1} + \ldots + A_m z_{t-m} + \mu + \delta_t \qquad \text{A2.1}$$

where m denotes lag length, and δ a Gaussian error term. While in general z_t may contain I(0) elements, as long as non-stationary variables are present as in the present case, we are exclusively restricted to I(1) elements. Reparametrization provides the VECM specification:

$$\Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \qquad \text{A2.2}$$

The existence of r cointegrating relationships amounts to the hypothesis that:

$$H_1(r) : \Pi = \alpha\beta' \qquad \text{A2.3}$$

where Π is p x p, and α, β are p x r matrices of full rank. $H_1(r)$ is thus the hypothesis of reduced rank of Π. Where r>1, issues of identification arise.[54]

In our case the prior expectation is that r=1.

[53] See Johansen (1991) and Johansen and Juselius (1990).

[54] See Wickens (1996), Johansen and Juselius (1990, 1992), Pesaran and Shin (1995a, 1995b), Pesaran, Shin and Smith (1996).

Appendix 3: Detailed Estimation Results

Table A3.1: Key to Variable Names Employed

Variable	Definition
LNY	natural log of real per capita GDP
INVRAT	investment rate, I/Y
WENROL	white school enrolment rate
LNBENROL	natural log of black school enrolment rate
DEGREES	total number of degrees issued by SA universities
NSDEGREES	total number of natural and engineering science degrees issued by SA universities

Table A3.2: Augmented Dickey-Fuller Statistics.

Variable	I(0)	I(1)
LNY	-2.44	-4.85*
INVRAT	-1.52	-5.52*
WENROL	-0.22	-6.49*
LNBENROL	0.70	-3.82*
DEGREES	9.24	-4.32*[55]
NSDEGREES	3.92	-5.05

[55] Subject to a structural break in 1973-7.

Table A3.3: Maximal Eigenvalue and Trace Statistics for Number of Cointegrating Vectors

```
Cointegration with unrestricted intercepts and no trends in the VAR
   Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
 List of eigenvalues in descending order:
.69108     .42639     .36224     .27037   .0046981
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r = 1        50.5110           33.6400                31.0200
 r<= 1      r = 2        23.8996           27.4200                24.9900
 r<= 2      r = 3        19.3412           21.1200                19.0200
 r<= 3      r = 4        13.5544           14.8800                12.9800
 r<= 4      r = 5         .20250            8.0700                 6.5000
*******************************************************************************
       Cointegration with unrestricted intercepts and no trends in the VAR
          Cointegration LR Test Based on Trace of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
 List of eigenvalues in descending order:
.69108     .42639     .36224     .27037   .0046981
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r>= 1       107.5087           70.4900                66.2300
 r<= 1      r>= 2        56.9977           48.8800                45.7000
 r<= 2      r>= 3        33.0981           31.5400                28.7800
 r<= 3      r>= 4        13.7569           17.8600                15.7500
 r<= 4      r = 5         .20250            8.0700                 6.5000
*******************************************************************************
```

Table A3.4: Long Run Cointegrating Vector

```
ML estimates subject to exactly identifying restriction(s)
      Estimates of Restricted Cointegrating Relations (SE's in Brackets)
                         Converged after 2 iterations
      Cointegration with unrestricted intercepts and no trends in the VAR
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4, chosen r =1.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
*******************************************************************************
 List of imposed restriction(s) on cointegrating vectors:
 a1=1;
*******************************************************************************
                  Vector  1
 LNY                  1.0000
                  (   *NONE*)

 INVRAT              -.23023
                  (   1.6135)

 WENROL             -11.0642
                  (   6.3386)

 LNBENROL             3.1389
                  (   2.1522)

 NSDEGREES         -.6180E-3
                  ( .4207E-3)

*******************************************************************************
 LL subject to exactly identifying restrictions= 276.3930
*******************************************************************************
```

Table A3.5: Maximal Eigenvalue and Trace Statistics for Number of Cointegrating Vectors

Cointegration with unrestricted intercepts and no trends in the VAR
Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix

43 observations from 1950 to 1992. Order of VAR = 4.

List of variables inc[1] We adjust the purchasing power of output for the price level that is maintained in different economies. $1 buys much more housing in Johannesburg than it does in London and this should be reflected in the 'value' of measured output. PPP measures undertake such an adjustment.

luded in the cointegrating vector:

LNY INVRAT WENROL LNBENROL DEGREES

List of eigenvalues in descending order:

.66798 .48830 .37702 .35390 .016143

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r = 1	47.4095	33.6400	31.0200
r<= 1	r = 2	28.8110	27.4200	24.9900
r<= 2	r = 3	20.3492	21.1200	19.0200
r<= 3	r = 4	18.7827	14.8800	12.9800
r<= 4	r = 5	.69980	8.0700	6.5000

Cointegration with unrestricted intercepts and no trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix

43 observations from 1950 to 1992. Order of VAR = 4.
List of variables included in the cointegrating vector:

LNY INVRAT WENROL LNBENROL DEGREES

List of eigenvalues in descending order:

.66798 .48830 .37702 .35390 .016143

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r>= 1	116.0521	70.4900	66.2300
r<= 1	r>= 2	68.6426	48.8800	45.7000
r<= 2	r>= 3	39.8317	31.5400	28.7800
r<= 3	r>= 4	19.4825	17.8600	15.7500
r<= 4	r = 5	.69980	8.0700	6.5000

Table A3.6: Long Run Cointegrating Vector

ML estimates subject to exactly identifying restriction(s)
Estimates of Restricted Cointegrating Relations (SE's in Brackets)
Converged after 2 iterations
Cointegration with unrestricted intercepts and no trends in the VAR

43 observations from 1950 to 1992. Order of VAR = 4, chosen r =1.
List of variables included in the cointegrating vector:

LNY INVRAT WENROL LNBENROL DEGREES

List of imposed restriction(s) on cointegrating vectors:
a1=1

	Vector 1
LNY	1.0000
	(*NONE*)
INVRAT	-2.5920
	(.42198)
WENROL	.27065
	(1.5891)
LNBENROL	-.33942
	(.47602)
DEGREES	.1096E-4
	(.1036E-4)

LL subject to exactly identifying restrictions= 231.7999

Chapter 5

Revisiting the Role of Human Capital

5.0 Introduction

We have now seen that technological advance matters for long run economic growth, and explored the channels that economists see as those responsible for the transmission of technological progress to improvements in output produced. We have also seen that “new” or endogenous growth processes are finding empirical confirmation not only internationally, but for South Africa also.

In the process of exploring the role of technology we have repeatedly made reference to the role and impact of human capital. Indeed technological progress is frequently though not exclusively associated with the focused application of human inventiveness, often in formal institutionalised contexts of explorations such as the laboratory.

This may well be so, but this then raises the question of how the contribution of human capital to the process of technological innovation is to be properly understood. How, why, and when does it make a difference to innovation? What forms of human capital are the appropriate ones? And does human capital contribute to growth only indirectly through technological progress, or does it have an independent and direct impact on growth also?

It is to these and related questions that we now turn.

5.1 The significance of having a learning society

When confronted with what is meant by the concept of human capital it is difficult to understand why the concept would *not* be thought of as central to the process of economic growth and development more broadly defined. In its broadest sense human capital is understood to embrace at least three separate and distinct components.[1]

The first is perhaps the most obvious. It refers to the *pure skills* obtained by economic agents, encompassing the education they have been exposed to, the scientific knowledge they have acquired and can dispose over, as well as skills acquired on-the-job. Thus it identifies the improved productive capacity of economic agents that results from education and training of all the different forms that they may encounter either in educational institutions or in the work place.

In the Schumpeterian tradition, e*ntrepreneurial capacity* forms a second form of human capital. This is not captured by formally taught sets of skills, but by the willingness to countenance risk in productive activity, to explore and create opportunity where previously there was none, and thereby to create new areas of economic activity.

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[1] See for instance Theodore Schultz (1993) in his Nobel-prize winning work.

Finally, the *stock of accumulated knowledge* is also seen as crucial to fully understanding the accumulated stock of productive capacity a society has at its disposal. Since individual human beings are finite (they die), the threat is that the stock of knowledge accumulated by individuals over a lifetime comes to pass with their passing also. Efficiency therefore dictates that human capital (in whatever form) not only comes to be created, but comes to be transmitted to the next generation of economic agents at as low a cost as possible. Accumulating a stock of knowledge, and the means of transmitting it are vital if the full benefits from the resource represented by human capital are to be fully realised.

It is difficult to imagine that the three components of human capital should not matter to long run economic development. And indeed even that they should matter well beyond the impact they have on the process of technological innovation narrowly defined. The efficiency gains they promise are on production of final output directly, as well as on the improved capacity of society to improve the process of knowledge accumulation.

In a sweeping review of "all" of human economic development Landes (1998) places perhaps his very strongest emphasis on the role and impact of knowledge creation and accumulation as the key to long run success in economic development.[2] This and the importance of a work ethic. Landes' discussion is impressive for its sweep, and the richness of the historical evidence that he advances in his cause. In the course of accumulating the historical track record from many different societies and epochs around the world, Landes details a number of factors related to the contribution of human capital as critical to long run developmental success during the course of his exposition:

- Having access to stocks of knowledge, particularly as regards technology of production. Knowing how to operate, manage and build, and then to modify and further design the machines and techniques by which we produce is crucial to the continued health of the process of production.
- Having the institutional means of transmitting knowledge between generations.
- Assigning people to tasks on unambiguous basis of merit and competence, rewarding good and imposing penalties for poor performance are essential to healthy incentive mechanisms.
- Creating opportunity for individual and collective entrepreneurship.
- Allowing people to keep and employ as they see fit the outcome of their enterprise – in short, having secure property rights.

Most intriguingly of all perhaps, such enabling characteristics have institutional requirements. Secure property rights to encourage savings and investment, and the facility of enforcing such rights. Secure personal and civil rights, to prevent the arbitrary exercise of power by either public or private instances. Stable government with consistent rules of conduct, responsive to complaint and the need for redress, honest and devoid of corruption, and which limits its claims on the social surplus, so

[2] See the more extensive discussion in Fedderke (1999).

as to enable investors to allocate scarce resources to projects with the highest rate of return.[3]

Importantly, different nations have possessed such characteristics at different points in time, and flourished as a result. Britain had them in greater measure than her competitors for much of the 18'th and 19'th centuries. Ming China had them with spectacularly successful results. Consider just one telling example: the greatest European explorers, the Portuguese, undertook their voyages of discovery in the caravel. An example of such a caravel, Columbus's *Santa Maria* measured 85 feet in length. At approximately the same time (the first half of the 15'th century) the Chinese mounted their own voyages of discovery in the Indonesian archipelago. The voyages were undertaken with fleets, the first (in 1405 under admiral Zheng He) used 317 vessels and 28000 men, the biggest ships were 400 feet long, 160 wide, with 9 masts, included dedicated horse ships to transport the animals, supply ships, even dedicated water tankers. Compare this with Vasco da Gama's 4 ships, and 170 crew of which only 54 survived the trip. Astonishing Chinese achievements, and well ahead of the Europeans of the time. Yet the sting in the tail of the moral is that China squandered its advantage. China turned inward (they appeared to have nothing to learn from barbarians), the voyages of discovery were abandoned, prohibited. Of course, a fierce internal court struggle preceded the decision. Yet the fact remains, in 1477 the vice-president of the Ministry of War hid or destroyed all records of the voyages of discovery, by 1500 anyone building a ship of more than two masts was subject to the death penalty, in 1525 all ocean-going ships were destroyed and their owners arrested, in 1551 to go to sea in a multimasted ship even for trade was criminalized.

All were critical mistakes because China forfeited the opportunity to learn, to acquire additional resources and information from other civilisations, no matter how much less advanced than they were themselves. As a consequence by 1500 Portuguese vessels entering the East, while perhaps smaller than their Chinese predecessors, came in greater and greater numbers and above all with now far superior technology of killing. Naval cannon using gunpowder (a Chinese invention) were unanswerable. The culmination of this pattern of development lay in the humiliation of the opium wars for China.

The interest of the anecdotes and examples lies in the systematic lessons that emerge. The success of the Portuguese voyages of discovery, and the gradual decline of the Chinese are not accidents of history. The Portuguese had invested long, systematically, and far-sightedly in the ability to improve their navigational skills and other technology of seafaring. Above all they had developed systematic learning strategies which ensured the updating and development of their technologies of discovery. And they went in the search of the new, of additional wealth, to bring back yet more information and knowledge, to gain additional competitive advantage against their European rivals. The Chinese by contrast went to fly the flag, to impress and have homage paid to them. Such expensive luxuries are not conducive to further development, and above all they inhibit learning.

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[3] In Fedderke, De Kadt and Luiz (1999b) we show on the basis of a time series statistical study of the South African experience that at least some of these factors were important to long term investment in the capital stock of the South African economy. Fedderke and Liu (1998) makes the same point for international capital flows to South Africa.

The difference lies in what we term the institutionalised learning capacity of the two civilisations. For the Portuguese high, for the Chinese low despite their impressive achievements. Europe was able to develop and extend an ever greater competitive lead over rivals, with the attendant capacity to exercise military force precisely because they institutionalised learning, curiosity, acquisition of information and understanding of the world about them, regardless of their relative levels and degrees of development. In this regard a number of factors become critical.

First is the *autonomy of intellectual enquiry*. In Europe, the authority of the church came to be challenged by secular authority (the state), by religious dissent (the Reformation), by the increased independence of institutions of learning from religious authority. The importance of Galileo lies not so much in the substance of his claims (they had been made before, within the ambit of the church), but in the nature of the claim to validity of his hypotheses.[4] Science, empirical evidence alone, vetted by peer review were to be the arbiters, not the institutional demands of the church, and its judgement as to the appropriateness of the claim to a larger telos. Truth alone was to count. The result was a more unfettered accumulation of knowledge, of technology, and hence of the ability to exercise power, both economic and military.

The *method* of learning and enquiry also became central to the institutionalised capacity to learn. Emphasis after the Renaissance in Europe came to be placed increasingly on seeing and explanation, of simplification as a means to deal with the complex, and on mathematics as a means of organising knowledge. Observation, precise description, replication, verification not only served to undermine authority, it led to the process of experimentation, the embrace of controversy, debate and an exchange of ideas and argument as a means to settle differences. All had the positive consequence of accelerating the advance of knowledge.

Third, learning was *routinized.* A common language of learning (Latin) facilitated the exchange of information. Improved communication helped the spread of knowledge. The discovery of the printing press proved to be the lubricant of information exchange on an unprecedented scale. Frequent meetings of learned societies, the development of periodical journals, allowed for the exchange of ideas, helped cooperation between researchers. Rivalry for honour and peer recognition spurred on individual researchers.

Lastly, but critically, *systematised means of storing, recovering, cross-referencing knowledge* allowed learning to follow Newton's example of using the shoulders of others to stand on.[5] Reinventing wheels is a costly inhibitor to progress; improving the

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[4] In fact, Giordano Bruno came closer to our present thinking about the structure of the universe than either Galileo or Copernicus (infinite space, billions of stars with orbiting planets - sun and earth among them - atomic structure of matter, etc.) and earlier than either. He was burnt at the stake for his trouble.

[5] Consider the contrast: "China lacked institutions for finding and learning - schools, academies, learned societies, challenges and competitions. The sense of give-and-take, of standing on the shoulders of giants, of progress - all of these were weak or absent. Here was another paradox. On the one hand, the Chinese formally worshipped their intellectual ancestors; in 1734, an imperial decree required court physicians to make ritual sacrifices to their departed predecessors. On the other, they let the findings of each new generation slip into oblivion, to be recovered later, perhaps, by antiquarian and archaeological research. The history of Chinese advances, then, is one of points of light, separated in space and time, unlinked by

means by which information is disseminated from commonly recognised stocks allows research resources to be focussed on the advance of knowledge, rather than on the remembrance of things already past.

Adoption of such institutions is a necessary (though not sufficient) condition for success. The example of the Iberian Peninsula illustrates this amply. Leaders of the European exploratory enterprise in the 15'th and 16'th century, the resultant glut of wealth was correlated with a waning of the questing spirit, a shift of centres of manufacturing elsewhere (Northern Europe),[6] and above all the institutionalised process of learning shifted decisively to the North. Before the Reformation, Spain, Portugal, Italy were the centres of learning not least because of the contact their geographical position offered to Islamic civilisation. With the Reformation things changed. Interdictions followed from 1521 against publishing and reading heresy. In 1558 the death penalty was introduced for the importation of officially unapproved foreign books and for unlicensed printing. Universities were placed under strict control in terms of what could be taught, and books required official approval. Scientific books were banned in Spain simply because their authors were Protestant. Study abroad by Spaniards was forbidden except at approved centres,[7] such that attendance at the University of Montpellier for medical training slowed from 248 students between 1510-59, to 12 from 1560-99. The consequence: the Iberians missed the scientific revolution, and ultimately lost out in the development race, while Northern Europe overtook in technological and productive capacity.

The Weberian work ethic also played its role not only in generating the commitment to accumulation. Far more significant was that the rupture of the authority of the church *generalised* the competitive advantage afforded by the ethic:

> The heart of the matter lay indeed in the making of a new kind of man - rational, ordered, diligent, productive. These virtues, while not new, were hardly commonplace. Protestantism *generalized them among its adherents, who judged one another by conformity to these standards*. (Landes 1998:177 - my emphasis)

Stress was placed on literacy (for girls as well as boys since everybody had to be able to read the Bible), with the result that a larger population pool was available for advanced schooling, with learning capacity and transmission growing appropriately.[8]

The advantage the Iberian peninsula had once enjoyed over China and other competitors was lost - and ironically for much the same reason that China lost out to the latecomers in the East. Closure of societies is fatal for purposes of long-term development, and openness combined with an institutionalisation of acquiring knowledge crucial if societies are to maintain competitive advantage.

Institutionalised learning, openness to the new, curiosity, are critical to long term success. But the process itself must be open and subject to evolution and revision. The learning process must itself be subject to learning. Britain led the world through the 18th and 19th centuries, in significant part because of its ability to innovate and its

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replication and testing....Much of the vocabulary was invented for the occasion and fell swiftly into disuse" (Landes, 1998: 343).

[6] It became easier to buy the output of others than to manufacture it oneself.

[7] Rome, Bologna, Naples.

[8] Literate mothers are also likely to matter in the reproduction of the learning impulse.

learning capacity. Yet its institutions became increasingly obsolete over the course of the 19'th century, and came to be overtaken by continental rivals (Germany). Invention, training, learning were decentralised and relatively haphazard in Britain. Over time the larger, better funded, systematised research institutions provided by German and ultimately American universities were simply better at both producing and transmitting knowledge suited to the industrial revolutions and finally information revolution.

All of these considerations emanate from a very long view of the process of economic development. And they point to the importance of what has already been termed a "learning society", with an institutionalised capacity to be open to the new, to absorb it and turn it to its own advantage. Human capital surely serves as one of the central enabling mechanisms of such institutionalised learning capacity. But it is perhaps useful to begin with an overview of what of required in the very long run, all the better to make sense of the detail work that is also required.

It is useful to have a sense of the very long run pay-offs that attach to human capital creation before we move on to questions of more detail. Creating human capital takes a great deal of time. The endowment of such capital that a society has will therefore take considerable time to change also. The true impact of human capital therefore is perhaps only evident in the very largest sweep of things – that which concerned Landes in his study. This does not preclude the detail work, and indeed it is with this that our discussion now continues.

5.2 A direct impact of human capital on economic growth?

We move now to consider the more detailed different mechanisms by which human capital may come to exercise an influence on the growth rate of an economy. Our starting point is the question of whether there exists any evidence to suggest that there may be a straightforward direct impact that runs immediately from human capital to growth in output.[9]

Certainly there is evidence to suggest that the question at least is plausible. In **Figure 5.1** we plot the average growth rate in per capita GDP of a sample of 118 countries in the world over the 1960-85 period, against the primary school enrolment rate in 1960.

What emerges from the evidence is a clear and strong positive association between the growth performance of countries and their human capital endowment at the beginning of the period. The greater the human capital endowment at the start of the period, the greater the likelihood that countries will have grown faster subsequently. The question being posed on the possible impact of human capital on growth is clearly plausible. The issue we confront is how and why human capital may come to exercise its influence.

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[9] On the presumption that human capital also exercises an indirect effect via technology.

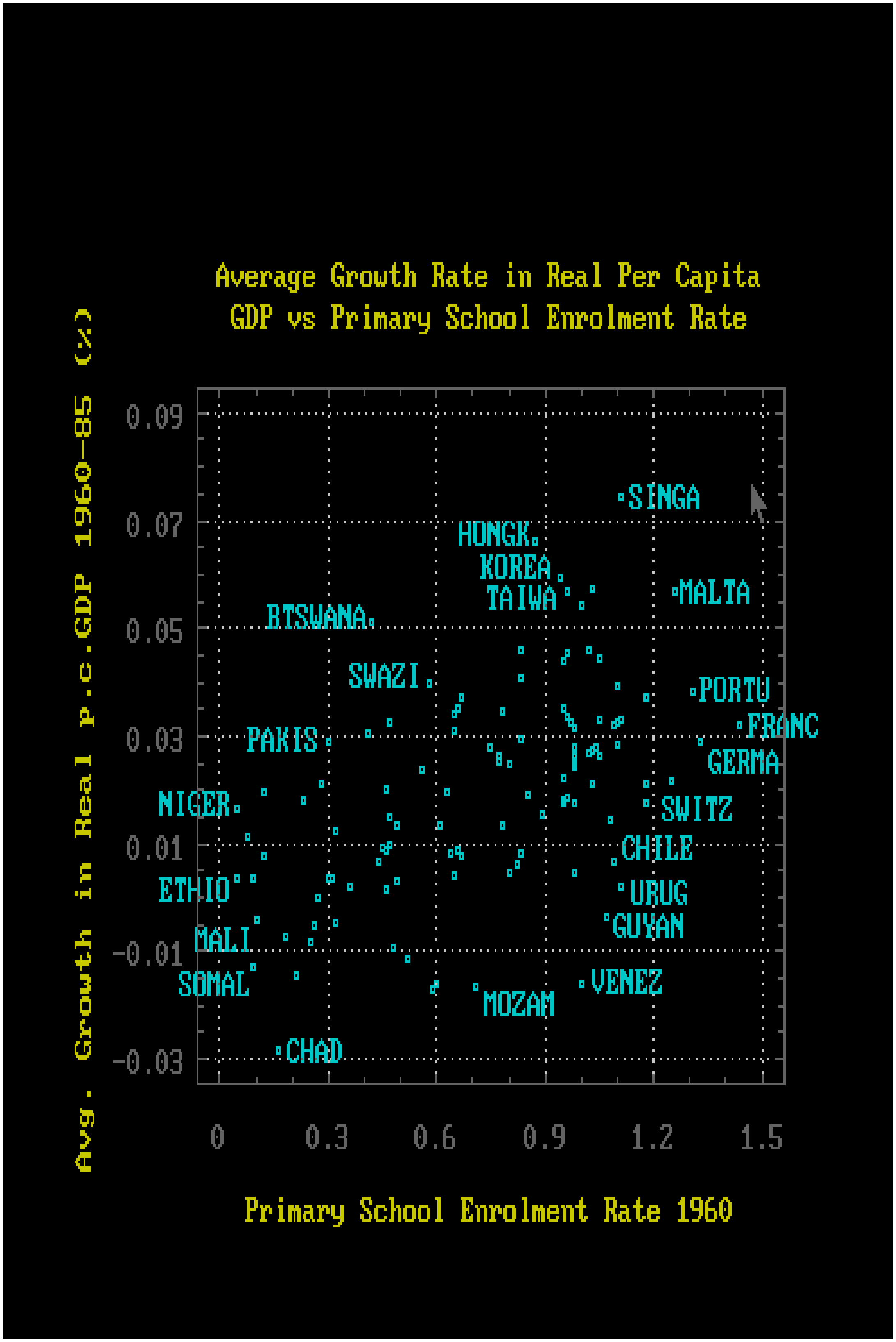

Figure 5.1: Plot of average growth in real per capita GDP, 1960-85, against primary school enrolment rate in 1960.

In the endogenous growth models encountered in Chapter 3 the introduction of technological change had the effect of generating increasing returns to scale, such that the growth process became such that the economy does not move to steady state, but instead experiences unbounded growth. In the case of the Romer (1990) model unbounded growth is the result of the role human capital plays, in particular in terms of adding to the physical capital stock through the research sector of the economy through innovation.

But the introduction of human capital need not have unbounded growth as a consequence. On the contrary, human capital can be successfully introduced into a traditional growth model of the economy,[10] maintaining the salient features of a neo-classical growth model, particularly convergence to steady state. Mankiw, Weil and Romer (1992) suggest that the introduction of human capital into a Solow model is justifiable, indeed desirable, since in excess of 50% of the capital stock of the USA in 1969 took the form of human rather than physical capital stock. Moreover, they argue that the introduction of human capital into the Solow model successfully enhances its explanatory power to such a degree as to preclude the necessity of resorting to endogenous growth models of either the Romer (1986) or (1990) variants.

In making this argument they suggest that all that is required is the introduction of human capital as an additional factor of production over and above physical capital and labour inputs. This renders the production function augmented to:

$$Y = F(K, L, H) \tag{1}$$

where Y denotes output, K capital, L labour and H human capital. The presumption is that marginal returns in all factors are positive but declining in the factor of production.

The implication is therefore that output can grow not only because of an augmentation of the physical capital stock, or the labour force available for production, or indeed because of improvements in the technology of production. Output can rise also since the human capital the economy has to dispose of has increased. Mankiw, Weil and Romer (1992) are concerned with the question of whether this proposition finds any empirical support.

In order to address the question they estimate two alternative equations. For the traditional Solow model they consider the impact of only growth in capital and growth in the labour force. In the modified Solow framework concern is with the question of whether growth in human capital stocks adds anything to our understanding of the growth process. Thus for the traditional Solow model they consider:

$$\ln\left(\frac{Y}{L}\right) = \alpha_1 \ln(s) - \alpha_2(g_L) \tag{2}$$

[10] Since these models have their genesis in the work of Robert Solow (see 1956 and 1957), they are also often referred to as Solow Models.

where Y/L denotes per capita output, s the savings rate S/Y, g_L the proportional growth rate of the labour force, and the α_i are two coefficients. This is contrasted with the modified Solow model:

$$\ln\left(\frac{Y}{L}\right) = \beta_1 \ln(s) + \beta_2 \ln(h) - \beta_3 \ln(g_L) \tag{3}$$

where all terms are defined as before, and h denotes the per capita stock of human capital, while the β_i are three coefficients.

The question they pose concerns the extent of the improvement in explanatory power as we move from equation (2) to equation (3).

Mankiw et al (1992) provide estimates of equation (2) for three samples of countries. The first is a sample of 98 non-oil producing countries, from which oil producers are excluded since oil entails virtually no value added in production, and the relatively high returns to the natural resource distorts the per capita income of oil producers.[11] The 98 country sample still contains a number of "small" countries, with populations of less than 1 million. Mankiw et al therefore define a second sample, excluding all countries with populations with less than 1 million inhabitants, and countries for which data quality is poor. As a third sample they separated out 22 OECD members with populations greater than 1 million inhabitants. Estimations were obtained from regressions of the log of per capita GDP in 1985, on average investment rates and labour force growth rates over the 1960-85 period. Their results are reproduced in columns 1 through 3 of **Table 5.1**.[12]

Table 5.1: The Impact of Human Capital on Output Growth. Figures in round parentheses are standard errors. Statistical significance is denoted by *.

Dependent Variable: lnGDP per working person in 1985						
	1	2	3	4	5	6
	Non-Oil n=98	Inter-mediate n=75	OECD n=22	Non-Oil n=98	Inter-mediate n=75	OECD n=22
Constant	5.48* (1.59)	5.36* (1.55)	7.97* (2.48)	6.89* (1.17)	7.81* (1.19)	8.63* (2.19)
ln(I/GDP)	1.42* (0.14)	1.31* (0.17)	0.50 (0.43)	0.69* (0.13)	0.70* (0.15)	0.28 (0.39)
$\ln g_L$	-1.97* (0.56)	-2.01* (0.53)	-0.76 (0.84)	-1.73* (0.41)	-1.50* (0.40)	-1.07 (0.75)
lnSchool				0.66* (0.07)	0.73* (0.10)	0.76* (0.29)
adj-R^2	0.59	0.59	0.01	0.78	0.77	0.24
s.e.e.	0.69	0.61	0.38	0.51	0.45	0.33

Source: Mankiw, Weil and Romer (1992).

[11] Readers should note that this incorporates essentially the entire rest of the world.
[12] For additional deliberation and extension of these results see also Andrēs, Domēnech and Molinas (1996).

The results have a number of significant features:

- Both the savings rate and labour force growth rate coefficients are of the correct sign,[13] and are statistically significant in two of the three samples, though for the OECD country sample both coefficients are insignificant.[14]

- Except for the OECD countries, differences in the savings rates, and labour force growth rates account for a large proportion (approximately 60%, on the basis of R^2 statistics) of cross country variation of end of sample period per capita GDP, and hence of the growth rate of output over time. The implication is that differences in the technology of production are not required in order to account for variations in income between countries.

The net implication for Mankiw et al is that the Solow model does not stand in need of substantial modification. The explanatory power of the model is good, and all the variables do the work that is expected of them. Yet the results are not entirely satisfactory either. First, the coefficients on the savings rate and labour force growth rate are potentially simply too high. The implication for the 75 intermediate country sample, for instance, is that a 1% increase in the savings rate, would result in a greater than 1% increase in end-of period per capita GDP. A 1% decrease in the labour force growth rate, would increase end of period output by more than 2%.

Second, the two explanatory variables account for virtually none of the cross-country variation in per capita income amongst OECD countries. This might be due to a high degree of homogeneity between countries, but does rouse at least some suspicion as to the validity of the results. Lastly, in all three samples the constant is large and significant. In a Solow-type of model, the constant would capture the augmented labour productivity gain across the estimation period. The implication is that the role of technology may be much more important in accounting cross country variation in income than Mankiw et al allow for. If so, the need for an endogenous explanation of technological change remains pertinent, and endogenous growth theory remains important.

Mankiw et al (1992) estimate equation (3) by regressing the log of per capita GDP in 1985, on average investment rates and labour force growth rates over the 1960-85 period as before, but adding the average percentage of the working-age population in secondary school for the 1960-85 period (ln School). We report the results in columns 4 through 6 of **Table 5.1**, and note that:

- The physical capital savings rate, the human capital endowment, and the labour force growth rate coefficients continue to have the correct signs throughout, and are statistically significant in the two large(r) samples. By contrast, only the human capital variable is significant for the OECD sample of countries.

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[13] Since the dependent variable is per capita output, ln(Y/L), an increase in the labour force would lower output per worker.

[14] A possible reason for this insignificance might be that the savings rates and labour force growth rates of OECD countries do not differ significantly enough to account for differences in the growth performance of OECD countries, and hence would not explain the final per capita GDP of the OECD countries.

- Differences in the physical capital savings rate, the human capital endowment, and the labour force growth rate now account for approximately 80% of the cross-country variation in per-capita income in the two large samples. For the OECD countries, differences in human capital alone account for approximately 20% of cross-country variation in per capita income - indeed the R^2 statistic shows a dramatic improvement over that of the Solow-model.

- The coefficients are now no longer of an order of magnitude which casts doubt on their validity. Returns in terms of per capita income in response to a percentage increase in each of the determining variables is now less than proportional, in contrast to the simple unmodified Solow-model case.

The implication drawn from these results by Mankiw et al is that the human capital augmented Solow-model, despite its simplicity, accounts for a significant proportion of cross-country variation in per capita output. They argue that the strength of the empirical evidence has to be accepted as forceful evidence in favour of the model, on their account – and that recourse to endogenous growth theory, given all the complexity it often introduces, may simply not be necessary.

Three doubts remain, however. First is the continued poor performance of the model for OECD countries. The obvious question has to be why this sub-grouping of countries falls outside the scope of the explanatory power of the model, while the growth performance of a strong majority of countries in the world is adequately accounted for by means of the Solow model. Does this point to the existence of a "stages of growth" phenomenon, such that different factors are important for growth at different levels of per capita GDP (given that OECD countries are at the upper end of the scale of per capita GDP)? If so, what are these stages, why do they exist, and which determining variables are significant at the various distinct stages of economic growth?

The constant term continues to play a very significant role in all three samples. As previously indicated, in Solow models this generally points to the presence of strong labour or capital augmenting technological change. The implication is thus as before that technological change may account for a significant proportion of the growth performance of countries. Again, therefore, the role of endogenous growth models that explicitly account for the growth in technology cannot be discounted.

It thus seems valid to continue to search for additional determinants of growth performance. And perhaps to allow the impact of human capital to be varied, exercising its influence both in the direct manner identified by the Mankiw et al, as well as the more indirect effects identified by endogenous growth theory.

Nevertheless, what the evidence of the present section has served to show is that there is certainly strong evidence that favours the existence of an immediate, direct effect of changes in human capital stocks on the growth rate in real per capita GDP, as *well* as the indirect effect suggested by endogenous growth theory.

5.3 Further extensions: back to endogenous growth and some additional lessons

It is worthwhile briefly to revisit contributions we might expect from human capital to economic growth through the endogenous growth framework. Partly this is in order to remind ourselves of the differences between it and the proposal put forward by Mankiw et al., but also in order to add some nuance to our understanding of the impact of human capital on growth within the endogenous growth framework.

Remember that in the Romer (1986) spill-over type of endogenous growth model human capital creation is really the *consequence* of the positive externality that is associated with the act of investment in physical capital stock. While learning-by-doing is the vehicle by which the learning effects that are attached to the act of investment in physical capital stock are transmitted amongst firms, the origin of the human capital remains rooted in physical investment. That was why the policy prescription that emerged from this approach to understanding technological progress was to recommend subsidies on physical capital, in order to counteract the fact that the social marginal rate of return lay above the private marginal rate of return to physical investment.

But in a further (though independent) extension of the spill-over approach to endogenous growth, Lucas (1988) proposed a production function for output that captures very similar ideas to those proposed by Romer, but capable of generating some important additional nuance. The production function suggested by Lucas can be represented by:

$$Y = AK^{\beta}\left[uhL\right]^{1-\beta} h_A^{\gamma} \tag{4}$$

where Y denotes output, A the state of technology, K capital, L labour, where the actual labour time at the disposal of the economy is now adjusted for the level of human capital it embodies, h, as well as the proportion of time u it devotes to the production of current output. While production is constant returns to scale,[15] the possibility of increasing returns (as in the Romer model) is introduced through the impact of the generally available human capital, h_A, to the economy. Indeed the increasing returns are present as long as the γ parameter is positive.

However two further implications make this model particularly interesting for our purposes. First, Lucas suggested that human capital growth in an economy could be represented by:

$$v = h\delta\left[1 - u\right] \tag{5}$$

where v represents the growth rate, δ the research success coefficient, and [1-u] represents the portion of time the existing stock of human capital is allocated to the creation of additional human capital rather than being employed in the production of final output. The story is really the same that we encountered in the theories of Karl Shell and of Romer (1990), that of the perfect university process, but with the explicit

[15] Note that $\beta+(1-\beta)=1$.

recognition that human capital can be either employed in the creation of final output, as well as in the creation of new human capital. The growth process comes to depend on the contribution of human capital to knowledge creation.

The reason why this formulation turns out to be interesting is that one can show that the final growth rate of the economy will be determined by v, the rate of growth of human capital creation. Moreover, the growth will turn out to be unbounded, even in the absence of increasing returns to scale. The result is analogous to the unbounded growth due to technological progress in traditional theories of economic growth, but now with an explicit recognition of the motor force behind this growth in the process of human capital formation.

The second reason for our interest is that where we also have increasing returns to scale in production ($\gamma>0$), the implication is that the usual consequence of economic theory, that the rate of return to factors of production will be highest where they are scarcest, will be reversed. Instead, the implication is that the rate of return to human capital will prove to be the highest where it is most abundant. In the presence of labour mobility, the implication is that labour well endowed with human capital will migrate to centres already intensive in human capital, simply because the rewards for doing so are large.

If this is the case for developing countries, the policy implications are profound. For it implies that if you are behind in the human capital accumulation stakes, you are likely to remain forever behind. Countries ahead of you in the growth race will steadily out-accelerate you. But worse, if you as a developing country try to rectify matters by improving investment in human capital, such human capital is simply likely to emigrate away to greener pastures. Already wealthy countries will stand to benefit from the hard investment undertaken by the poor country – and accelerate away even more rapidly thanks to the poor country's efforts.[16] The situation for poor countries is doubly perverse. They are poor because poorly endowed with human capital. But the policy intervention designed to ratify the situation, of saving in order to be able to invest in education, merely serves to benefit the already rich, enabling them to accelerate their growth yet further.

Thus if human capital maters to growth, and if increasing returns to human capital are indeed present, poor countries face the tough task of having to keep the environment for skilled people at home even more attractive than otherwise would have been the case. Policy intervention must be conscious of the need to improve the incentive for human capital to stay, rather than leave. Since the evidence we presented above on the South African manufacturing sector suggests that such increasing returns due to the generally available human capital may indeed be present in the South African economy, this is a policy implication that is particularly important in the South African instance.

[16] On this view therefore openness of the economy may allow human capital to migrate away from developing to developed countries. Openness under this view carries serious dangers for developing countries. However, without ameliorating the danger for human capital accumulation, Barro and Sala-i-Martin (1995) demonstrate that greater openness may bring advantages to both technology innovating and imitating countries.

Since South Africa has been losing some of its best human capital over a long period of time now, we devote a specific case study, entitled "The Parable of the Sage", to some general reflections on just how costly this has proved. We reflect further on the fact that it was often the unsympathetic stance of the political and policy environment that accelerated the exodus. But to keep matters in perspective, we also add an additional case study on India, in a box entitled "India: Awakening Information Technology Giant", to illustrate that the brain drain phenomenon need not be entirely crippling. It can be reversed in the presence of the right sorts of policies and incentives to human capital, even in very poor countries such as India.

So the theory thus far has come to imply that increasing returns to scale in human capital may lead to perverse *international* allocation of human capital. But this unfortunate *international* allocation of human capital may well be exacerbated by further counterproductive *intranational* human capital allocation. Recall that the Romer (1990) conception of the interaction between growth and technology also generates a low income level trap. In this model we have a sector dedicated to the creation of knowledge, with human capital used in order to produce final output. The difficulty for developing countries is that at low levels of human capital accumulation, there may simply not be the critical mass of human capital to generate sufficient returns from the pursuit of new knowledge. As a consequence human capital will come to migrate to final goods production rather than new knowledge production, simply because the return there are higher. The consequence is that more developed nations, with their ability to create new knowledge will come to forge ever further ahead of developing nations.

Thus developing nations are potentially caught in *two* vicious cycles that result from the impact of human capital on long run economic performance. The one results in an unfavourable international allocation of human capital away from developing nations to developed nations. And the other ensures that what human capital remains in developing nations may not be allocated to where it has the most dramatic long term impact.

Either way policy makers face demanding challenges in ensuring that incentives in developing economies are such as to ensure that human capital not only remains at home, but that if it so remains, that it is most productively employed.

Two final points are worthy of emphasis in the context of endogenous growth theory and its view of human capital. *First*, if the increasing returns emphasised during the course of our discussion do indeed attach to the human capital dimension, then the implication is not only that human capital should be core to any developmental strategy. This much we have already emphasised. It also implies that potentially significant indivisibilities attach to the impact of human capital on long run growth. If returns to human capital are increasing, the return to ever higher levels of education and training should be increasing also. Again on the proviso that the increasing returns are indeed present, policy should then pay attention to its human capital creation strategy as a totality. It is no longer simply a question of sorting out primary and secondary education. Tertiary education should ideally become part and parcel of the most basic developmental human capital creation programme.

Thus the implication is that if countries concentrate only on a "partial" human capital creation strategy, the pay-off may be considerably less dramatic than if a more holistic approach is adopted. Indeed, in the limit there may be very small, perhaps even negative returns to human capital in a partial human capital creating approach, since critical mass levels of human capital are not breached.

But the second point is equally instructive. Given the presence of the two perverse traps pointed to above, care must be taken in interpreting evidence on human capital formation and its impact on economic growth. A negative association would in fact *not* serve to prove the absence of a positive impact of human capital creation on economic growth. Instead, it may simply be pointing to the presence of one or both of the two traps we have identified. That creation of human capital represents a drain of resources on poor countries, with benefits that migrate to developed nations.

The Parable of the Sage or: Keeping the Best - a Story of five Sirs and One Mathematical Genius

by Raphael de Kadt

There lived long ago, in a faraway place, a wise man. Some years back we might have called him a "thinker" or "philosopher", recalling the original meaning of the term "philosophy" – the love of wisdom, the "good and the true". Many of his compatriots thought him odd, even somewhat demented. Many were fearful of his intellect, of his effortless superiority in argument. The powerful and influential among them were especially discomfited by his uncanny knack of casting doubt on the legitimacy both of their actions and of their offices. Deep down, they feared the power of his mind, his boundless curiosity and his love of virtue. For this man often saw things in strange and unusual ways. The King, who like so many monarchs was not noted for his sharpness of mind, was disturbed by the oracular pronouncements of this sage. Even more bothered were the King's counsellors. Craven and sycophantic, as are most beneficiaries of patronage, they conspired to make the circumstances of his life uncomfortable. Subtly, and then not so subtly, they denied him the means to pursue his studies and engage in reflection. His ability to communicate his insights and his wisdom were constrained. The tools he needed to pursue his scientific enquiries were ever more difficult to get hold of. For a while he endured the deprivations and continued with his quests. But the counsellors became increasingly vengeful. Deprivation turned to harassment. Being good, but also shrewd, our sage left the land of his birth, never to return. He wandered far and wide on foot, meeting with many experiences – some dangerous and unpleasant, others enchanting. He passed through forests and deserts, through temperate grasslands and tropical jungles. Then one day he chanced upon another traveller who invited him to accompany him on his return to his own land. There, in the land of the stranger, he was bought to the court of the Regent. This Regent and his advisors were of a quite different kind. Democratically elected and accountable to their people, they were open to diversity of opinion and supportive of the life of the mind. They valued curiosity and saw virtue in dissidence. Immediately they recognised the genius of the itinerant sage. They provided him with the wherewithal to practice his scholarly craft, listened to him with attention and bestowed honours upon him. The recognition brought its own rewards. Emboldened, the sage went on to achieve ever-greater things. He was, in due course, himself elected an advisor to the Regent. The scribes began to chronicle his accomplishments in ever-larger tomes, for his contributions to his adoptive land had, indeed, been impressive. Its civilisation had flourished even more under his influence. Its science and technology became the envy of the whole world, its people prospered as no people had ever done before. They lived longer and healthier lives with marvellous amenities and magical potions to ease their aches. Within the lifetime of the exiled sage, and under his guidance, they journeyed the moon and made wonderful machines to do all their calculations.
What a lucky people they were – and so wise they were to give sanctuary to the refugee from the land of the foolish King and his paranoid courtiers.

This parable may be somewhat forced and contrived, but in it can be seen the elements of a not uncommon modern story: the story of the migration of talent from less hospitable to more hospitable places. In the very broadest terms, it is the story of the virtues of "open societies" and the vices of "closed societies". It is the story, in particular, of the loss to many modern dictatorships and authoritarian regimes of their most gifted and capacious minds; and the story, too, of the beneficiaries of these migrations. It is the story of Fascism and of Pogroms in Europe, and of the triumphs American science and technology and of the American economy. Sadly it is, too, the story of South Africa during the long, dark night of Apartheid. For South Africa lost, during the second half of the twentieth century, some of its most genuinely creative and powerful intellects. Migration, of course, is a feature of all historical epochs, and the reasons for it are many and do no always involve political repression and persecution. People leave the land of heir birth for adventure, for the pursuit of romance or to explore distant climes and cultures. Sometimes they return, sometimes not. There are, however, particular patterns of migration that should be a special cause for concern among those charged with governing a country whose economy desperately needs to grow. Commonly, this pattern is termed "the brain drain". South Africa has long suffered from it.

Of especial concern has been the story of the emigration of people of quite exceptional talent, the kinds of people who perhaps correspond to the figure of the “sage” in our parable. Just as Hitler facilitated the acquisition by the United States of people such as Einstein, Fermi, von Neumann and Harsanyi, to name just a few, so circumstances in South Africa facilitated the acquisition by Britain and the United States of far too many of its top drawer scientists. The names of Sir Raymond Hoffenberg, Sir Solly (later Lord) Zuckerman, Sir Basil Schonland and Sir Aaron Klug come to mind. So too does that of the great mathematician Seymour Papert, developer of the Logo programming language, co-founder of the MIT’s famous Artificial Intelligence laboratory and a major driving force behind the computer revolution. Whether the political climate had any direct bearing on the decisions of Klug, Zuckerman or Schonland to re-locate to the United Kingdom is difficult to establish. It certainly did, however, in the cases of Hoffenberg and, probably, Papert. Hoffenberg, – regarded by many as the outstanding South African medical scientist of his generation, and who was later to become President of the Royal College of Physicians, had a banning order served on him by the National Party government. This severely interfered with his work. As Professor Peter Folb of the Department of Pharmacology at the University of Cape recently observed, not only was Sir Raymond harassed by the security police, but – much as our parable might suggest – he received scant support from the medical profession as a whole. And, as in the parable, it was only in the United Kingdom that he was to be appropriately honoured and recognised for his scientific talent. It might be that, in the case of Aaron Klug who was later to win the Nobel Prize in Chemistry and – following in Lord Zuckerman’s footsteps – to become President of the Royal Society, the “logic” of a career in “big science” was the overwhelming factor. It might be that in his case, as in the cases of the post Second World War careers of Zuckerman and Schonland, South Africa simply did not offer the opportunities, resources and support requisite to scientific careers at that level. The fact of the matter, however, is that all these talents were lost to South Africa.

This story of this loss invites a study in contrast. The figure in this study is that of Sir Mark Oliphant, the great Australian physicist. The story of Sir Mark is appropriate because he, too, is of the same rank as Hoffenberg, Klug, Schonland, Zuckerman and Papert. His, however, is a story of a “prophet” who does not go without honour in his native land. Sir Mark, who during he Cold War came to be labelled a “peacenik”, was one of that remarkable group of physicists based in America who helped to make the atomic bomb. While Professor of Physics at the University of Birmingham, his laboratory developed the magnetron, which was crucial to the improvement of radar. Sir Mark, who died this year, was the subject of an obituary in the *Economist* of July 22nd. The obituary, which is the principal source of the information in this box, points out that, after his return to Australia, he founded the Research School of Physical Sciences at the Australian National University in Canberra and helped to establish the Australian Academy of Sciences. Both institutions, the obituary observes, are now world-class. After he retired from science, he was appointed in 1971 as governor of South Australia. His term of office is widely regarded as remarkable for its enlightened character and for his stances on the environment and racism. His death elicited extraordinarily wide and admiring coverage in the Australian media. Knighted in 1959, he was able to make contributions to the scientific, technological and cultural life of his homeland in a measure equal to his talents. This, sadly, was not the fate of Sir Raymond Hoffenberg. To return to our parable: he was honoured in “the land of the stranger”. What contributions, one is prompted to ask, were lost to South Africa though the exodus of so much extraordinary talent? And how, in future, might South Africa succeed in retaining a larger share of its finest intellects? What incentives, what facilities and what rewards are needed? How do we learn to honour those whom we so desperately need to keep?

India: Awakening Information Technology Giant

by John Luiz

Source: Adapted from Akshay Joshi. Information Technology – Advantage India. www.idsa-india.org

India, after having missed the industrial revolution, is on the threshold of the information revolution due to a combination of factors, some global and some of her own doing. India concentrated on developing skilled scientific manpower by opening government-funded 'centres of excellence' and public sector industries. The urge for self-sufficiency and the encouragement for research fuelled the scientific temper of this nation. Till the late 1980s, there was a steady growth in the Indian IT industry accompanied by a brain drain to the West. In 1988, an autonomous organisation called the National Association for Software and Services Companies (NASSCOM) was formed and it started working closely with the Indian government for the development of the IT sector.

1991 saw the opening up of the Indian economy. In 1991-92 a World Bank funded study by the Department of Electronics (DOE) in India visualised a $ 1 billion a year potential for software exports from India by the year 2000. This was the first benchmarking exercise carried out by India. It achieved the target of $1 billion a year well ahead of time. Since 1991, the Indian software industry has grown at over 50 percent every year and will be a $5.7 billion industry in 1999-2000. Due to the 'offshore software development revolution' in the 1990s, almost 273 of the 'Fortune 1000' companies are outsourcing their software requirements to India. The market capitalisation of Indian software shares stood at $27.3 billion in December 1999. In 1998, the BJP government formed the Prime Minister's (PMs) IT Task Force in which eminent people from the government, industry, defence forces and the research community were taken. This task force appreciated that the challenge was to develop an information infrastructure in India which constitutes addressing problems like the cost of the personal computer (PC), the cost of connectivity and IT literacy. The report has suggested a new IT organisational structure in the government, like appointing an advisor to the PM on the lines of the set up in the US, setting up a separate IT division in the Planning Commission and forming a high level committee at the centre and state levels constituting several task forces on the lines of the National Computer Board in Singapore. The report calls for setting up 'tool rooms' throughout the country for the purpose of offering a wide range of services like design and development, training, consultancy, software-housing and the like. The report aims at making India a $100 billion player in the IT world.

1999 also saw the approval for the National Telecom Policy (NTP-1999), formation of the IT Ministry and the passage of the IT Bill – all steps in a positive direction. The second benchmarking exercise in India was initiated by the government when NASSCOM commissioned McKinsey and Company, the pre-eminent management consulting firm, to help develop a vision and strategy to capture the opportunities thrown up by the digital revolution and generate rapid growth for India's IT industry and, thereby its economy. The report predicts that India has the potential to become a global superpower in the knowledge economy. Some of the key findings of this report are that by the year 2008:

- Software and Services will contribute over 7.5 per cent of the overall Gross Domestic Product (GDP) growth of India.
- Exports in the IT sector will account for 35 per cent of the total exports from India.
- There are a potential 2.2 million jobs in IT by 2008.
- The overall revenues from the IT sector will be nearly $90 billion including $50 billion in exports, and the minimum market capitalisation of IT shares will be $225 billion.

According to this report, technology, economy and market drivers are reshaping the global information technology landscape which offer Indian and India-centric companies unique opportunities in four broad areas: value-added IT services, software products, IT-enabled services and e-business.

Why does Information Technology suit India? Information Technology by its very nature needs and breeds democracy, freedom and democratic institutions. India is the largest and most vibrant democracy which encourages the free flow of information and ideas. English, which is fast becoming the international business language, thanks to the Internet, is used extensively in India. India also has a well educated human resource pool who have a good grounding in mathematics. Add to this the confidence of successful young entrepreneurs, who are now in decision-making positions all over the world. The brain drain which took place since independence is now changing to a reverse brain drain, with successful IT savvy Indians pouring money and resources into India. These whiz kids are also networking with each other to ensure success to more people. Many successful entrepreneurs are now returning to India to exploit the opportunities in this market. Indian Institutes of Technology (IITs), were recently categorised as among the world's pre-eminent technical finishing schools. Today there are more than 20000 Indian millionaires in the Silicon Valley. Most of them started off with little more than an engineering degree.

Another major global paradigm shift, which is benefiting India, is the falling costs and importance of hardware and the increasing costs of software. Today hardware costs only 10 percent while the software component costs 90 percent of the computer system. Since hardware is losing importance, countries like Korea are losing market share in the IT industry, while countries like India are benefiting because of software. Countries like India, which have a strong intellectual and human capital in the field of software stand to benefit by the increasing importance of software in the information technology industry.

An important ingredient of India's IT strategy in the 21st century will be to "Anchor Indian IT MNCs" abroad, that is, encourage top Indian IT companies to become global MNCs. In Europe, Nokia is worth almost 2 per cent of Finland's GDP. Sweden is called the 'Silicon Valley of Mobile Phones' because of Ericsson, while SAP has played an `Anchor MNC' role for Germany. Silicon Valley in the USA serves as a regional development model which has an economic leverage of its own in the world. Companies like Hewlett Packard (HP) and Cisco played a critical anchor role in the Silicon Valley. All these MNCs encouraged innovation within their country and created a global brand equity for their products.

5.4 Some international evidence on the impact of human capital on economic growth

The impact of human capital has by now been extensively researched. Our discussion here cannot hope to cover all of the studies that have been published. However, we do hope to point out some of the most important findings that have emerged from the literature.

The first piece of international evidence has already been addressed in the section dealing with the approach advocated by Mankiw, Weil and Romer (1992). Inclusion of human capital variables has by now become standard in cross country growth regressions. Given the wealth of such studies now available in the literature, we cannot hope to cover all of the evidence that has now accumulated. Instead we focus on just a few studies that prove instructive in their findings. We present some of the central papers together with their findings in Table 5.2.

The central points to emerge from the empirical studies can be summarised as follows:

1. Human capital variables generally are found to be positively related to long run growth performance of countries.
2. This positive relation is not found to be robust, in either cross sectional or panel data contexts.
3. This may well be due to the “webs of association” that exist between educational and other economic and social indicators, rendering human capital coefficients subject to potential spuriosity.
4. Quality may be more important than the quantity of education.
5. Time series evidence in favour of endogenous growth theory is mixed. Controlling for different types of innovative activity and structural breaks is likely to be crucial.
6. The international human capital migration predicted by Lucas finds confirmation.
7. The potential for domestic misallocation of human capital finds some support.
8. Microeconomic evidence from Africa also reports both internal and external productivity improvements from education.

Finally, we supplement to econometric and statistical evidence on he impact of human capital on growth with a number of case studies. In a box entitled “Small Countries, Big Achievements” we detail some of the qualitative lessons that emerge from considering case study evidence from a number of success story countries: Ireland, Finland and New Zealand. Again, it appears as if the process of human capital investment carries positive benefits for long run economic growth, though on occasion the pay-off to such investment is a long time in materialising.

Table 5.2: Summary results from central studies with a bearing on the impact of human capital on long run economic growth.

Study	Findings
Barro (1991)	The seminal cross country growth regression paper. The sample includes a maximum of 118 countries – though the study also considers subsamples along the lines of Mankiw et al. Both primary and secondary school enrolment rates are found to consistently have a positive impact on growth in real per capita GDP.[17]
Levine and Renelt (1992)	The seminal paper testing for the robustness of cross country growth regressions. The sample is the same as that employed by Barro (1991). Again both primary and secondary school enrolment rates are found to be positively associated with economic growth. However, the finding is not robust, in the sense that both human capital variables are found to be statistically insignificant for some specifications.[18]
Fedderke and Klitgaard (1998)	The paper again reports results for the Barro-type cross country growth regressions, and again on the same sample. Both primary and secondary school enrolment rates are employed in estimation. While the paper reports a positive impact of human capital on growth, it points to a possible reason for the Levine & Renelt lack of robustness finding. Numerous and strong statistical associations between human capital and other economic and social indicators of development are identified. Inclusion of human capital variables in growth equations may thus lead to spurious results.
Hanushek and Kim (1995)	The paper controls for both the quantity and the quality of human capital. Results establish that improvements in cognitive skills as measured by maths & science attainments translates into far stronger and more robust impacts on growth than average years of schooling. See Table 8 of the paper.
McDonald and Roberts (1997)	One extension amongst many of testing growth equations in a panel data context. Findings on the human capital variables is mixed, confirming the lack of robustness findings of Levine & Renelt on panel data.
Jones (1995)	One of very few time series studies in growth theory. Data is for the OECD. The test is not for a direct impact of human capital on output growth, but a test for an impact of various R&D and human capital indicators on TFP growth. The empirical findings reject the endogenous growth proposition of increasing technological innovation with rising R&D and human capital indicators.

[17] Many other papers have since followed in these footsteps.
[18] Again, a number of other studies have since reported similar lack of robustness.

Crafts (1996)	A cliometric approach to the impact of human capital on long run growth. Thus comes to add perspectives from economic history, and extends the time series approach. Finds confirmation of endogenous growth theory in various OECD countries. However, the study points to the importance of considering measures of innovation-enabling mechanisms beyond the standard ones mostly used in growth models: such as R&D expenditure and scientists. Also identifies the significance and importance of structural breaks in time series modelling of technological innovation.
Dolado, Goria & Ichino (1993)	Examine the impact of immigrants to 23 OECD countries on ECD country growth rates. Establishes that the human capital endowment of immigrants from less developed nations is close to that of OECD natives. See Table 5 of the paper. Confirms that the human capital content of immigrants has a positive impact on receptor country growth. Thus confirms the international human capital migration hypothesis of Lucas (1988).
Bigsten et al (1998)	Examines the rates of return on human and physical capital in a panel of 5 African countries. Rate of return on physical capital in a production function context exceeds the rate of return on human capital in a ratio of 4:1. Potential confirmation of the Romer (1990) point that low human capital endowments may lead to low rates of return on human capital.
Weir (1999)	Application of human capital theory to microeconomic context. Examines the effects of education on farming productivity in Ethiopia. Reports substantial internal (private) benefits of schooling for farmer productivity in the form of efficiency gains. Subject to a threshold effect however (at 4 years of schooling). Also reports substantial external (spill-over) benefits from schooling. There are increases in farm productivity if school enrolments in rural areas increase.

Small Countries, Big Achievements.

by Raphael de Kadt

In 1999, The Irish Council for Science, Technology and Innovation (ICSTI), with the assistance of the National Council for Curriculum and Assessment (NCCA) published a benchmarking study of school science, technology and mathematics (STM) education in Ireland against Scotland, Finland, Malaysia and New Zealand.

The five countries "were identified as open, knowledge-based societies, generally on the periphery of major trading areas". The study was informed by the recognition that "in order to meet economic and social challenges, there is an increasing need for the citizens of these countries to create and use new and existing knowledge, much of which will be *scientific and technologically based*". (Emphasis added) It is important to note that in the decade 1991-2000, all the societies benchmarked achieved solid real per capita growth rates. This is especially significant given that some of them (Ireland, Scotland, Finland and New Zealand) were growing off relatively high GDP bases. Especially notable for our purposes has been the extraordinary performance of the Irish and Finnish economies in terms both of economic growth performance and the creative embrace of product innovation and entrepreneurial flair. Both Ireland and Finland have, in their distinctive ways, become major global players in the domain of the so-called "new economy".

Ireland

The Irish case is remarkable in a number of respects. First, apart from a relatively poor real GDP growth rate in 1991 of 1.9% (it's real GNP growth for that year was 2.5%), for the remainder of the decade its real GDP growth rate was 3.3% , 2.6%, 5.8%, 9.5%, 7.7%, 10.75, 8.9%, 6.7% and 6.4% respectively (Source: *IMF World Economic Outlook, May 1999*). This growth took place against a background of steadily declining unemployment levels (from 14.7% in 1991 to 6.2 % in 2000) and low rates of inflation (ranging from a high of 3.2% to a low of 1.4%) One distinctive feature of the Irish economy is that, along with Malaysia, it is one of the most open in the world. Its total openness, covering both exports and imports was estimated for 1997 at 148% of GNP. (*IMF Financial Statistics Yearbook, 1998*) This trade openness increased to 165% in 1998, placing Ireland second in the OECD behind Luxembourg. (*Benchmarking STME in Ireland Against International Good Practice, p 57)* In addition to trade openness, factors that the study identified as having had a significant effect are a "significant amount of FDI", a "well-educated, relatively cost-competitive workforce", fiscal prudence and a national wage-agreement process. Especially notable is that, notwithstanding the fact that Ireland's small economy accounted for only 0.3% of the world weight, it received the fifth largest amount of US direct investment abroad in 1997(*OECD Survey, Ireland May 1999* cited in *BSTM p 55)* The rate of return for US FDI in Ireland is "almost double that of Europe or the world average".(p55)

In terms of sectoral trade, Ireland along with the other benchmarked countries experienced a move from traditional sector dependency to dependency "on more high-tech, high-value-added, capital-intensive sectors" (p58) This could only have occurred in consequence of appropriate human capital formation policies. However, the Irish authorities are themselves concerned that Ireland has depended too much on the importation of both capital and technologies from abroad and that is has not yet developed a sufficiently vital endogenous capacity to innovate.

Finland

Reference to Finland nowadays conjures up an image of a cell-phone economy associated with the successful brand name “Nokia”. Notwithstanding the buffeting it received in the aftermath of the disintegration of its erstwhile state-socialist neighbour, the Soviet Union, the Finnish economy rebounded impressively through the course of the 1990’s. Again, what is notable about the Finnish success story is that it coincides with a **substantial increase in investment in education at university and polytechnic level**. Especially notable are a) the substantial size of the investment in R&D in the universities and b) the general increase in expenditure on polytechnic and university education. The R&D expenditure in universities amounted to one fifth of the total R &D expenditure in Finland. Further, R&D expenditure in Finland, in 1997, was 2.8% of its GDP – which was higher than the average for the OECD. From 1985 to 1997, the proportion of GDP spent on R&D in Finland rose steadily as did the proportions of R&D expenditure by both universities and business. (Source:*Statistics Finland*) So the importance of the public financing of R&D, and its synergistic connection with private sector vitality and innovations, appears also to be borne out in the case of Finland.

There are several general properties of the Finnish educational system that warrant special mention. The first is the high level of spending on education as a whole. Finland, by OECD standards, spends a high percentage of its GDP on education (6.6%in 1995- *Source: Education at a Glance, OECD Indicators,1998, cited in Education in Finland, Statistics Finland*). Second, notable is the breadth of education in Finland conjoined, as it is, with a specific pattern of prioritisation.

Three more specific features seem to invite special mention. First, at the tertiary level, Finland - as we have already noted - has chosen to invest heavily in the development of polytechnics. The total number of students enrolled in polytechnics has increased from 148 at the time of their foundation in 1991/2 to 82,211 in 1998/1999. That is an increase of over 5,500%! First year enrolments have increased from148 to 29,337 or almost 200 times. This compares with respective increases in university student enrolments over the same period from 112,921 to 142,962 and 15,329 to 7,985. Thus the increase in polytechnic enrolments has substantially outstripped that in university enrolments. However, judging by the increases in university expenditure, the growth in university R&D activity and the increase in the number of students earning higher qualifications, a *prima facie* case can be made that the **quality** of university education has improved.

Second, there is an interesting pattern in terms of field of study at the tertiary level. The biggest field of study in 1997/8 was engineering followed by the humanities, the natural sciences, the social sciences and economics and the educational sciences in that order. Bringing up the rear were, in descending order of enrolments, veterinary medicine, theatre and dance and fine arts. This suggests a higher educational system characterised by both breadth and balance and, by extension, a population characterised by educational breadth. The high rank enjoyed by Finland in “innovation” and “creativity” ratings may well be connected with this breadth. This balance and breadth seems, in some measure, to correlate with the evolution of a system with a significant degree of functional differentiation among types of institution.

Third, a feature of the education system as a whole is the emphasis that is placed on the acquisition of foreign languages – especially English. This phenomenon is not uncommon in the case of small countries with large neighbours and trading partners who speak different languages. The Netherlands is a famous case in point and its deliberate cultivation of multilingualism has almost certainly brought commercial benefits. In the case of Finland, pupils at the lower secondary level read at least two foreign languages. Depending on mother tongue, one of English, Finnish or Swedish is a compulsory second language. The other is elective. Leaving aside Finnish and Swedish, the most popular second language is English (93% of pupils) followed by German, French and Russian. Other languages are also taught. This practice has undoubtedly contributed to the openness of the economy and to the effectiveness with which Finns have been able to enter the highly competitive global telecommunications and electronics markets.

In conclusion, a few summary points may be made about the Finnish education system.

- Through the 1990's Finland's rate of expenditure on Education increased at least as much as, and usually more than the increase in the rate of growth of GDP. (*Statistics Finland*)
- There are nine years of compulsory schooling for children aged 7-16
- Learning at least two foreign languages is compulsory
- Expenditure on education, as a percentage of GDP, is high by OECD standards
- There has been a substantial growth in expenditure on universities and polytechnics
- 50% of Finns who are now 20 years of age can expect to earn a degree
- Participation in university education is higher in Finland than in other EU states
- Finland has twenty universities for its population of five million people.
- Mathematics education is compulsory at post-primary level for all pupils from ages 13 through to 15/16

New Zealand

New Zealand, along with the other benchmark countries, has evolved into one of the most open and lightly regulated economies in the OECD. Except for 1991 and 1998 (the year of the Asian economic crisis), it has experienced positive economic growth rates, coming off a relatively low base in the early 1990's to reach highs of 5.1%, 6% and 4.0% in 1993, 1994 and 1995 respectively. By 2000, is real GDP growth rate had rebounded to a respectable 3.3%. The basic trend of it unemployment rate has been downwards as has the broad trend of its inflation rate.

One aspect of the educational practices in the countries in the benchmarking study is that teachers from all subject areas tend to be treated the same in terms of incentives. In only two of the countries – Malaysia and New Zealand – are dedicated incentives to attract and retain STM teachers used. New Zealand offers a scholarship of US$5,000.00 to people with academic qualifications to teach mathematics, physics and technology. Its immigration policy also favours teachers of science, mathematics and technology from other countries (p30).

General Features of the Education Systems of the three Benchmarked Countries

- Incentives are used/advocated to reward good teaching and to recruit and retain well-qualified people in the teaching profession. These range from good pay to awards such as the Malaysian "Master Teacher" awards. (Although Malaysia is not one of our three countries, it is included in both the Irish benchmarking study and in the OEC *Education at a Glance* data).
- It is acknowledged that steps have to be taken to improve the attractiveness of teaching as a career, not least in the field of STM teaching. However, in only two systems out of the five – and those are the two in which teachers are least well paid in general – are special incentives offered to STM teachers.
- In all the systems, and especially in Ireland, teachers are well paid at all levels in the educational system. In 1996, the pay of Irish teachers after 15 years experience ranged from US$ 35,061 to US$ 37,154. This was second only to Germany with an equivalent range of US$35,885- US$41,081. This, when converted into Rands, is the kind of attractive pay that private sector accountants, some IT specialists or financial analysts might expect to earn in South Africa.
- In the OECD countries in1996, the number of teaching hours per year ranged from a low of 629 (parts of the Greek system) to a high of 964 hours in the lower secondary sector in the United States. The Irish system posted a relatively high figure for 1996. The OECD mean for 1996 at primary level was 791 hours; the Irish primary figure was 915 hours. All countries show a decline in the number of teaching hours as one progresses upwards through the system from primary to upper-secondary.*(Source: Education at a Glance: OECD Indicators 1998)*

- It would seem that, by comparison with the United States, our three “small countries” get good value from money spent on education when measured on an expenditure per pupil basis in US dollar terms This is especially so for Ireland.
- All the OECD countries listed in the 1998 *Education at a Glance: OECD Indicators* report had low pupil : teacher ratios in all parts of their education system. These ranged from an Irish high of 22.6 in the primary school system to a Finnish low of 12.4 at the lower secondary level. (The Greek “all secondary figure for 1996, the year under consideration, was 11.3).
- The amount of study time in our three selected countries (as well as for the OECD more generally) spent on mathematics and science education ranged from between less than one third to more than one fifth.
- All three of the selected small countries can now be regarded as “well educated” if measured by the ratio of upper-secondary graduates to the population at the typical age of graduation. The percentages for 1996, in descending order, are: Finland, 98%, New Zealand 93% and Ireland 79%.
- All three countries combine breadth of education with a commitment to improving the quality of education in STM.
- Pupils in Ireland and New Zealand performed close to the international average in both the 1995 TIMSS Mathematics and Science assessments, both at the fourth and eighth grade levels. Finland did not take part in the study.

5.5 The South African evidence

We have seen that theoretically human capital creation should make a difference to economic growth. In addition international empirical evidence on balance confirms this prior theoretical expectation.

In this section we now face two questions.

The first concerns the legacy of South Africa's human capital creation. Just how good has it been – or perhaps more appropriately, just how bad?

The second question then concerns the issue of whether the nature of South Africa's human capital creation has been such as to influence its growth path, for better or for worse.

5.5.1 South Africa's legacy of human capital creation

Needless to say the issue of South Africa's legacy of human capital creation is a vexed one. It was one of the principal vehicles through which the policy of apartheid significantly skewed the opportunities facing its citizens, and thereby seriously damaged the long term developmental capacity of the economy. It is here perhaps more than anywhere else in the present study that the legacy of apartheid is not only evident historically, but continues to exercise its influence to the present day.

Human capital creation can be viewed in a number of distinct dimensions. In the theoretical discussion of human capital above we have already seen that we can distinguish at least between the pure skills, the entrepreneurial and the knowledge stock dimensions of human capital. And the pure skills dimension itself can be further broken down into educational and vocational subcomponents. In the discussion that follows we focus on the educational system in South Africa, and its performance. This is not to say that the other dimensions of human capital are less significant. The focus is merely determined by data availability considerations.

The discussion that follows draws substantially on earlier published findings on the South African educational system.[19] In the earlier work we addressed the performance both of South Africa's schooling system, as well as various components of its tertiary educational system. In the discussion that follows we simply highlight some of the more salient features that emerge from the data.

5.5.1.1 A characterization of the performance of South Africa's schooling system

That all is not well with South Africa's schooling system is not news. The performance or lack of it in various parts of the schooling system forms the focus of much anecdotal evidence, and debate surrounding the issue intensifies annually on publication of matriculation pass rates.

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[19] See Fedderke, De Kadt and Luiz (2000a,b).

But it is possible to be precise about the nature of the schooling system's performance.[20] In **Figure 5.2** we report the matriculation pass rates in the South African schooling system, distinguishing between "white" and "black" matriculation pass rates.[21]

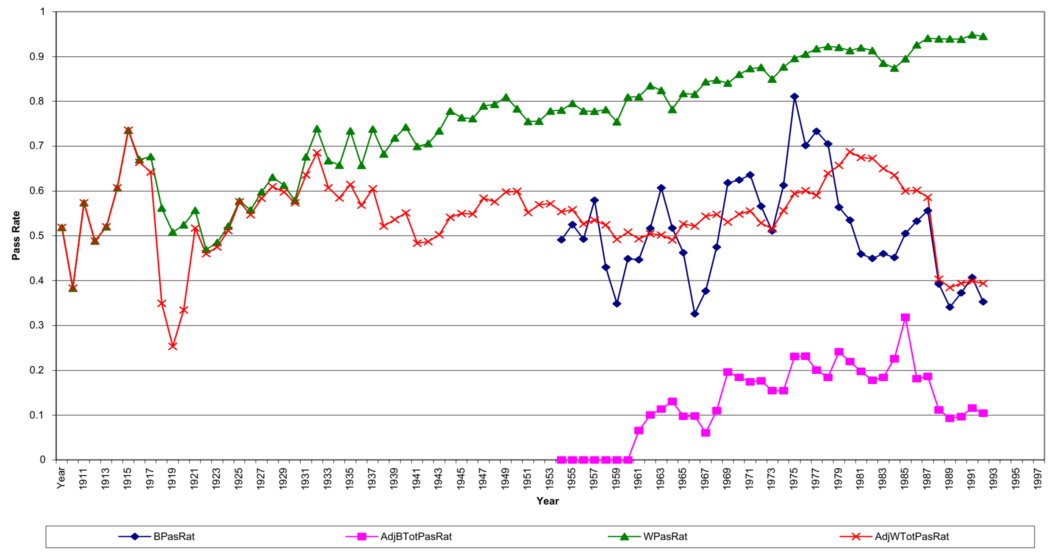

Figure 5.2: Matric Pass Rates. Source: Fedderke, De Kadt and Luiz (2000a).

While the white matriculation pass rate (**WPasRat**) shows an unambiguous trend improvement over the entire 1911-93 sample period, for black matriculation the evidence is far more mixed. While black pass rates (**BPasRat**) increase from 1955 through to 1976, they then decline steadily through 1993. In the period for which we have separate figures for both black and white pass rates (1963 - 1993), with the singular exception of 1976 when the black matriculation pass rate approaches the white, the black rate consistently falls below the white rate by a very considerable degree. During this period the white pass rate stays within the 75% -95% range, while the black pass rate - with few exceptions - falls below 60%. The difference, in the worst years for black education, lies in the region of 60 percentage points.

A further distinguishing feature of the two pass rates is that the black pass rate fluctuates wildly. By contrast, the white pass rate fluctuates in an almost equivalently wild fashion only during the very early period of political and societal consolidation after Union (1910 -1923).[22]

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[20] For a fuller discussion of these results see Fedderke, De Kadt and Luiz (2000a).

[21] For purposes of precision and consistency we have followed the classificatory conventions deployed by the South African authorities during both the pre-Apartheid and Apartheid periods. We consider it important to record the information under these contrived rubrics since the system of racial estates and statutory race classification had profound implications for the administration of educational matters and for the distribution of educational resources and opportunities. Hence the use of the racial classificatory conventions employed under apartheid.

[22] The distinction becomes evident from a comparison of the standard deviation which attaches to the percentage change in matriculation pass rates for whites and blacks: 8.85 and 16.57 respectively.

The black schooling system thus not only produced pass rates which prove to lie considerably below those of the white system, but the black system also appears to have been far more prone to either a series of shocks, or did not serve as a consistent screening mechanism - or both. Either reason for the fluctuations in pass rates is likely to have proved damaging for any positive incentive mechanisms present for black pupils - lowering the likelihood that what human capital accumulation was on offer to pupils in the black schooling system would be absorbed.

Raw matriculation pass rates form a legitimate standard of comparison of the alternative schooling systems only if the two examination standards are comparable. Anecdotal evidence if nothing else makes this assertion questionable. We therefore weight the matriculation pass rates of white and blacks by the proportion of total matriculation candidates sitting mathematics (in either higher or standard grade).[23] In **Figure 5.3** we report the results as **AdjWTotPasRat** and **AdjBTotPasRat** for white and black candidates respectively. The implication of weighting the pass rates is that the divergence between the measures of white and black schooling system output is further exacerbated. At no point in time does the weighted black pass rate approach the weighted white pass rates – with the minimum differential at approximately 30 percentage points.

The weighted pass rates for whites further suggests that the improvement in the white schooling system has been considerably less dramatic than implied by the unweighted rate. Indeed, while there is some improvement in the weighted pass rate post-1975, the 1930-75 period does not manifest any consistent trend. Moreover, weighted black pass rates also manifest somewhat different trend patterns from the unweighted series. The improvement in weighted pass rates runs through the late 1980's, declining thereafter to the end of the sample period. Thus the decline sets in a decade later than implied by the unweighted pass rates.

The maths-weighted matriculation pass rates further prove to manifest considerably higher volatility for both whites and blacks. In the case of blacks the standard deviation of the percentage change of the pass rate increases from 16.57 to 30.37, while for whites the increase is from 8.85 to 13.09.

In terms of weighted pass rates even the best schooling system in South Africa is thus subject to severe quality constraints. Indeed, a consideration of the proportion of black and white pupils taking mathematics in either higher or standard grade reinforces the point. For whites the proportion of total matriculation candidates sitting mathematics has been in steady decline since the 1930's - accelerating during the course of the 1980's, to reach a low of 40% of all white matriculation candidates - see **Figure 5.3**. By contrast the proportion of black candidates writing maths rose until the late 1980's,

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[23] We choose mathematics for the following reasons: mathematics has as clearly identifiable objective performance standards as any subject available to matriculation candidates. Application of subjective standards of assessments are therefore minimized. Moreover, we consider mathematics to be foundational to a wide range of cognitive activities and vocational skills. Lastly, mathematics (and science) was used as the central indicator of the quality of the educational system in the Hanushek and Kim (1995) growth study - and proved a more significant predictor of long run economic performance than the quantity of education.

though the trend has been reversed since, and has come to lie at the 30% level in 1993.

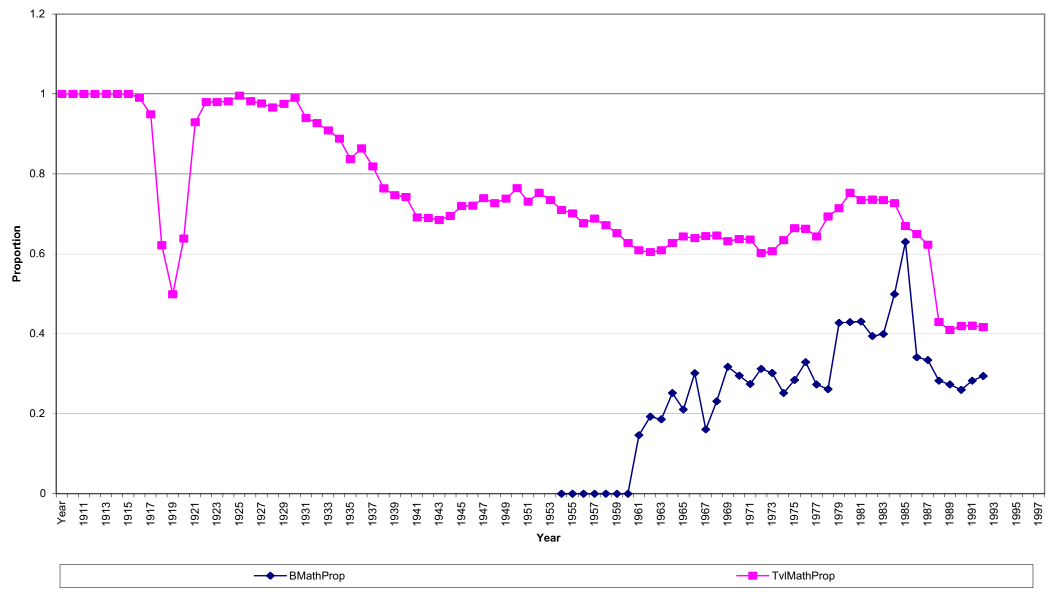

Figure 5.3: Proportion of Matric Candidates with Maths. Source: Fedderke, De Kadt and Luiz (2000a).

So the performance of the schooling system in South Africa is poorer than we might wish for. But can we provide some insight as to why this might be the case?

Part of the answer lies with the nature of the inputs into the schooling system. Where inputs into the human capital creation process are poor, it is hardly surprising that the output will suffer in terms of its quality also.

Evidence that inputs into the schooling process have suffered from poor quality emerges in at least three distinct dimensions.

First, a comparison between pupil-teacher ratios in white and black schooling suggests that the educational opportunities in the two schooling systems were not equal. **Figure 5.4** reports the pupil teacher ratios for both public and private schools for whites and blacks.[24] The most salient point to emerge from an examination of the data is that white educational opportunity, regardless of whether the opportunity arose in public or private schools, is consistently and considerably better than black educational opportunity. White public school pupil-teacher ratios (**WPubPupTch**) never rise above the mid-20 level (the very highest ratio is 24.06 in 1952), while the best black pupil-teacher ratio is provided by the private schooling system (**BPvtPupTch**) in 1941 at a ratio of 31.61. Case and Deaton (1998), on the basis of cross sectional survey evidence from South Africa, note that while differences in

[24] Again, for a fuller discussion of these results see Fedderke, De Kadt and Luiz (2000a).

pupil-teacher ratios in the 10:1 to 40:1 range may not significantly determine the educational performance of pupils, an increase in pupil-teacher ratios from 30:1 to 60:1 is a statistically significant determinant of educational performance. In this context it is noteworthy that the pupil-teacher ratio for black public schooling (**BPubPupTch**) remained in the range from 50:1 to 70:1 for a protracted period from 1957 to 1993, while black private schooling over the same period did not do significantly better.

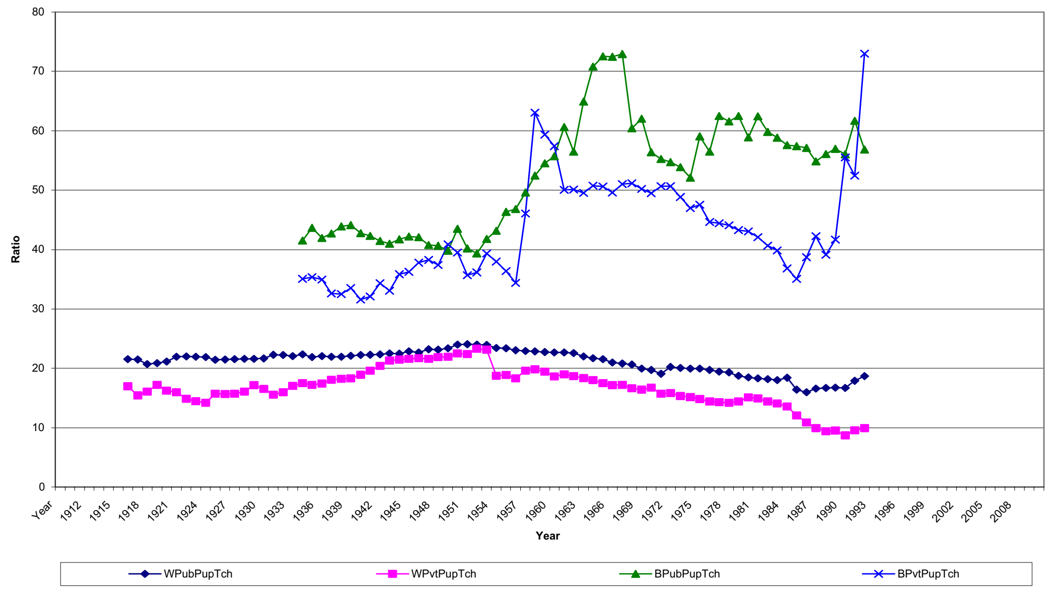

Figure 5.4: Pupil Teacher Ratios for Black and White Public and Private Schools. Source: Fedderke, De Kadt and Luiz (2000a).

Second, real expenditure per pupil showed wide disparities between the racially defined schooling systems. In **Figure 5.5** we report the per capita expenditure figures by racial grouping. While in absolute terms real expenditure on black schooling increased dramatically throughout the 1980's, this did not translate into a strong increase in real per capita expenditure per pupil.[25] On these figures white per pupil expenditure (**RealWperCap)** remains at least at seven times the level of that for blacks (**RealBPerCap**), and almost twice that for Coloureds and Asians (**RealC&APerCap**). Thus the rapid increase in real expenditure on black education has not allowed black schooling to eliminate the backlog with white education. Moreover, a closer examination of black per pupil expenditure suggests that over the 1983-93 period per pupil expenditure remained virtually stagnant in real terms. The implication of the present section is thus that the divergence of quality between the white and black schooling systems is potentially even more dramatic than suggested by the pupil teacher ratios examined above. The ratio of seven to one on

[25] It should be noted that there exists some controversy concerning the appropriate expenditure figures on black schooling. For a fuller discussion and a consideration of alternative evidence see Fedderke, De Kadt and Luiz (2000a).

real per pupil expenditure is several orders of magnitude greater than the ratio of two to one we reported with respect to pupil-teacher ratios.

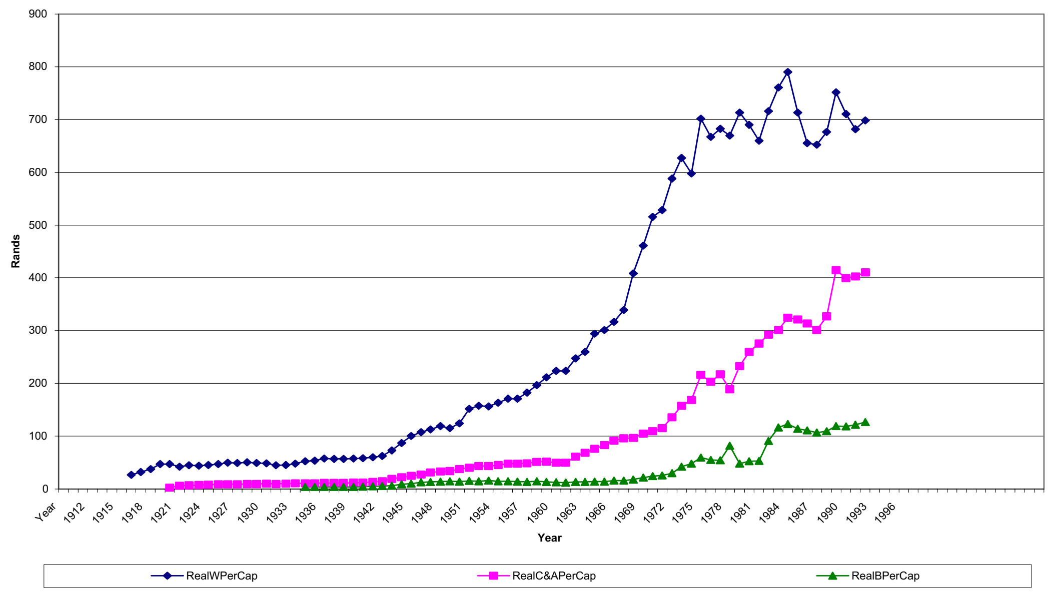

Figure 5.5: Real Per Pupil Expenditure by Race. Source: Fedderke, De Kadt and Luiz (2000a).

Third, differentials in teacher qualifications similarly point to the presence of large disparities in the quality of inputs into the schooling process between black and white schooling. We consider the percentage of teachers in public schools who fall into one of two limiting categories. The first, which we label **iUNQLRAT**, denotes the proportion of the total teacher body for the racial category **i** which holds a Matric qualification or less. The second, which we label **iSPUQLRAT**, denotes the proportion of the total teacher body for the racial category i which holds a tertiary qualification.[26] They represent respectively "under"-qualified and "super"-qualified teachers. **Figure 5.6** reports both categories of teachers for both white and black racial groups. Surprisingly the **iUNQLRAT** category of teachers is fairly similar between the white and black schooling systems, with approximately 20% of teachers proving to be unqualified. The only significant difference to emerge is that the proportion falls to approximately 10% for the white schooling system almost a decade earlier than it does for the black schooling system.

Thus in a number of crucial dimensions we find that the quality of inputs into the educational process in white and black schooling are sufficiently large to serve as plausible explanations of the differential performance we observe in the white and black schooling systems.

In a more detailed econometric exploration, Fedderke and Luiz (2000) confirm that the inputs into education matter for educational attainment. The findings rest on the

[26] "Tertiary" education denotes either a degree or a diploma.

specification of an educational production function linking inputs to outputs in the two South African schooling systems. The specification estimated is given by:

$$iPRAT = F(iPUBPTR, iRPPEXP, REPR) \qquad (6)$$

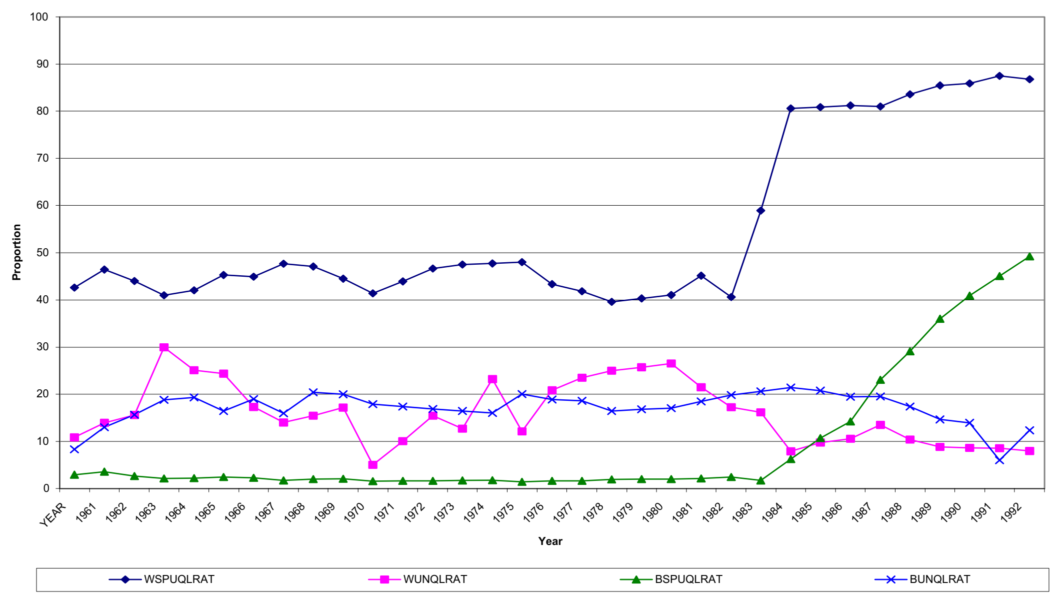

Figure 5.6: Teacher Qualifications. Source: Fedderke, De Kadt and Luiz (2000a).

where iPRAT denotes the pass rate[27] of racial grouping i,[28] RPPEXP real per capita expenditure, and REPR denotes a political instability variable. [29] The salient results are presented in **Table 5.2**.[30]

The implication of the econometric findings is that the inputs into schooling have a strong, statistically significant and benevolent impact on pass rates in white schooling, while for black schooling the impact of political instability dominated all other factors, lowering matriculation pass rates.[31]

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[27] Defined as a log-odds ratio.
[28] Again defined as black (B) or white (W).
[29] On the definition and construction of this variable see Fedderke, De Kadt and Luiz (1999a).
[30] Given the nonstationary time series character of the data, we employed the ARDL cointegration technique due to Pesaran and Shin (1995a,b), Pesaran, Shin and Smith (1996). For a fuller discussion see Appendix 1 to the present chapter.
[31] We report only long run equilibrium coefficients, not the full dynamics. The error correction terms confirm the presence of a stable equilibrium relationship between variables. Full results are available in Fedderke & Luiz (2000).

Table 5.2: ARDL Cointegration Estimation Results.

White Schooling ARDL (6,6,3,2) 1944-50 n=50		Black Schooling ARDL (2,1,2,4) 1968-93 n=28	
	WPRAT		BPRAT
Constant (t-ratio)	9.01* (7.97)	Constant (t-ratio)	7.33 (1.20)
WPUBPTR (t-ratio)	-2.86* (9.40)	WPUBPTR (t-ratio)	-0.97 (0.66)
WRPPEXP (t-ratio)	0.24* (5.20)	WRPPEXP (t-ratio)	-0.18 (1.17)
REPR (t-ratio)	0.02 (1.49)	REPR (t-ratio)	-0.32* (3.47)
ecm(-1) (t-ratio)	-0.997 (6.22)	ecm(-1) (t-ratio)	-0.65 (5.16)
ARDL Diagnostics		ARDL Diagnostics	
R^2 = 0.98	adj-R^2 = 0.97	R^2 = 0.91	adj-R^2 = 0.83
σ = 0.10	DW = 1.97	σ = 0.23	DW = 1.90
AR = 0.03	RESET = 2.08	AR = 0.02	RESET = 1.51
NORMAL = 7.29*	HETERO=0.94	NORMAL = 0.14	HETERO=0.14

Source: Fedderke and Luiz (2000).

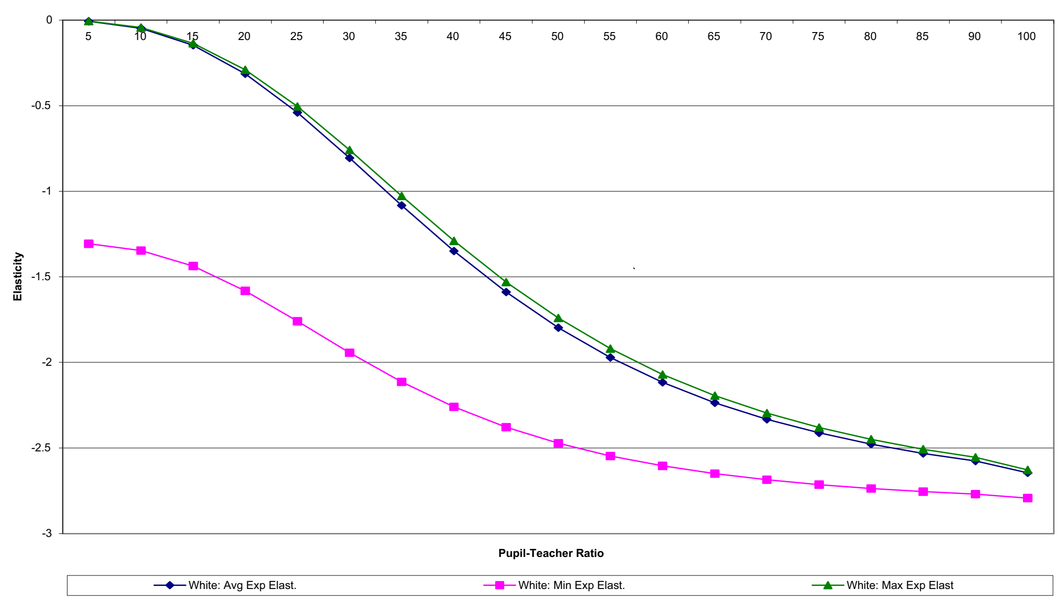

Figure 5.7: White Schooling: imputed elasticity of matriculation pass rates with respect to the pupil-teacher ratio.

Given the variable elasticity of pass rates with respect to pupil teacher ratios implied by the specification estimated, in **Figure 5.7** we provide an indication of the magnitude of the elasticity of pass rates for white schooling over a range of pupil-teacher ratios. What is startling about the evidence is the strength of the implied elasticity, confirming that inputs matter, and matter substantially. This is all the more important since this evidence emerges on ranges of inputs which are comparable to those for which many studies did not find statistical significance for the USA.[32]

The question here must of course be why statistically the inputs matter in the white schooling system, and not in the black. But in fact the difference between the two production functions is readily interpretable. Over the sample period under consideration, whites in South Africa had access to institutions that allowed them to exercise at least some control over the educational production process. Certainly provincial educational administrators could be accessed through political representation in order to address any inefficiencies in the educational process. By contrast, blacks had access to no such institutions – and certainly the officials responsible for the delivery of educational services had no incentive to respond to delivery failure reported by parental complaints. Thus the distinct institutional background that distinguishes the two schooling systems appears to have carried profound implications not only for educational attainment by pupils, but implicitly for the efficiency with which resources were being employed within the schooling structures also.

The institutional structures that govern policy formation in the schooling system, as well as the inputs into the educational process appear to be crucial in determining educational attainment of pupils. Where parents have the capacity to influence policy, the use of inputs in education has proven to be more efficient than where they do not. The labour market gives individuals a stake in the educational process. What governance structures of schooling should reflect are adequate means for allowing agents to realize such stakes in their own best interests.

Thus for South Africa's schooling system the evidence is of large quality differentials in the output of the schooling system attributable to poor inputs into the schooling process, and to inappropriate governance structures.

And recall that the evidence suggests that even the best parts of the system could be doing better.

On the upside of the evidence, at least we know what is going wrong (though we need even more information), and therefore what the appropriate forms of policy intervention should be if we wish to improve schooling performance.[33]

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[32] This applies particularly to pupil-teacher ratios. White pupil-teacher ratios are in ranges similar to those found in the US, where they appear to be insignificant. The difference lies in the fact that US studies have tended to use cross-sectional data (see for instance Hanushek 1995, 1996), rather than time series, due to the absence of time series data. Yet since the impact of changing inputs is likely to take time to emerge, time series is clearly the way to go here.

[33] For an elaboration on the policy issues that arise out of the schooling education data, see Fedderke (2000b).

5.5.1.2 A characterization of the performance of South Africa's tertiary educational system

The next question to ask is whether the poor schooling system in South Africa has translated into a poor tertiary educational system, and whether the patterns that were evident at the schooling level have been reproduced for tertiary institutions?

The data to be presented in this section covers the university system in South Africa.[34]

In tertiary education we find the patterns of performance to be somewhat different from those we found for schooling. For universities the distinction between the historically white universities, and universities historically designated for other race groups, is not in terms of the quality of inputs as measured by student-lecturer ratios, or by expenditure per student.[35] Indeed, real expenditure per student for universities was higher in the black universities than it was for whites. Nevertheless, our findings show that the quality of output of black universities in terms of both the degrees they issued and their research output lay considerably below that of the universities designated white.

Only the teacher training college system emulates the results we found for South African schooling. Here again, inputs as well as outputs of the teacher colleges prove to be of considerably lower quality for blacks than for whites.[36]

In technical training, the differential between whites and blacks emerges primarily in the form of poor access to such training by blacks, rather than in the form of poor inputs into black technical training as measured by student -lecturer ratios and real per student expenditure. A more general finding to emerge from our data on technical education in South Africa is that significant under-investment in technical forms of human capital has been maintained over the sample period, and for all population groups.[37]

In the university system student-staff ratios show relatively little variation across race groups – see the evidence of **Figure 5.8**.[38] Indeed, during the course of the 1960's and 1970's the student-staff ratios at the black, coloured and Asian (BCA) institutions lay

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[34] Again this section draws substantially from Fedderke, De Kadt and Luiz (2000b), which is also concerned with the technikon, teacher college, and apprenticeship contract data for South Africa. The restriction to the university sector in the current context is because it is the most significant tertiary educational sector both in terms of student numbers, and in terms of its anticipated innovative capacity. Since it is the supposed pinnacle of the tertiary system, it is also held to be indicative of the health of the sector as a whole. Fedderke, De Kadt and Luiz (2000b) note some crucial differences between the various parts of the tertiary system, however.

[35] We note at the outset that for universities the distinction between "white" and "black" makes less sense than elsewhere in the educational system. Since student bodies always tended to be mixed, the designation cannot be taken to reflect the racial composition of the institutions being referred to so much as a series of historically determined labels. For reasons that will become clear from the ensuing discussion, "historically advantaged" and "historically disadvantaged" is also misleading. All labels in the current context are thus misleading, and we therefore stick to the historical ones. At least these give a sense of continuity and contiguity with past usage.

[36] The full results are available in Fedderke, De Kadt and Luiz (2000b).

[37] The full results are available in Fedderke, De Kadt and Luiz (2000b).

[38] A fuller discussion of the issues touched on here is contained in Fedderke, De Kadt and Luiz (2000b).

below that maintained in the white university system.[39] This pattern only changes after 1980, when the student-staff ratio of all parts of the university system begins to demonstrate an upward trend. During the course of the 1980's the student-staff ratio of both the Coloured and Asian universities is of essentially the same order as of the white universities, though there also appears to be greater cyclical variability in Asian and Coloured student-lecturer ratios. However, the strongest change during the course of the 1980's, concerns the student-staff ratio in black universities, which rises dramatically during the 1980's, to approximately double that which prevails in the white university system.

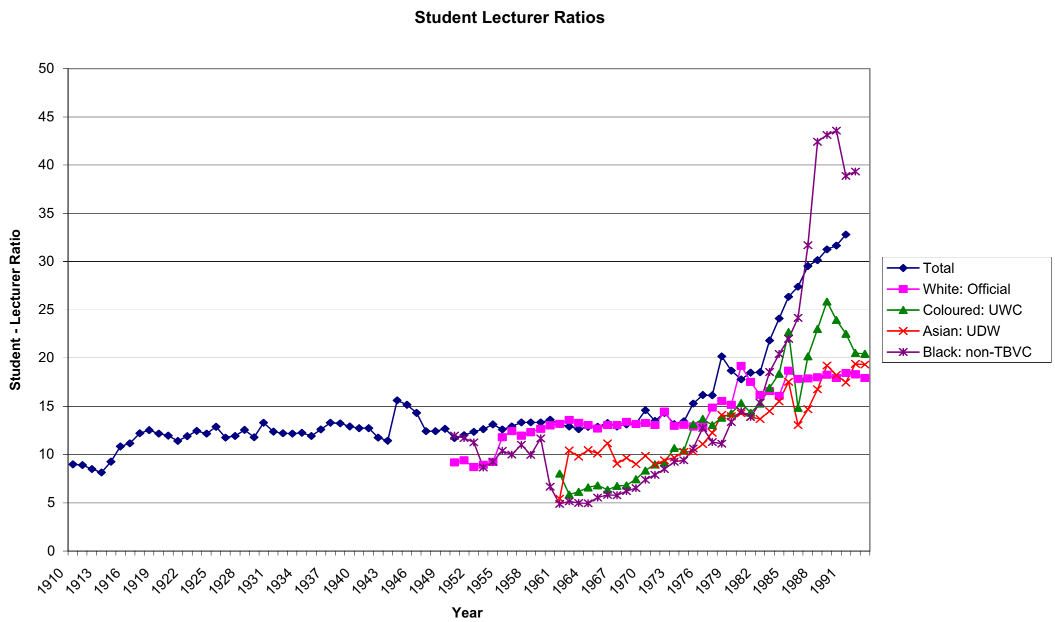

Figure 5.8: Student Lecturer Ratios: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

There are three immediate and important implications that emerge from the evidence provided by student-lecturer ratios. First, the low student-lecturer ratios in BCA-universities during the pre-1980 sample is likely to be influenced by the poor performance of the BCA-schooling systems, detailed above. Thus the ability of the BCA-tertiary education system to attract sufficient student intake is likely to have suffered from a supply-side constraint, making it difficult to attract students in sufficient numbers.

Second, it becomes likely that student-staff ratios for universities may well not be a reliable indicator of quality of learning environment,[40] particularly since we know the

[39] This is true even where (as in Figure 5.8) we employ the white university student enrolment figures which do not count the students of other races attending these universities. Where the adjusted student enrolments for white universities are employed, there is a further though marginal upward adjustment in the student-lecturer ratio at white universities.

[40] The ratio of students to lecturers does not control in any way for the quality of the lecturing staff employed in the respective sets of institutions. Ideally, the ratio should be appropriately weighted for

student intake to have been poorly prepared for tertiary education. This is thus quite unlike the case for the South African schooling system, where pupil teacher ratios were found to show strong variation across the racially defined schooling systems, and this variation was found to exert strong influence on educational attainment.

A third implication of this evidence is that the development of separate university systems for the distinct ethnic groupings of South Africa's population was an extraordinarily inefficient use of scarce resources. Universities are notoriously expensive in terms of start up costs. To develop entirely new universities with a student body generally poorly prepared, and with low student-staff ratios, may well have prevented the already existent universities from improving their quality. A more rational approach to the development of the tertiary educational system would have been to take advantage of economies of scale in incorporating BCA students into their historic student body.[41]

The real expenditure per student data further strengthens the patterns observed in **Figure 5.8**. We present the data in **Figure 5.9**.[42] For historically white universities, real per student expenditure has remained essentially constant over the full 1910 to 1993 period, though the 1980's and early 1990's have seen some decline from the height of per student expenditure achieved during the course of the 1970's. For all other racial groupings in the university system, per student expenditure during the course of the 1960's and 1970's was higher than for the white university system, though the 1980's has seen convergence between the expenditure figures for the various sections of the university system. The black university system did not differ from Coloured and Asian universities in this respect. For black universities real per student expenditure consistently lay above that for the white university system during the 1960's and 1970's, and it is only the sharp increase in student numbers at black universities during the 1980's that drives down per student expenditure below that of other parts of the university system.

A number of explanations account for these data patterns - and a number of implications follow. First, the high per student expenditure figures in the BCA-universities can be accounted for in terms of the start-up costs of any new university system. Again, consistent with our suggestions emerging under the discussion of the student-lecturer ratio, the difficulty likely to have been experienced by the BCA universities is the recruitment of a suitable student body. Thus, the investment in infrastructure and in the high level human capital required to start up a new set of universities was for a small student body, who were in consequence funded to a disproportionately high level on a per capita basis. Only during the course of the 1980's does a quality differential come to be indicated in per student expenditure levels at universities.

This evidence is once again corroborates that the educational system imposed by the apartheid ideology was wasteful of scarce resources.

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the quality of lecturing input. Unfortunately, no ready statistics were available to enable such a quality adjustment.

[41] This is a point that generalises across the tertiary educational system in the Apartheid era in South Africa.

[42] Again, a fuller discussion of the data and its characteristics can be found in Fedderke, De Kadt and Luiz (2000b).

The resources expended in developing an entirely new university sector in parallel with an already existing system might have been far more efficiently employed in expanding the capacity of the existing system, with the associated economies of scale that might have been realized in the process. As it was, the educational system was starved of a large body of resources, that might have been more appropriately employed in improving the quality of the primary and secondary schooling system feeding the universities, or in expanding existing universities.

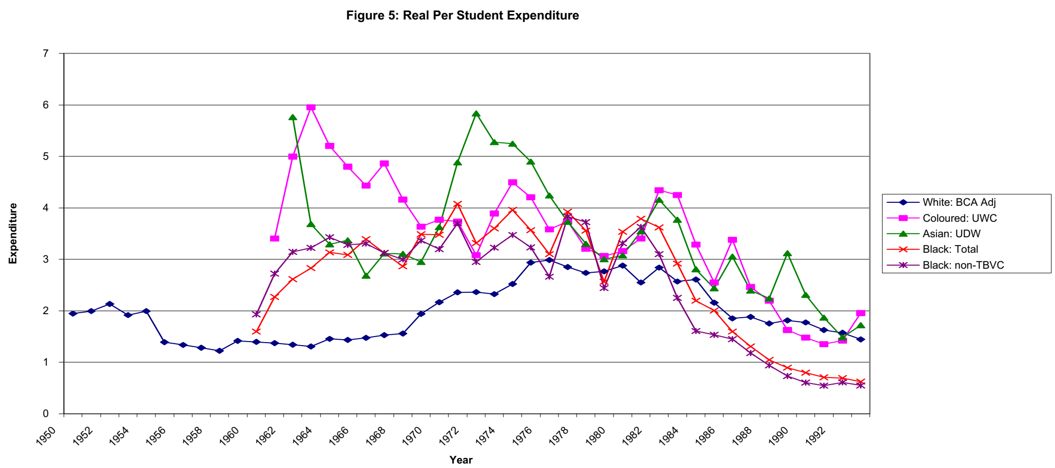

Figure 5.9: Real Per Student Expenditure: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

So the evidence on inputs into the university system suggests that the patterns of inequality that characterised schooling in South Africa, and which in turn issued in large differentials in performance by pupils in schools, are not repeated for the university system in South Africa. The question now must be whether the more equal allocation of resourcing in the university system managed to produce a university system of an undifferentiated level of excellence throughout.

Anecdotal evidence suggests that this was not the case, but what does the hard data tell us?

Figure 5.10 reports the absolute output of university degrees in South Africa. Absolute output measures of the university system suggest a steady and, since 1960, sometimes steep increase in the total degrees granted by universities. The evidence suggests that the white universities dominate the university system as a whole in output terms, despite the growing degree output of black universities particularly during the course of the 1980's.

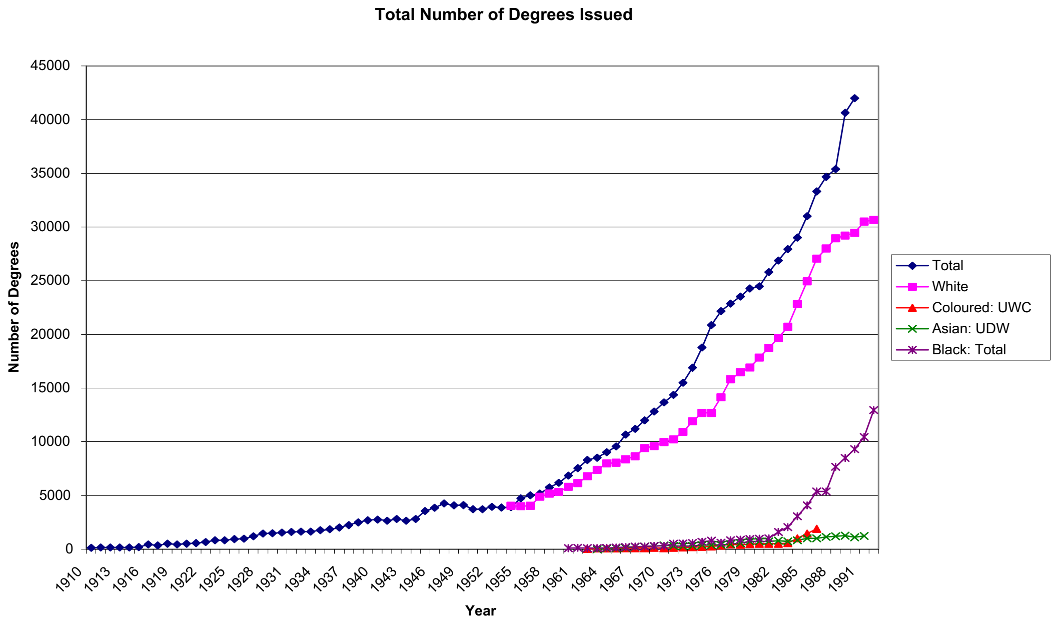

Figure 5.10: Total Number of Degrees Issued: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

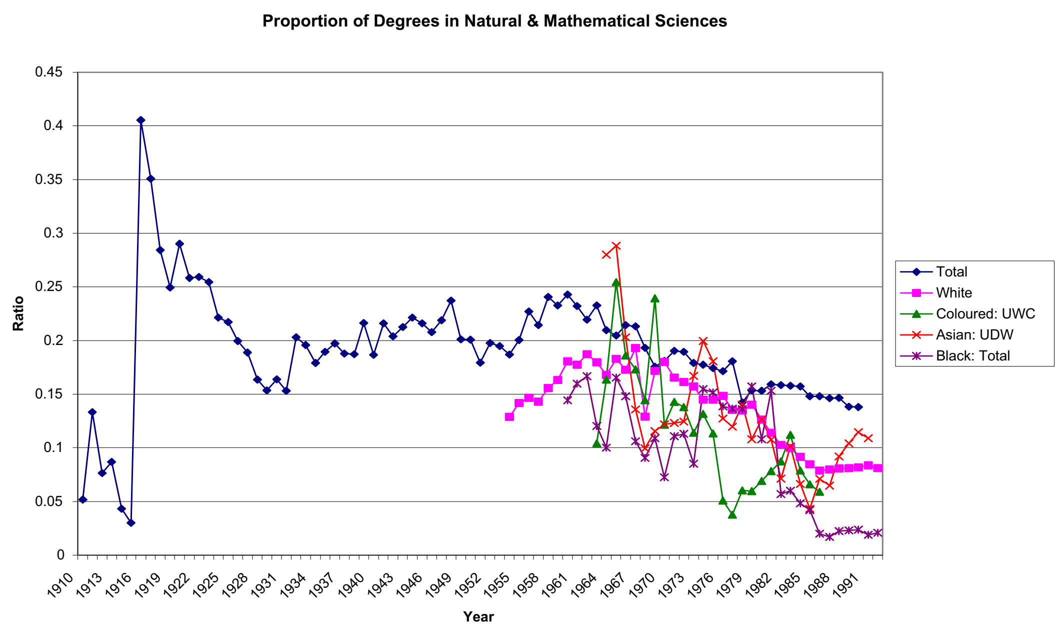

Figure 5.11: Proportion of Degrees in Natural and Mathematical Sciences: Universities. Source: Fedderke, De Kadt and Luiz (2000b).

While the absolute output of degrees suggests that black universities were expanding their output as the number of students entering the system increased during the 1980's, absolute numbers of degrees do not yet control for the quality of the output being generated.

In **Figure 5.11** we report the proportion of total degrees issued by the various university systems that emerge in the natural and engineering sciences (NES).[43] For the white and Asian university systems, the proportion of NES degrees falls from a high point of 20% in the mid 1960's, to a little under 10% in the early 1990's.[44] While the black university system initially had a similar proportion of NES degrees conferred, during the course of the 1980's at precisely the time when student enrolments were expanding rapidly, the NES proportion fell rapidly, and by 1993 had reached a low of 2%. While the trend for both systems has been downward, the performance of the black universities in producing science graduates is far poorer than that of the white university system. Moreover, while the strong increase in student numbers in the black university system in the early 1980's was matched by an increasing conferral of degrees this was clearly achieved by an expansion of students reading toward "soft" rather than science degrees. **Figure 5.11** demonstrates a sharp decline in the proportion of science graduates precisely at the point at which both student numbers and total degrees conferred were experiencing sharp growth.

This evidence carries the implication that the black university system, while beginning to absorb increasing numbers of black students emerging from the black schooling system, was unable to translate the increased enrolment into NES graduates with the same facility as the rest of the university system. While this may point to the poorly prepared student intake that the black university system had to contend with, it is also indicative of a low capacity within the black university system to generate NES graduates.

Similar implications emerge from student throughput rates,[45] and real expenditure per degree data. All sections of the university system saw an increase in the cost per degree produced over the course of the 1980's. However, the increase has been the most dramatic in the black university system, to the extent that the cost per degree in the black university system in 1993 had reached 1.5 the level maintained in the white universities.

White and black university systems also have significantly different throughput rates. For white universities approximately 17% of the total student body in 1993 was

[43] We choose NES degrees for the following reasons: the mathematical sciences have as clearly identifiable objective performance standards as any subject available to university students. Application of subjective standards of assessments are therefore minimized. Moreover, we consider the mathematical sciences to be foundational to a wide range of cognitive activities and vocational skills. Lastly, mathematics (and science) was used as the central indicator of the quality of the educational system in the Hanushek and Kim (1995) growth study - and proved a more significant predictor of long run economic performance than the quantity of education. We have also already seen from the evidence of Chapter 4 that the impact of science degrees on output growth in manufacturing is positive both for South Africa, and internationally.

[44] The higher proportion of NES degrees in the total student body is attributable to the impact of Coloured and Asian students present in the white university system, but classified in terms of their racial categories. In this instance the bias could not be corrected for.

[45] Defined as the ratio of degrees conferred to the total student body.

receiving a degree, and the trend for the white university system was upward. By contrast, black universities while sharing an upward trend in the total degree throughput rate since the early 1980's, had reached a throughput rate of only 10% in 1993, significantly below that of white universities. In the case of the throughput of NES degrees black universities reported close to 0.002 in 1992, while white universities reported 0.01. While particularly the NES throughput rate is poor for both university systems therefore, it is evident that matters have been far worse in the BCA university system. The sharp uptake in additional students through the 1980's has not been translated into an improved university sector performance.

There is a final but perhaps also most important indicator of the differential quality of South African universities. Universities are distinguished from other forms of tertiary educational institutions by virtue of the expectation that they be engaged not purely in teaching activity, but that they contribute to the advancement of knowledge through the publication of original research. And given our discussion of endogenous growth theory, and the empirical findings we have already shown on the growth impact of R&D, this feature of the university system attains additional significance. In **Figure 5.12** we report both the absolute level of research unit output of the racially categorized universities, as well as their per lecturer research unit output.[46] The evidence confirms the suggested quality differential that we have already established as existing between the "white" universities and BCA universities. Not only is the absolute level of research output in white universities considerably higher than in BCA universities, but this is translated into considerably higher per capita research output also.

But again, while BCA universities essentially produce no research output to speak of at all, note that even the white university system produces less than one publication per lecturer per annum. Something is amiss even in the "good" part of the system.

Moreover, we note that even the best part of the university system in South Africa has at the very least manifested declining quality over time. First, the white university research output has ceased to increase in absolute terms from the late 1980's, and in per lecturer output terms the output declined through to the early 1990's, though it has since stabilised. Also – most research in South Africa is done in a very small number of universities. See **Tables 5.3** and **5.4**.

The declining per lecturer and static absolute levels of research output during the late 1980's and 1990's may well be attributable to the increased resources devoted to the development of the BCA university system. In the preceding discussion, we have already suggested that the expenditure on BCA universities proved to be an expensive way of obtaining relatively low quality degree output. The evidence on research output, suggests that an additional cost may well have been a declining capacity of the front ranking research universities in South Africa to continue to fulfil their vital

[46] Publication units are not quality adjusted. This is particularly serious since a publication of an article in a South African journal with very low impact factor would be ranked as equivalent to an article in a leading international journal with maximal impact rating. Moreover, research collaboration is penalized on a pro rata basis by the national publication unit system. Collaboration with Nobel Prize winning scientists therefore comes to be ranked below single-handed review articles of secondary material. Finally, the national register of approved journals excludes a number of leading journals, while rating obscure South African magazines as legitimate fora for research. Bizarre incentive mechanisms.

research function. The reallocation of funds to the development of the BCA university system therefore had opportunity costs not only in terms of foregone development opportunities in the already existent university system, but potentially also in preventing the resourcing of growing research capacity in the South African university system.

Again in the light of the wider evidence on the importance of R&D on growth, this finding is of particular concern for South Africa.

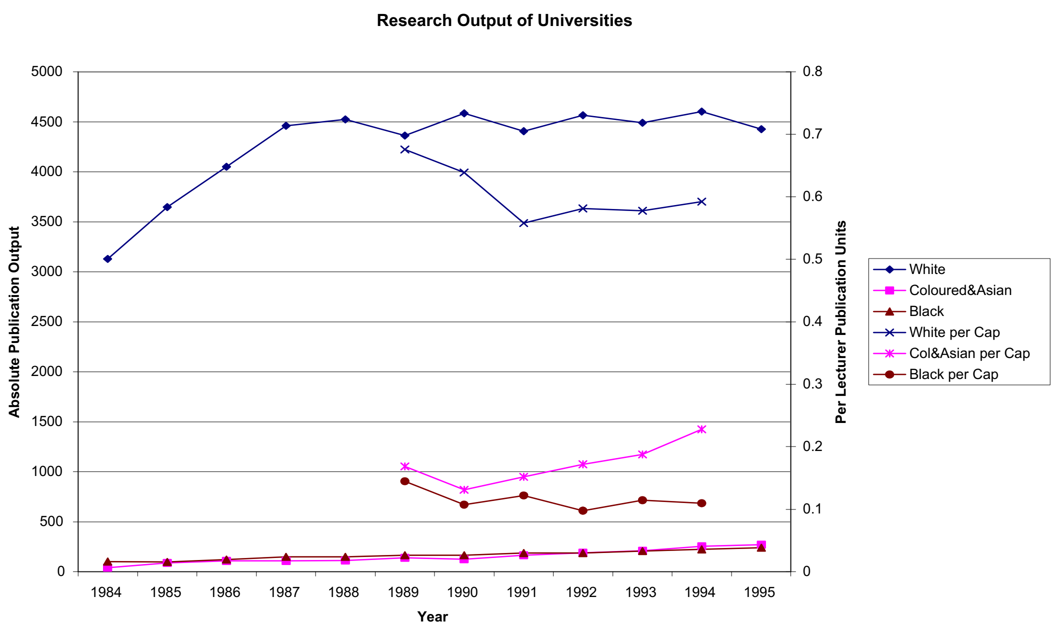

Figure 5.12: Research Output of Universities. Source: Fedderke, De Kadt and Luiz (2000b).

In a broader developmental context, it raises the important question of whether it is desirable for a society to concentrate solely on devoting resources to a broad based mass tertiary educational system premised on the lowest common quality denominator. Or whether it is not desirable to have at least some tertiary education devoted to the production of both high quality degrees, as well as world quality research. If the latter route is chosen (and the experience of the East Asian countries may be taken to at least suggest that it is not entirely unfruitful - as long as the right type of educational output is emphasized), the implication would be for the identification of a small number of core institutions, properly funded, and with appropriate incentive structures designed to encourage greater attention to research activity.

Finally, in this regard it is possible to identify a strong inter-institutional difference in terms of research output between white universities. The evidence suggests the presence of a three tier structure to the university system, as suggested in **Table 5.4.**

Table 5.3: Per Capita Publication Unit Output by University, 1989-94

	1989	1990	1991	1992	1993	1994	Rank1989	Rank1994
Wits	1.17	1.09	0.78	0.83	0.74	0.84	1	3
Cape Town	1.04	0.98	0.93	0.93	0.89	0.91	2	1
RAU	0.92	0.82	0.71	1.03	1.00	0.89	3	2
Natal	0.68	0.59	0.58	0.49	0.65	0.56	4	5
Rhodes	0.59	0.56	0.49	0.47	0.43	0.47	5	6
Stellenbosch	0.55	0.49	0.45	0.51	0.50	0.65	6	4
Pretoria	0.51	0.50	0.43	0.47	0.48	0.45	7	7
Free State	0.41	0.43	0.41	0.37	0.40	0.39	8	8
Potch	0.40	0.45	0.35	0.41	0.36	0.36	9	9
UPE	0.38	0.29	0.34	0.33	0.22	0.28	10	10
Medunsa	0.26	0.14	0.23	0.07	0.16	0.12	11	15
UNISA	0.24	0.25	0.24	0.25	0.23	0.25	12	11
UDW	0.20	0.19	0.21	0.22	0.18	0.24	13	12
Vista	0.15	0.10	0.11	0.11	0.09	0.09	14	17
UWC	0.14	0.09	0.11	0.13	0.20	0.22	15	13
Zululand	0.14	0.08	0.12	0.14	0.12	0.16	16	14
North	0.10	0.11	0.08	0.08	0.11	0.10	17	16

Table 5.4: Ranking of Universities in Terms of Research Output

Top Ranked: Per Lecturer	Mid Ranked: Per Lecturer	Bottom Ranked: Per Lecturer
Cape Town	Stellenbosch	Port Elizabeth
RAU	Natal	UNISA
Wits	Rhodes	Durban-Westville
	Pretoria	Western Cape
	Free State	Zululand
	Potchefstroom	Vista
Top Ranked: Absolute Output	**Mid Ranked: Absolute Output**	**Bottom Ranked: Absolute Output**
Wits	Stellenbosch	Rhodes
Pretoria	Natal	Potchefstroom
Cape Town	UNISA	Western Cape
	RAU	Durban-Westville
	Free State	Port Elizabeth
		North
		MEDUNSA
		Vista
		Zululand
		Fort Hare

Such a structure might provide some guidance as to how a functional differentiation between universities might come to be structured. The three-tier system might be identified with “ivy league” research universities, state universities or liberal arts colleges, and finally community colleges. Our concern here is not to identify which university should fulfil which of these functions. Nor is it to denigrate any one of the three functions. We are arguing instead that the existing capacity within the university system is not such as to place all universities on an equal footing, and that it may therefore be sensible to develop the existing structures into institutions that fulfil different pedagogical functions, all of which are important. As the evidence makes clear, the system as it is in any event has strong functional differences – we might as well recognise them, and reward them appropriately.

In concert with the earlier evidence presented on the South African university system, therefore, the implication of the present section is that the black university system proved not only to generate output that was of poor quality, but that it proved to be poor output that was expensive. While the poor preparation of pupils passing through the black schooling system is sure to have played its role, the poor design and implementation of a duplicate black university system intended to run in parallel with the white, is likely to have contributed not insignificantly in its own right.

What is more the suggestion above has been that the development of the human capital creating institutions in South Africa has been such as to inhibit the development of a strong capacity to stimulate the R&D activity so vital to long run economic growth.

5.5.2 Testing for the impact of human capital creation on long run economic growth in South Africa

So much for the descriptive account of South Africa's human capital creating institutions. But while we have seen that matters are not as sound as we might like, the question must be whether there is evidence to suggest that this really matters in hard growth terms?

In this final section we examine the impact of the human capital dimension on the long run economic performance of South Africa.

In the preceding chapter we have already established that at least for the manufacturing sector, investment in human capital in a number of distinct dimensions does appear to be adding to the presence of technology spillover effects.

The analysis in the current chapter adds to this analysis of spillover effects. In the current context our focus is on the impact of human capital on long run growth performance in the economy directly, and for the economy in aggregate.

In order to examine this question we employ a standard growth equation, incorporating investment in both physical and human capital as potential determinants of economic growth.

The data employed are determined by the long time series available from the above mentioned studies collecting the evidence on the South African human capital accumulation track record over 1910-93.

As empirical methodology we employ the vector error correction methodology of Johansen, incorporating the cointegration techniques appropriate to nonstationary time series data. Appendix 2 to the present chapter outlines the technique in greater detail.

The specification employed is given by:[47]

$$\ln Y = F\left(\frac{I}{Y}, H\right) \tag{1}$$

where lnY denotes the natural log of real per capita output (GDP) of the economy, I/Y denotes the investment rate given by the ratio of real gross domestic fixed investment to real GDP, and H denotes a vector of human capital variables, incorporating:

- the "white" school enrolment rate. The schooling variables are all specified as the enrolment rate of the relevant age cohort, obtained from census data. For whites, since the schooling pupil data covers both primary and secondary schooling, the age cohort is the 5-19 age group. Readers should note that the variable is likely to result in downward bias, since a significant proportion of pupils in the "white" schooling system are likely to complete schooling no later than at age 17. **Figure 5.13** illustrates the enrolment rate as WENROL. Enrolment rates are chosen in line with international convention in growth studies.
- the "black" school enrolment rate. The relevant age cohort, given the findings of Wittenberg (1999),[48] is given by the 5-24 age group. **Figure 5.13** illustrates the enrolment rate as BENROL.
- the total number of degrees issued by South African universities. The variable is denotes by DEGREES. **Figure 5.14** illustrates.
- the total number of degrees in the natural and engineering sciences issued by South African universities. The variable is denoted NSDEGREES.

Since all variables employed are nonstationary, the appropriate estimation technique is that provided by Johansen VECM. Appendix 3 to the chapter provides the relevant augmented Dickey-Fuller test statistics, confirming all variables to be I(1). See Table A3.2.

We examine two specifications, employing the two alternative tertiary education variables, DEGREES and NSDEGREES, and we report the results of estimation in **Table 5.5**.

The quality of the two sets of results is strongly differentiated. First, note that the long run relationship that included *total* degrees issued (DEGREES) has none of the human capital variables to be statistically significant. The only significant determinant of the output variable is the investment rate. Thus on this specification there would appear to be little more to be said on the impact of human capital creation on long run growth.[49]

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[47] Readers will recall that this mirrors the specification employed by Mankiw et al (1992).
[48] Completion of schooling takes longer in South Africa's black population groups. The discussion of the time series data and the inequalities in resourcing implied by the data suggests many reasons why this might be the case – none of which implies fault on the part of the pupils themselves. But this is not our current concern.
[49] In fact, the maximal eigenvalue and trace statistics also indicate that there may be problems with this specification, since there is evidence of a number of cointegrating vectors present in the data. See Table A3.5 of Appendix 3. Thus imposing a single cointegrating vector on the data may produce misleading results, with estimated coefficients being linear combinations of the cointegrating vectors that are

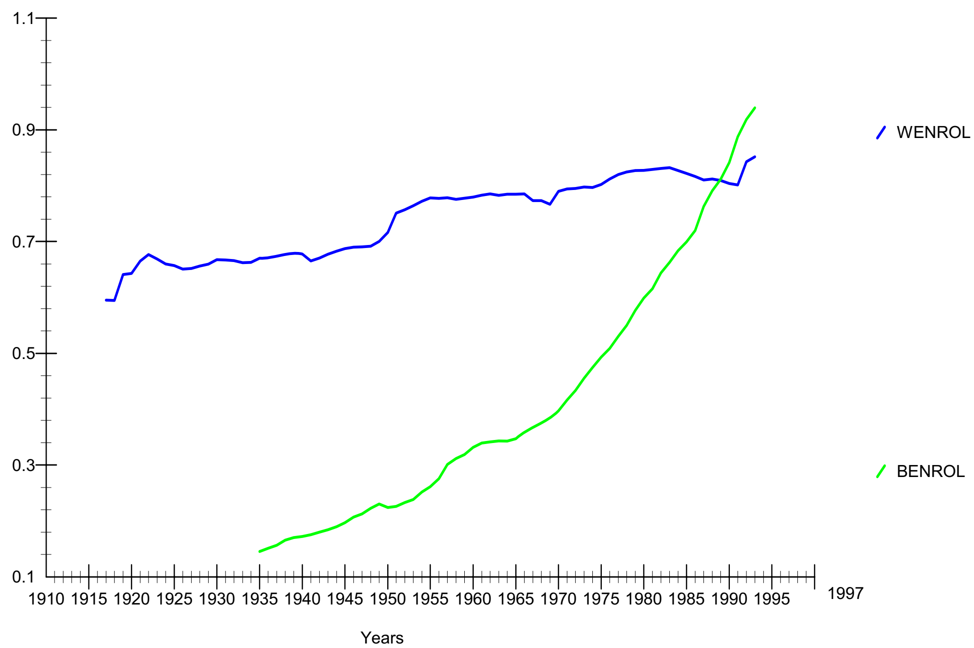

Figure 5.13: White and black schooling enrolment rates.

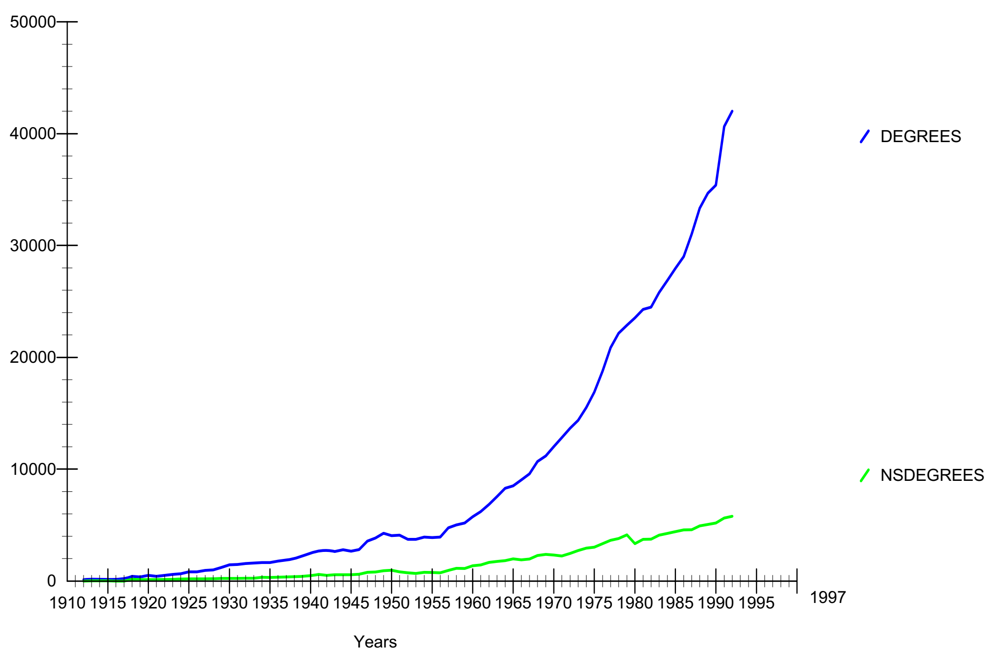

Figure 5.14: Total degrees, and Natural and Engineering Science degrees issued.

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present. While we examined a number of alternative just identifying restrictions on a system of equations, none produced theoretically or statistically congruent results.

By contrast, the specification that loads on the natural and engineering science degrees, generates results that are both statistically and theoretically sound. In particular we note that the estimation:

- Unambiguously has a unique cointegrating vector present in the data.[50]

- All of the human capital variables are now statistically significant in addition to the investment rate. The implication is that investment in both physical and human capital is a significant determinant of long run output values in the South African economy.[51]

- The error correction mechanism confirms the presence of a long run equilibrium relationship in the data, as implied by the cointegrating vector.

What is particularly startling about the estimation results is that once the estimated coefficients are standardized, the impact of the human capital variables come to demonstrate a very strong impact on output.

The implication of these findings is that the human capital variables carry their significance jointly, rather than singly.[52] The implication of this finding is that it provides confirmation of the Romer (1990) or Lucas (1988) implication of increasing returns to human capital. The impact of human capital emerges once the synergies between primary and secondary, and tertiary education come to be recognised. It is not enough to have only some parts of the educational system contributing to output – one needs to recognize the contribution of all components of the educational process to the generation of output. It is the educational system *as a vertically integrated whole*, and not just components of its that are important for economic growth.

The finding is thus a confirmation of the view that human capital creation in South Africa comes to contribute to output creation *directly*, and in aggregate, as well as through its contribution to technological innovation already discussed in the previous chapter.

But a number of the features of the preferred specification below demand further comment, and in turn carry significant policy implications.

The first point to note is that it is the natural and engineering science degrees that appear to generate the strong impact on economic output, rather than degrees in general. This finding accords well with that of Hanushek and Kim (1995) on an international sample of countries, in which schooling in mathematics and science had a growth impact eight times the magnitude of general education. Thus the implication is that while education in general helps, it also matters what sort of training is being

---

[50] See Table A3.3 of Appendix 3.
[51] See Table A3.4 of Appendix 3.
[52] A zero restriction on the human capital variables jointly is rejected at the 1% level. The Chi square statistic is 10.72 for 3 degrees of freedom. We also estimated the specification with only the school enrolment variables included in the estimation, and found the school enrolment rate on its own to be insignificant. Again, the implication is that the human capital variables appear to be significant only in concert.

undertaking. The growth payoff from training in science and engineering appears to exceed that of general training.

Table 5.5: Two alternative long run specifications. Figures in round parentheses are chi-squared statistics on the appropriate overidentifying restrictions on the cointegrating space for statistical significance. Figures in square parentheses are standardized coefficients. Figures in curly parentheses are standard errors. Significance is denoted by *.

	LNY	LNY
INVRAT	2.59*	0.23*
	(35.11)	(32.71)
	[0.22]	**[0.02]**
WENROL	-0.27	11.06*
	(.03)	(10.69)
	[-0.05]	**[1.96]**
LNBENROL	0.34	-3.14*
	(.36)	(7.02)
	[0.47]	**[-4.34]**
DEGREES	-0.00001	
	(.69)	
	[- 0.28]	
NSDEGREES		0.001*
		(.0004)
		[4.15]
ECM(-1)	-0.10	-0.05*
	{0.06}	{.02}
adj-R^2	.030	0.35

This finding also strengthens the conclusion we had already noted in the descriptive part of the human capital discussion on South Africa. The expenditure of large resources on developing a university system that emphasised quantity over quality, and at the same time neglected the research dimension, has been costly at least in growth terms. It has not been the general increase in degree output that has contributed significantly to South Africa's economic growth. Instead it has been the natural and engineering science degrees that have so contributed. As a consequence, the policy choice to develop a costly and for the most part frankly mediocre to poor widely-based university system has been foolhardy as a development strategy. It has meant that that part of the university system which has most actively contributed to knowledge-creation and economic growth, has gone into stasis, and has been increasingly hampered from contributing to South Africa's long run economic development. In short, the university sector has been hindered from making its full contribution to the creation of a learning society.

The second point carries much the same import as the preceding: that it matters where and how resources are deployed. At first sight the strong negative impact of the enrolment rate in black schooling seems utterly counterintuitive, and therefore deeply questionable. But this is so only at first sight. In the descriptive evidence we have presented above and in our discussion of the schooling production function for South Africa we have pointed out two fundamental insights with regard to South Africa's black schooling system.

First, we noted that the quality of inputs into black schooling over the 1910-93 period was far inferior to the inputs into white schooling. And our estimated production function showed us that the quality of inputs matter in determining the quality of output from schooling. In addition, the educational production function evidence showed that over and above the poor quality of inputs given to black schooling, the institutions governing black schooling in South Africa precluded the users of the black schooling system from ensuring that what resources were deployed to black schooling, were at least used productively. The consequence was that not only were poor inputs provided to black schooling, but such inputs were also frequently used inefficiently.

The consequence of this combination of factors is quite simply that while black enrolment rates rose sharply in South Africa, unfortunately this quantitative increase in schooling did not reflect a qualitative improvement in the schooling that was taking place – and through no fault of the black pupils using the schooling system. It is particularly instructive to see that just as the sharp increase in black enrolment rates is taking place as of the mid-1970's the black matriculation pass rate begins to decline sharply. Unfortunately South Africa's black population was being sluiced through an educational system that was simply not preparing them adequately for the future.

This provides us with a sensible interpretation of the evidence we are obtaining from our estimation. The implication of the results is not that rising enrolment of black pupils lowers long run output in South Africa *per se*. Rather, the implication is that a mere quantitative expansion of educational opportunities, which does not pay any attention to the quality of the education that is taking place, is not particularly helpful for purposes of generating output growth.

And it is not difficult to understand why this is so. Education is an expensive activity. South Africa, in expanding its educational system, now spends far more than comparable developing or middle income countries as a percentage of GDP on education – see **Table 5.6.** Yet educational achievements in South Africa on many international comparator test scores lie below those of the competitor nations. Thus we are spending much on education, without getting bang for our buck. And whatever is spent inefficiently on education, without generating much by way of quality output, will cease to be available for other uses –such as investment in physical capital stock, for instance.

Table 5.6: Public Expenditure on Education: % of GNP

Public Expenditure on Education: % of GNP	
	1997
Argentina	3.5
Botswana	8.6
Brazil	5.1
Chile	3.6
Hong Kong	2.9
India	3.2
Korea	3.7
Malaysia	4.9
Mexico	4.9
Singapore	3.0
South Africa	7.9
Thailand	4.8
Turkey	2.2
Uruguay	3.3

Really, this is the same point we advanced in interpreting the contribution of the NSDEGREES variable above. What matters is not so much throwing resources at the problem, or making sure that large numbers of students find themselves with paper qualifications. What matters crucially is the *quality* of the education that they receive – and how consonant such education is with the demands of employment in an information and knowledge intensive modern economy. In this our results confirm the finding of Hanushek and Kim (1995).

Our evidence thus tells us that human capital matters directly for growth. But it does so only if deployed wisely. Not all education and training delivers the same rate of return – and tertiary level science and engineering appears to offer particularly strong returns (see the standardized coefficient). But even for the generalized education offered by schooling quality matters. The South African legacy of apartheid, with its strong investment in the human capital of one part of its population, and the systematic under investment in the rest of its population, provides a useful if unfortunate natural experiment. Schooling matters, but the quality of the schooling offered matters even more.

At one level the evidence is thus reassuring. Investment in human capital offers a means of improving the growth performance of the South African economy in the long run. On the other hand, this is likely to be a long run impact, playing itself out over the next generations. And in the meantime we sit with the legacy of the apartheid developmental strategy which wilfully and systematically under invested in one of the central engines of long run growth: the human capital of its population. Given the *au contraire* behaviour of countries such as Singapore and Korea, it is little wonder that we have such a strong growth differential between South Africa and the Far East.

5.6 Conclusions

It has been a long haul through the human capital sections, and we will be brief in summary.

But the findings that have emerged from this chapter are of vital importance.

First, we have seen that human capital is found to have both a direct as well as an indirect impact on economic growth. Moreover, in identifying this impact we have to take account both the quantity and the quality of education that is offered. The impact of human capital creation in South Africa emerges when the full vertical integration of the human capital creation process is recognised.

While human capital creation has exercised a positive impact on South African growth, we also have to recognise the strong failings of the South African educational system. Both the schools and the tertiary educational sectors are subject to failure – though of different sorts. The one is cheap and nasty, the other expensive and nasty.

Given that R&D is crucial to long run growth, it is vital that South Africa identify at least a few institutions capable of generating the requisite research output and research scientists in sufficient numbers. It is time we took seriously the need to concentrate resources in producing excellence, rather than spreading them thinly in the pursuit of mediocrity.

Appendix 1: ARDL Cointegration Estimation

Hsiao (1997) lays the foundations for the use of conventional estimation techniques where the forcing variables are strictly exogenous, regardless of whether the variables are I(0) or I(1). Hsiao demonstrates that where forcing variables are strictly exogenous, conventional Wald statistics are asymptotically distributed (under the null of reduced rank cointegration). This allows for the restriction of the parameter space at the most general stage, economizing on degrees of freedom. Pesaran and Shin (1995b) advocate the use of autoregressive distributed lag models for the estimation of long run relations, suggesting that once the order of the ARDL has been established, estimation and identification can proceed by OLS. While the presence of a long run relationship between variables remains critical to valid estimation and inference, Pesaran and Shin (1995b) demonstrate that valid asymptotic inferences on short- and long-run parameters can be made under least squares estimates of an ARDL model, provided the order of the ARDL model is appropriately augmented to allow for contemporaneous correlations between the stochastic components of the data generating processes included in estimation. Hence ARDL estimation is applicable even where the explanatory variables are endogenous, and, since the existence of a long run relationship is independent of whether the explanatory variables are I(0) or I(1), ARDL remains valid irrespective of the order of integration of the explanatory variables. The ARDL methodology thus has the advantage of not requiring a precise identification of the order of integration of the underlying data. Pesaran (1997) provides a useful discussion.

The PSS approach begins by estimating the error correction model given by:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=1}^{k}\sum_{i=1}^{p} \gamma_{ji} \Delta x_{j,t-i} + \left(\delta_1 y_{t-1} + \sum_{j=1}^{k} \delta_{j+1} x_j \right) + u_t \qquad \text{A1}$$

and estimating by means of an F-test (henceforth referred to as PSS F-tests) the significance of a joint zero restriction on the δ's of the error correction model. The distribution of the F-test is non-standard, and critical values are provided by Pesaran, Shin and Smith (1996). The test is further subject to potential ambiguity, in the sense that the test has an upper and lower critical bound value. As long as the computed statistic exceeds the upper bound, the null of no association can be unambiguously rejected. Similarly, as long as the computed statistic falls below the lower bound, the null of no association cannot be rejected. However, where the test statistic falls between the upper and lower bounds, it is indeterminate.

What remains critical, is the need to establish the existence of a unique long run relationship (i.e. that the F-tests confirm only one of the variables included in estimation as an outcome variable, and that all other variables act as forcing variables), and that an appropriate order to the ARDL is selected. We follow Pesaran and Shin (1995b) in a two step strategy, selecting the ARDL orders on the basis of the Akaike Information criterion (AIC), then estimating the long and short run coefficients on the basis of the selected model. Estimation can be shown to be feasible on the basis of the "Bewley regression":

$$y_t = \varsigma + \eta t + \sum_{i=1}^{k} \theta_i x_i + \sum_{j=0}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{m=0}^{q-1} \delta_m \Delta x_{t-m} + u_t \qquad \text{A2}$$

by the instrumental variables method, where:
$1, t, \sum x, \sum \Delta y, \sum \Delta x$
serve as instruments.

The methodology presumes that the x and u are uncorrelated. Where they are correlated, the methodology remains valid, but the "Bewley regression" requires augmentation.

Appendix 2: The Johansen VECM methodology.

Johansen[53] techniques of estimation employ a vector error-correction (VECM) framework, for which in the case of a set of k variables, we may have cointegrating relationships denoted r, such that 0≤r≤k-1. This gives us a k-dimensional VAR:

$$z_t = A_1 z_{t-1} + \ldots + A_m z_{t-m} + \mu + \delta_t \qquad \text{A2.1}$$

where m denotes lag length, and δ a Gaussian error term. While in general z_t may contain I(0) elements, as long as non-stationary variables are present as in the present case, we are exclusively restricted to I(1) elements. Reparametrization provides the VECM specification:

$$\Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \qquad \text{A2.2}$$

The existence of r cointegrating relationships amounts to the hypothesis that:

$$H_1(r) : \Pi = \alpha\beta' \qquad \text{A2.3}$$

where Π is p x p, and α, β are p x r matrices of full rank. $H_1(r)$ is thus the hypothesis of reduced rank of Π. Where r>1, issues of identification arise.[54]

In our case the prior expectation is that r=1.

[53] See Johansen (1991) and Johansen and Juselius (1990).
[54] See Wickens (1996), Johansen and Juselius (1990, 1992), Pesaran and Shin (1995a, 1995b), Pesaran, Shin and Smith (1996).

Appendix 3: Detailed Estimation Results

Table A3.1: Key to Variable Names Employed

Variable	Definition
LNY	natural log of real per capita GDP
INVRAT	investment rate, I/Y
WENROL	white school enrolment rate
LNBENROL	natural log of black school enrolment rate
DEGREES	total number of degrees issued by SA universities
NSDEGREES	total number of natural and engineering science degrees issued by SA universities

Table A3.2: Augmented Dickey-Fuller Statistics.

Variable	I(0)	I(1)
LNY	-2.44	-4.85*
INVRAT	-1.52	-5.52*
WENROL	-0.22	-6.49*
LNBENROL	0.70	-3.82*
DEGREES	9.24	-4.32*[55]
NSDEGREES	3.92	-5.05

[55] Subject to a structural break in 1973-7.

Table A3.3: Maximal Eigenvalue and Trace Statistics for Number of Cointegrating Vectors

```
Cointegration with unrestricted intercepts and no trends in the VAR
   Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
 List of eigenvalues in descending order:
.69108     .42639     .36224     .27037   .0046981
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r = 1        50.5110           33.6400                31.0200
 r<= 1      r = 2        23.8996           27.4200                24.9900
 r<= 2      r = 3        19.3412           21.1200                19.0200
 r<= 3      r = 4        13.5544           14.8800                12.9800
 r<= 4      r = 5         .20250            8.0700                 6.5000
*******************************************************************************
       Cointegration with unrestricted intercepts and no trends in the VAR
          Cointegration LR Test Based on Trace of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
 List of eigenvalues in descending order:
.69108     .42639     .36224     .27037   .0046981
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r>= 1       107.5087           70.4900                66.2300
 r<= 1      r>= 2        56.9977           48.8800                45.7000
 r<= 2      r>= 3        33.0981           31.5400                28.7800
 r<= 3      r>= 4        13.7569           17.8600                15.7500
 r<= 4      r = 5         .20250            8.0700                 6.5000
*******************************************************************************
```

Table A3.4: Long Run Cointegrating Vector

```
ML estimates subject to exactly identifying restriction(s)
      Estimates of Restricted Cointegrating Relations (SE's in Brackets)
                         Converged after 2 iterations
      Cointegration with unrestricted intercepts and no trends in the VAR
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4, chosen r =1.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        NSDEGREES
*******************************************************************************
 List of imposed restriction(s) on cointegrating vectors:
 a1=1;
*******************************************************************************
                  Vector  1
 LNY                  1.0000
                  (   *NONE*)

 INVRAT              -.23023
                  (   1.6135)

 WENROL             -11.0642
                  (   6.3386)

 LNBENROL             3.1389
                  (   2.1522)

 NSDEGREES         -.6180E-3
                  ( .4207E-3)

*******************************************************************************
 LL subject to exactly identifying restrictions= 276.3930
*******************************************************************************
```

Table A3.5: Maximal Eigenvalue and Trace Statistics for Number of Cointegrating Vectors

```
      Cointegration with unrestricted intercepts and no trends in the VAR
   Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables inc
```

[1] We adjust the purchasing power of output for the price level that is maintained in different economies. $1 buys much more housing in Johannesburg than it does in London and this should be reflected in the 'value' of measured output. PPP measures undertake such an adjustment.

```
luded in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        DEGREES
 List of eigenvalues in descending order:
.66798     .48830     .37702     .35390    .016143
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r = 1        47.4095           33.6400                31.0200
 r<= 1      r = 2        28.8110           27.4200                24.9900
 r<= 2      r = 3        20.3492           21.1200                19.0200
 r<= 3      r = 4        18.7827           14.8800                12.9800
 r<= 4      r = 5          .69980           8.0700                 6.5000
*******************************************************************************


      Cointegration with unrestricted intercepts and no trends in the VAR
          Cointegration LR Test Based on Trace of the Stochastic Matrix
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        DEGREES
 List of eigenvalues in descending order:
.66798     .48830     .37702     .35390    .016143
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r>= 1       116.0521           70.4900                66.2300
 r<= 1      r>= 2        68.6426           48.8800                45.7000
 r<= 2      r>= 3        39.8317           31.5400                28.7800
 r<= 3      r>= 4        19.4825           17.8600                15.7500
 r<= 4      r = 5          .69980           8.0700                 6.5000
*******************************************************************************
```

Table A3.6: Long Run Cointegrating Vector

```
ML estimates subject to exactly identifying restriction(s)
      Estimates of Restricted Cointegrating Relations (SE's in Brackets)
                         Converged after 2 iterations
      Cointegration with unrestricted intercepts and no trends in the VAR
*******************************************************************************
 43 observations from 1950 to 1992. Order of VAR = 4, chosen r =1.
 List of variables included in the cointegrating vector:
 LNY             INVRAT          WENROL          LNBENROL        DEGREES
*******************************************************************************
 List of imposed restriction(s) on cointegrating vectors:
 a1=1
*******************************************************************************
                  Vector  1
 LNY                  1.0000
                  (   *NONE*)

 INVRAT              -2.5920
                  (   .42198)

 WENROL               .27065
                  (   1.5891)

 LNBENROL            -.33942
                  (   .47602)

 DEGREES            .1096E-4
                  ( .1036E-4)

*******************************************************************************
 LL subject to exactly identifying restrictions= 231.7999
*******************************************************************************
```

Chapter 6

The Contribution of Factor Markets to Economic Growth-Capital and Labour

6.0 Introduction

We have now investigated the impact of science and technology on long run economic growth in some detail, in both theoretical and empirical dimensions. The implication of the theory and the evidence considered we have seen is that the impact of science and technology on growth is positive. And this impact can be viewed both in terms of a technology dimension explicitly, as well as in terms of the contribution of human capital to economic growth directly.

What remains to be addressed is the contribution of the other factors of production to long run economic growth. In fact, in most discussions of economic growth it is these dimensions of the growth process that receive priority attention.

We saw at the outset in Chapter 1 that the three fundamental motor forces of economic growth are growth in capital stock, growth in employment, and growth in technology. Since the focal point of our discussion thus far has been technology, it is time to consider the contribution of the two factors of production to economic growth in South Africa.

We also note right away that investment in physical capital and technological change are connected in terms of at least some of the new endogenous growth theory. As a consequence understanding the driving forces of investment in physical capital is useful not only since it is a direct contributor to economic growth, but also because it provides better insight into determinants of technological progress. And at least potentially there are interactions between employment creation and human capital creation that deserve exploration.

In the case of the labour market, there is the additional consideration that our interest in employment generation lies not only in its contribution to economic growth, but also directly in the importance of employment creation as a means of addressing the welfare of South Africa's citizens directly.

The focus of our discussion here will not be on the contribution of capital and labour to economic growth directly. In Chapter 2 we have already established that both factors of production are important to long run economic growth, though in differing degrees and with variation across economic sectors.

Instead in this chapter we consider some of the factors that determine investment in physical capital stock, and employment in South Africa.

6.1 The capital market: some descriptive evidence

Investment rates in physical capital in South Africa have shown a downward trend for a considerable period of time. Given the centrality of investment in physical capital stock as a determinant of sustainable long run economic growth, such evidence is then a legitimate source of concern.

The descriptive data suggests two distinct forms of structural change in the South African capital market. Relative capital usage by economic sector has been subject to steady long-run changes over the 1970-97 time frame, suggesting that at least some of the changing patterns of capital usage in the economy cannot be exclusively identified with the changing policy environment of the 1990's. But second, a consideration of growth rates in the real capital stock also makes it plausible to suggest that for at least some economic sectors the 1990's also mark a structural break – and the altered policy environment to which the capital market were also subject, may well have been responsible for at least some of these changes. What is most notable about the structural break associated with the 1990's, is its association with the emergence of a series of manufacturing sectors as those which maintained the highest investment rates on average from 1990-97. This marks the first time point in the 1970-97 time frame in which manufacturing sectors constituted such an unambiguous leadership position amongst South African economic sectors.

We also suggest that a possible reason for the restructuring of the South African capital markets may be declining degrees of capital market distortions. What is noticeable about 1970's and 1980's investment rates, is that there is a strong presence of sectors with heavy state-led investment activity amongst sectors maintaining sustained high levels of investment expenditure. Such heavy state-led demand for investment goods may well have had distortionary impacts on the cost of capital. Those sectors with heavy reliance on state intervention show strong declines in their investment activity during the course of the 1990's, to be replaced by sectors dominated by the private sector, and that may well have been crowded out by state activity in earlier decades. This suggests that the increased reliance on market forces in the policy environment of the 1990's may well be stimulating a restructuring of the South African economy and capital market, and which may have the result of improving the efficiency of production in South Africa.

6.1.1 The distribution of capital stock across South Africa's economic sectors

The South African capital market is dominated by a relatively small number of sectors.[1] Thus at the following comparison years, the top five employers of physical capital equipment were:

- In 1970: Electricity, Gas & Water; Agriculture, Forestry & Fishing; Transport, Storage & Communications; Basic Iron & Steel; Wholesale & Retail Trade.

[1] If we ignore the dominant position of Electricity, Gas & Water, however, the preponderance of certain key sectors is perhaps not as severe as for the labour market. See Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000).

- In 1980: Electricity, Gas & Water; Agriculture, Forestry & Fishing; Transport, Storage & Communications; Gold & Uranium Ore Mining; Basic Iron & Steel.
- In 1990: Electricity, Gas & Water; Gold & Uranium Ore Mining; Transport, Storage & Communications; Finance, Insurance & Real Estate; Diamond Mining.
- In 1997: Electricity, Gas & Water; Basic Iron & Steel; ; Finance, Insurance & Real Estate; Transport, Storage & Communications; Diamond Mining.

Electricity, Gas & Water is consistently the single largest employer of Machinery & Equipment in the South African economy, and its lead over the closest rival was extended through the course of the 1970's and 1980's (with the strongest increase manifested during the 1980's), and only the 1990's has seen a narrowing of the gap.

A second feature of the absolute capital employment figures is that the top five capital-using sectors are generally not manufacturing sectors – the one exception being Basic Iron & Steel.[2] Indeed, a rather surprising feature is the preponderance of service sectors amongst sectors with strong exposure to Machinery & Equipment in the South African economy. By contrast both Gold & Uranium Ore Mining, and Diamond & Other Mining show only intermittent presence amongst the top five strongest users of Machinery & Equipment in the South African economy. While this may be an accurate representation of conditions in the mining sector, an alternative explanation may lie in the fact that a considerable proportion of the mining sectors' capital stock is recorded under the Buildings & Construction category excluded from consideration for the present study. As such, the capital stock figures recorded under Machinery & Equipment for mining sectors may be biased downward.

The relative importance of sectors as employers of capital in South Africa therefore needs to be tempered by the realization that in absolute terms, changes in the four to five largest sectors in terms of the stock of Machinery & Equipment employment will have a disproportionately large impact on the level of the aggregate capital stock of the economy. By contrast, strong changes in relative terms in the manufacturing sector will simply not translate into very significant changes in the aggregate stock of Machinery & Equipment in the economy as a whole

Evidence from the absolute level of capital usage as measured by Machinery & Equipment does lend some credence to the possibility that the 1990's and its changed policy environment have had an impact on capital usage in the South African economy. This is most evident in the declining Machinery & Equipment capital stock in Electricity, Gas & Water, and above all the strong increase in the usage of this category of capital by the Basic Iron & Steel, and Diamond Mining sectors. Given that the period after 1985 saw a sharp decrease in the value of the Rand without any recovery post-1990, the

[2] One important caveat is in order here. This is that our data set treats the manufacturing sector at a relatively disaggregated level, while other sectors (services, mining) are treated at a relatively high level of aggregation. Thus the comparison across sectors is placing the manufacturing sector at a disadvantage. We recognize the problem. However, to our knowledge no more disaggregated data than that employed for this study is publicly available on capital stock in non-manufacturing sectors, and we therefore have no means of improving the precision of our comparison.

implication is that the increased exposure to capital in these sectors took place despite the increasing supply price of capital goods.

A last observation is in order. Given the preponderance of a small number of sectors in terms of the employment of Machinery & Equipment in the South African economy, we should note that changing conditions particularly in terms of the real cost of capital, and the productivity of capital in those sectors, are likely to again carry disproportionate consequences for capital market conditions for other sectors. The Electricity, Gas & Water sector in particular may have had a strong influence in determining a higher price for capital stock (in financial markets) to the South African economy for the 1970-97 period than might have prevailed without the strong state-led expansion in this particular sector.

6.1.2 The growth rate of the physical capital stock

An examination of the absolute employment of capital stock in the economy by sector, and changes in the absolute levels of employment of capital stock points to the importance of the proportional growth rate in the capital stock by sector.

Table 6.1 provides details of the average growth rates in the real stock of Machinery & Equipment maintained by sectors, reported in terms of decade averages.[3] The growth in the real stock of capital as measured by Machinery & Equipment for the economy as a whole has shown a sharp downward trend over the 1970-97 period. While the 1970's saw an average[4] growth rate in real capital stock of 7.08%, this has declined to 3.77% and 1.4% in the 1980's and 1990's respectively.

[3] We employ decade averages since the growth rate of the capital stock is subject to very strong fluctuations on an annual basis.
[4] Computed as an average across all sectors. It is thus unweighted for the relative size of capital stock in each of the sectors.

Table 6.1: Proportional Growth Rate: Machinery & Equipment. Figures are average annual percentage growth rates.

A high Rank, indicates a high growth rate	Avg. Growth 1970's	Avg. Growth 1980's	Avg. Growth 1990's	Rank70's	Rank80's	Rank90's
All Economic Activities	7.08	3.77	1.40			
Instruments	-2.33	2.23	-7.79	5	18	1
Gold & Uranium Ore Mining	8.04	8.94	-5.39	31	37	2
Other Maf & Recyc	-2.68	2.03	-4.95	4	16	3
Electricity, Gas & Water	10.96	7.03	-4.16	36	36	4
Agriculture, Forest. & Fish.	5.47	-2.94	-2.72	24	4	5
Wearing Apparel	1.32	2.34	-1.36	17	20	6
Construction	13.48	-1.11	-1.08	39	8	7
Machinery & Appara	0.49	2.47	-0.97	15	21	8
Mining & Quarrying	9.32	6.16	-0.45	34	33	9
Transport, Storage & Commun.	8.15	4.71	-0.13	32	28	10
Electrical Machine	5.58	0.67	-0.01	25	12	11
Textiles & Knit	-4.43	2.50	0.80	1	23	12
Footwear	0.38	0.26	1.45	14	10	13
Coal Mining	15.51	6.33	1.48	40	34	14
Other Chem & Fibre	7.61	0.32	2.07	30	11	15
Tobacco	-0.33	-4.69	3.88	10	2	16
Basic Chemicals	4.24	0.85	4.08	23	14	17
Petroleum Refined	11.02	2.72	4.16	37	25	18
Finance, Insurance, Real Est	5.72	5.86	4.90	26	30	19
Paper	-0.68	18.30	5.05	9	40	20
Furniture	-2.98	9.54	5.12	2	38	21
Diamond & Other Mining	10.00	2.48	5.55	35	22	22
Wholesale & Retail Trade	6.68	0.74	5.66	29	13	23
Fabricated Metals	4.09	-2.47	5.72	22	5	24
Wood	-2.73	2.65	5.98	3	24	25
Other N-Metal Minerals	0.31	2.23	6.45	12	19	26
Motor Vehi & Acces	-1.94	6.08	7.51	6	32	27
Manufacturing	3.99	1.06	8.00	21	15	28
Community, Soc & Per Service	11.49	3.78	8.96	38	27	29
Rubber	0.79	-0.11	9.61	16	9	30
Radio Tv & Communi	6.27	-1.27	9.99	27	7	31
Leather & Tanning	0.35	-2.01	10.44	13	6	32
Plastics	3.25	6.59	10.64	20	35	33
Food	0.12	2.84	10.74	11	26	34
Beverages	3.16	5.89	12.24	19	31	35
Basic Iron & Steel	8.38	-3.52	13.58	33	3	36
Publish & Printing	-1.61	5.66	14.15	8	29	37
Glass	-1.79	10.50	20.38	7	39	38
Bas N-Ferrous Meta	2.12	2.09	25.87	18	17	39
Transport Equipmen	6.47	-10.61	26.19	28	1	40

Source: Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000)

However, this aggregate trend inevitably conceals strong sectoral differences. In particular, the most noticeable structural change in the growth of capital to emerge is that manufacturing sectors that traditionally had relatively low growth rates in comparison with other sectors in the economy, during the course of the 1990's have shown the most rapid expansion of capital stock in the South African economy.

Thus the ten sectors of the South African economy with the most rapidly growing capital stock in the South African economy in the 1990's were manufacturing sectors (see the column marked Rank90's). By contrast, the 1980's not only saw a very severe negative impact on numerous manufacturing sectors in terms of the growth of their capital stock, but saw a number of sectors with strong state involvement (Electricity, Gas & Water), or strong mining presence (Gold & Uranium, Coal) amongst the leading investors in capital stock.

The 1970's show an even more marked bias toward the strongest growth in capital stock for sectors with a strong mining bias, or heavy state involvement (the ten sectors with the strongest growth rate in capital stock during the course of the 1970's were: Electricity, Gas & Water, Transport, Storage & Communication, Petroleum Refining (hence SASOL), Construction, Gold & Uranium, Coal, Diamond Mining, Community, Social & Personal Services, Basic Iron & Steel, and Other Chemicals & Fibers).

The evidence is such as to suggest the plausibility of a distortion in the South African capital markets due to the heavy reliance on the mining of primary commodities during earlier phases of development of the South African economy, and the presence of substantial government-led investment in capital stock in a number of core sectors (Electricity, Gas & Water, Petroleum Refining). The gradual disappearance of a reliance on primary commodities in the South African economy, and reduced state involvement in "strategic" investments at least plausibly has triggered a restructuring of the South African capital market. In particular, sectors whose access to capital might have been limited due to the demand emerging from mining and state sectors (both increasing the financial cost of entry into financial capital markets), have shown strong growth in their capital stock.

As can be argued for the South African labour market therefore,[5] the evidence suggests that the 1990's, with their greater reliance on market forces and a decreased reliance on state led investment, are leading to a restructuring of the South African capital markets. Since restructuring of capital markets inevitably takes time to accomplish, such a process is likely to be in its early phases.

The encouraging implication of such a line of reasoning (if correct), is that one reason why investment expenditure in South Africa is currently at such low levels is simply that strong growth rates in capital stock are being maintained in sectors with low absolute levels of capital stock. Such sectors may have been prevented from increasing their capital stock from past distortions in the economy's capital markets. But over time, if the

[5] See Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000) – though for the labour markets the reasons for the restructuring are different.

restructuring of the capital markets in line with new patterns of development, and greater reliance on market forces is allowed to proceed, the absolute volume as well as the proportional increases in manufacturing sector capital stock may well come to raise the aggregate growth rate of the economy's capital stock to more reassuring levels than are being currently maintained.

An alternative explanation might be that relative factor prices are forcing a switch to capital in place of labour.[6] However, since of the ten sectors with the strongest growth in capital stock, five experienced negative growth rates in real per labourer remuneration over the 1970-97 period,[7] and three further sectors[8] experienced growth rates in labour productivity that exceeded those of the real wage, this may not prove to constitute a general explanation of the structural change in capital employment noted.[9]

At the very least, both the move toward a smaller reliance on primary commodities in the South African economy over the 1970 – 1990 period, and greater emphasis on market forces in the policy environment of the 1990's, are at least plausibly the reason for the restructuring of the South African capital market, and we will return to this question in later sections.

6.1.3 The investment rate by economic sector

A crucial consideration for South African capital markets is what proportion of total real output is reinvested in productive capacity in the form of Machinery & Equipment. For this purpose we compute the net investment rate[10] for each economic sector.[11]

Table 6.2 reports decade averages for the net investment rate, together with a ranking of economic sectors in terms of their investment rate.[12]

We note immediately that the investment rate evidence for the economy as a whole confirms the pessimistic evidence gained from the growth in capital stock data, and if anything darkens the picture yet further. For the economy as a whole the investment rate throughout the 1970-97 period has been poor, remaining at 2% throughout the 1970's and 1980's, and declining yet further to 1% during the course of the 1990's.[13]

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[6] In other words a rising real cost of labour may be making it advantageous to switch from labour- to capital-intensive production.
[7] TV, Radio & Communications Equipment, Leather & Leather Products, Basic Iron & Steel, Publishing & Printing, and Transport Equipment.
[8] Plastics, Beverages, and Basic Non-Ferrous Metals.
[9] For a more detailed discussion, see Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000).
[10] The ratio of net investment to real value added. Net investment is corrected for depreciation.
[11] One limitation we face is that the data currently is not yet consistently available by category for both RGDP and Real Net Investment for all South African economic sectors. This means that consistent investment rate ratios were computable for only 37 sectors in the economy.
[12] Again decade averages are employed in order to deal with the problem of volatility in investment.
[13] By way of a final reminder, in case these rates look low. Recall that our investment rate is computed purely for the Machinery & Equipment component of capital stock, not total capital stock.

Table 6.2: Investment Rates

high rank indicates high investment rate	1970'sAvg	1980'sAvg	1990'sAvg	Rank70's	Rank80's	Rank90's
Electricity, gas & water	0.26	0.25	-0.13	37	36	1
Gold & uranium ore mining	0.02	0.05	-0.04	22	34	2
Agriculture, forestry & fishing	0.04	-0.02	-0.02	31	2	3
Professional & scientific equipment	0.01	0.01	-0.01	15	26	4
Building construction	0.04	-0.01	-0.01	28	4	5
Other industries	-0.01	0.00	0.00	2	18	6
Electrical machinery	0.02	0.00	0.00	24	10	7
Transport, storage & communication	0.04	0.03	0.00	29	32	8
Wearing apparel	0.01	0.00	0.00	16	19	9
Machinery & equipment	0.00	0.00	0.00	7	8	10
Textiles	-0.01	0.01	0.00	1	21	11
Footwear	0.00	0.00	0.00	12	17	12
Tobacco	0.00	0.00	0.00	10	6	13
Furniture	0.00	0.01	0.01	5	25	14
Coal mining	0.04	0.03	0.01	30	33	15
Wholesale & retail trade	0.01	0.00	0.01	20	16	16
Other chemicals & man-made fibres	0.08	0.00	0.01	35	9	17
Metal products excluding machinery	0.01	0.00	0.01	18	5	18
Wood & wood products	0.00	0.00	0.01	11	20	19
Basic chemicals	0.02	0.00	0.02	23	14	20
Leather & leather products	0.00	0.00	0.02	13	15	21
Finance & insurance	0.03	0.02	0.02	27	30	22
Motor vehicles, parts & accessories	0.00	0.01	0.02	8	22	23
Television, radio & communication equipment	0.01	0.00	0.03	21	13	24
Paper & paper products	0.01	0.06	0.03	17	35	25
Non-metallic minerals	0.00	0.00	0.03	6	11	26
Printing, publishing & recorded media	0.00	0.01	0.04	3	24	27
Rubber products	0.01	0.00	0.04	14	12	28
Plastic products	0.03	0.02	0.05	26	31	29
Food	0.00	0.01	0.05	9	23	30
Other mining	0.07	0.02	0.06	33	28	31
Beverages	0.02	0.02	0.07	25	27	32
Coke & refined petroleum products	0.21	0.29	0.08	36	37	33
Glass & glass products	0.00	0.02	0.08	4	29	34
Other transport equipment	0.01	-0.01	0.09	19	3	35
Basic non-ferrous metals	0.06	0.00	0.13	32	7	36
Basic iron & steel	0.07	-0.04	0.16	34	1	37
All Economic Activity	0.02	0.02	0.01			

Source: Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000)

But as for the growth in the aggregate capital stock, the aggregate investment rate picture strongly obscures strong sectoral differences, and evidence that the 1990's have begun to see evidence of a restructuring of the South African economy in response to a declining primary commodity reliance in the economy as a whole, and perhaps reduced levels of distortion emerging from government-led investment projects.

As for the growth in the capital stock, what is noticeable is the emergence during the course of the 1990's of the manufacturing sector as leader in investment rates in a number of its sub-sectors.

Unsurprisingly, a number of the sectors that feature in the top-ten ranking in terms of growth in the Machinery & Equipment capital stock measure, also emerge as sectors with high investment rates.[14] Symmetrically, a number of mining sectors (see for instance Gold & Uranium Ore), and sectors with strong state-led investment (see for instance Electricity, Gas & Water) show strong declines in their investment rates during the course of the 1990's.

Indeed, for a number of manufacturing sectors the average investment rate in Machinery & Equipment has been in excess of 6% per annum, in some cases substantially so. Thus Beverages (7%), Coke & refined petroleum products (8%), Glass & glass products (8%), Other transport equipment (9%), Basic non-ferrous metals (13%), Basic iron & steel (16%) have all maintained very healthy investment rates throughout the course of the 1990's. By contrast the 1980's proved a period of exceptionally low investment rates, particularly for the manufacturing sectors – perhaps reflecting the high levels of political uncertainty that prevailed during this decade. Given the improved political climate, the prospects of improved investment rates has not only emerged, but been realized for a number of manufacturing sectors.

Once again the evidence is such as to suggest the plausibility of a distortion in the South African capital markets due to the heavy reliance on the mining of primary commodities during earlier phases of development of the South African economy, and the presence of substantial government-led investment in capital stock in a number of core sectors (Electricity, Gas & Water, Petroleum Refining). The gradual disappearance of a reliance on primary commodities in the South African economy, and reduced state involvement in "strategic" investments at least plausibly has triggered a restructuring of the South African capital market. In particular, sectors whose access to capital might have been limited due to the demand emerging from mining and state sectors (both increasing the financial cost of entry into financial capital markets), have shown strong growth in their capital stock.

The implication is that the 1990's, with their greater reliance on market forces and a decreased reliance on state led investment, are leading to a restructuring of the South African capital markets.

[14] The sectors that are exceptional are Coke & refined petroleum products – but this may be due to a reclassification of the sector – as it was previously classed as the Refined petroleum sector. Also, Other Mining maintains a higher investment rate ranking, than it does a growth in real capital stock ranking.

As for the growth in real capital stock therefore, the encouraging implication of such a line of reasoning (if correct), is that one reason why investment expenditure in South Africa is currently at such low levels is simply that strong growth rates in capital stock are being maintained in sectors with low absolute levels of capital stock. Such sectors may have been prevented from increasing their capital stock due to past distortions in the economy's capital markets. But over time, if the restructuring of the capital markets in line with new patterns of development, and greater reliance on market forces is allowed to proceed, the absolute volume as well as the proportional increases in manufacturing sector capital stock may well come to raise the aggregate growth rate of the economy's capital stock to more reassuring levels than are being currently maintained.

6.1.4 Links between capital productivity, real cost of capital and capital usage

In **Table 6.3** we report the correlations between real user cost of capital and both the investment rate, and the growth rate of the real capital stock of each sector, over the full 1970-97 period.

While for the economy as a whole the correlation is only –0.54 for the Investment Rate, and –0.53 for the growth rate in real capital stock, the majority of economic sectors demonstrate a negative correlation between user cost of capital and growth in capital stock that is stronger than the average. In effect, the economy-wide average is lowered by the presence of a few outlier sectors. [15]

In particular, Textiles & Knitwear, shows a positive correlation between the cost of capital and investment that would not be predicted by economic theory. All other sectors of the economy show the negative association between the marginal cost and marginal changes in the use of capital that economic theory anticipates.

Indeed, in the case of a number of sectors this negative correlation is particularly strong. For Construction (-0.88, -0.84), Wholesale & Retail Trade (-0.82, -0.83), Agriculture, Forestry & Fishing (-0.74, -0.82), Gold & Uranium Ore Mining (-0.84, -0.79), and Electricity, Gas & Water (-0.79, -0.77) the association is particularly strong.

Thus over time, and for most sectors, the real user cost of capital does carry the potential of constituting at least one of the major determinants of investment expenditure in the South African economy – precisely as would be anticipated by economic theory.

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[15] The median for the correlation between user cost and investment rate is –0.59, and the correlation between user cost and the growth rate of the real capital stock –0.54.

Table 6.3: Correlations: Investment Rate and Real Growth in Capital vs Real User Cost of Capital

	User Cost vs Investment Rate	User Cost vs Growth in Capital Stock
Agriculture, Forest. & Fish	-0.74	-0.82
Coal Mining	-0.59	-0.47
Gold & Uranium Ore Mining	-0.84	-0.79
Diamond & Other Mining	-0.41	-0.49
Food	-0.62	-0.60
Beverages	-0.64	-0.48
Tobacco	-0.30	-0.22
Textiles & Knit	0.05	0.03
Wearing Apparel	-0.53	-0.37
Leather & Tanning	-0.44	-0.42
Footwear	-0.30	-0.29
Wood	-0.60	-0.54
Paper	-0.49	-0.49
Publish & Printing	-0.62	-0.56
Petroleum Refined	-0.40	-0.37
Basic Chemicals	-0.50	-0.54
Other Chem & Fibre	-0.43	-0.28
Rubber	-0.64	-0.62
Plastics	-0.56	-0.47
Glass	-0.59	-0.57
Other N-Metal Minerals	-0.60	-0.62
Basic Iron & Steel	-0.45	-0.48
Bas N-Ferrous Meta	-0.52	-0.40
Fabricated Metals	-0.62	-0.63
Machinery & Appara	-0.56	-0.48
Electrical Machine	-0.74	-0.66
Radio Tv & Communi	-0.69	-0.67
Instruments	-0.31	-0.30
Motor Vehi & Acces	-0.57	-0.52
Transport Equipmen	-0.66	-0.70
Furniture	-0.67	-0.57
Other Maf & Recyc	-0.34	-0.48
Electricity, Gas & Water	-0.79	-0.77
Construction	-0.88	-0.84
Wholesale & Retail Trade	-0.82	-0.83
Transport, Storage & Commun.	-0.75	-0.75
Finance, Insurance, Real Est	-0.77	-0.69
All Economic Activities	-0.54	-0.53
Average	-0.57	-0.53

Source: Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000)

Economic theory would anticipate a link between real capital productivity and the real user cost of capital. One measure of capital productivity is provided by the ratio of output to capital stock. **Table 6.4** reports the correlation between real capital productivity and the real user cost of capital by economic sector for which the relevant data is available.

It is noticeable that for most sectors the correlation between capital productivity and the real user cost of capital is not only positive, but frequently very strong. For one sector[16] the correlation lies above +0.9, for six[17] sectors above +0.8, for seven[18] above +0.7, and for fourteen[19] is equal to or above +0.50. Thus for 28 out of 37 sectors for which the requisite data is available, the correlation conforms not only to economic theory, but is reasonably strong – if it is borne in mind that economic theory assumes all other influences on the real user cost to be held constant in predicting a positive correlation between the productivity and the cost of factors of production.

For only five[20] sectors does the correlation lie between 0 and +0.5, and is the link predicted by economic theory thus relatively weak – and five[21] more sectors had the negative correlation between capital productivity and the real user cost contradicting economic theory.

Noteworthy is the distinct performance of these groupings of economic sectors in terms of investment rates. The grouping of sectors with the strongest correlation between the real user cost of capital and capital productivity, viz. in excess of +0.8, also shows the highest average growth rate in real capital stock over the 1970-97 period. For average investment rates computed over the full 1970-97 time frame, it is not as clear that the group of sectors with a strong positive correlation between real user cost of capital and capital productivity also has the highest investment rate. Nor does the average 1970-97 growth rate in real capital stock unambiguously decline as we move to sectoral groupings with lower correlations between real user cost of capital and capital productivity.

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[16] Basic Non-Ferrous Metals.

[17] In declining order: Publishing & Printing, Transport equipment, Beverages, Food, Other Chemicals & Man-made Fibers, Leather & Tanning.

[18] In declining order: Rubber, Wood, Footwear, Fabricated Metals, Other Manufacturing & Recycling, Plastics, Instruments.

[19] In declining order: Other Non-Metallic Minerals, Basic Iron & Steel, Basic Chemicals, Furniture, Motor Vehicles & Accessories, Coal Mining, Glass, Textiles & Knit, Agriculture, Forestry & Fishing, Radio, TV & Communications Equipment, Electrical Machinery, Wearing Apparel, Petroleum Refined, Electricity, Gas & Water.

[20] In declining order: Tobacco, Wholesale & Retail Trade, Paper, Finance, Insurance, Real Estate.

[21] In declining order: Diamond & Other Mining, Transport, Storage & Communications, Gold & Uranium Ore Mining, Machinery & Apparatus, Construction.

Table 6.4: Correlations

	Cor: uc vs y/k	Average Investment Rate: 1970-97	Average Investment Rate: 1990-97	Average Growth in Real Capital: 1970-97	Average Growth in Real Capital: 1970-97
Bas N-Ferrous Metal	0.92	0.06	0.13	0.09	0.26
Publish & Printing	0.87	0.02	0.04	0.06	0.14
Transport Equipmen	0.84	0.03	0.09	0.07	0.27
Beverages	0.84	0.03	0.07	0.07	0.12
Food	0.84	0.02	0.05	0.04	0.11
Other Chem & Fibre	0.81	0.03	0.01	0.03	0.02
Leather & Tanning	0.80	0.01	0.02	0.05	0.13
Rubber	0.79	0.01	0.04	0.03	0.10
Wood	0.78	0.01	0.01	0.02	0.06
Footwear	0.75	0.00	0.00	0.02	0.03
Fabricated Metals	0.75	0.00	0.01	0.02	0.06
Other Maf & Recyc	0.74	0.00	0.00	-0.01	-0.04
Plastics	0.73	0.03	0.05	0.07	0.11
Instruments	0.70	0.00	-0.01	0.00	-0.06
Other N-Metal Minerals	0.67	0.01	0.03	0.03	0.07
Basic Iron & Steel	0.65	0.06	0.16	0.06	0.14
Basic Chemicals	0.59	0.01	0.02	0.03	0.04
Furniture	0.58	0.01	0.01	0.05	0.06
Motor Vehi & Acces	0.58	0.01	0.02	0.04	0.08
Coal Mining	0.56	0.03	0.01	0.08	0.02
Glass	0.54	0.03	0.08	0.10	0.21
Textiles & Knit	0.54	0.00	0.00	0.00	0.01
Agriculture, Forest. & Fish.	0.53	0.00	-0.02	0.00	-0.03
Radio Tv & Communi	0.52	0.01	0.03	0.05	0.11
Electrical Machine	0.52	0.01	0.00	0.02	0.00
Wearing Apparel	0.52	0.00	0.00	0.01	-0.01
Petroleum Refined	0.52	0.20	0.08	0.06	0.04
Electricity, Gas & Water	0.50	0.14	-0.13	0.05	-0.04
Tobacco	0.49	0.00	0.00	0.01	0.05
Wholesale & Retail Trade	0.47	0.01	0.01	0.04	0.06
Paper	0.35	0.03	0.03	0.08	0.05
Finance, Insurance, Real Est	0.28	0.02	0.02	0.06	0.05
Diamond & Other Mining	-0.04	0.05	0.06	0.06	0.06
Transport, Storage & Commun.	-0.05	0.02	0.00	0.04	0.00
Gold & Uranium Ore Mining	-0.08	0.01	-0.04	0.04	-0.05
Machinery & Appara	-0.50	0.00	0.00	0.01	-0.01
Construction	-0.56	0.01	-0.01	0.04	-0.01

Source: Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000)

But it is worth recalling that the analysis of the preceding sections has suggested that market distortions in South African capital markets appear to have been falling over time, leading to a reallocation of capital stock. If so, the effect of the theoretically appropriate relationship between user cost of capital and capital productivity should have had desirable impacts on the investment rate and the average growth rate in the real capital stock in later time periods rather than earlier ones. This is indeed borne out by the evidence:

- For the seven sectors with the strongest correlations between the real user cost of capital and capital productivity, the average investment rate was 6%, while the average growth rate in real capital stock was 15%, over the 1990-97 period.
- For the seven sectors with correlations between the real user cost of capital and capital productivity between 0.7 and 0.8, the average investment rate was 1%, while the average growth rate in real capital stock was 4%, over the 1990-97 period.
- For the fourteen sectors with correlations between the real user cost of capital and capital productivity between 0.5 and 0.7, the average investment rate was 2%, while the average growth rate in real capital stock was 5%, over the 1990-97 period.
- For the five sectors with correlations between the real user cost of capital and capital productivity between 0 and 0.5, the average investment rate was 2%, while the average growth rate in real capital stock was 5%, over the 1990-97 period.
- For the five sectors with negative correlations between the real user cost of capital and capital productivity, the average investment rate was 0%, while the average growth rate in real capital stock was 0%, over the 1990-97 period.

With the exception of perhaps only the sector grouping with a correlation between +0.7 and +0.8, the evidence appears to suggest the presence of declining investment rates in sectors as they conform less closely to the dictates of standard economic theory. Where the real user cost of capital is less closely linked to real capital productivity, the growth in capital also tends to be lower.

Two implications appear to flow from such evidence. The first is that for purposes of policy intervention in South African capital markets, "well-functioning" capital markets, defined as those that link factor rewards to factor productivity in accordance with the requisites of economic theory, appear to be more likely to generate higher investment rates. But second, the point raised a number of times through the course of the discussion in this paper, viz. that South African capital markets may well have been subject to distortions that may have declined over time, again is consistent with the evidence presented above.

6.1.5 Evaluation of the descriptive evidence

Correlation coefficients between user costs of capital and capital usage (as embodied in the investment rate and growth in capital stock of Machinery & Equipment) suggest that over time, and for most sectors, the real user cost of capital seems to carry the potential of constituting at least one of the major determinants of investment expenditure in the South African economy - as would be anticipated by economic theory.

The user cost of capital appears to have formed a significant constraint on investment in real capital stock during the course of the 1970's, but the severity of this constraint declined during the course of the 1980's and 1990's. It could therefore be argued that the state in its effort to direct investment in South Africa may have raised the user cost of capital, and that the steady withdrawal of the state from the capital markets and increased reliance on market forces over time may have lowered such distortions. The disappearance of this negative association may also be a reflection of the negative sentiment generated by the increased level of political uncertainty that has characterized the 1980's, and the political transition of the 1990's. In other words, the importance of the real user costs of capital as an explanatory variable of investment behaviour may to some degree have been eroded by a political uncertainty factor.

The descriptive analysis of capital productivity, defined here as the ratio of value added to the capital stock of Machinery & Equipment, suggests that while the 1970's and 1980's showed strong deviations in the distribution of capital across sectors in the economy, such that the productivity of capital was strongly differentiated across sectors, subsequent reallocation of capital stock in the economy appears to have equalized the productivity of capital across sectors. From a theoretical point we would anticipate that more perfect capital markets would serve to equalize the marginal product of capital across sectors, thereby generating more efficient allocation of capital stock.

Examination of correlation coefficients between real user costs of capital and various measures of capital stock growth suggest the presence of declining investment rates in sectors as they conform less closely to the dictates of standard economic theory. In other words, where the real user cost of capital is less closely linked to real capital productivity, the growth in capital also tends to be lower.

For purposes of policy intervention in South African capital markets, “well-functioning” capital markets, defined as those that more closely link factor rewards to factor productivity, are those that are likely to realize strong and sustainable investment performance. It is left to subsequent, detailed econometric work to explore these relations in greater detail.

6.2 An econometric examination of South Africa’s investment function[22]

Given the importance of the investment rate to long run growth, it is vital that we develop a deeper understanding of the determinants of investment in South Africa.

The modern theory of investment expenditure has come to be focussed on the effect of irreversibility and uncertainty. While recognition of the importance of these two determinants of a changing size of the capital stock have been long recognized, recent contributions to the theory have provided a more comprehensive understanding of the issues. Most important of these has been that the impact of uncertainty on investment is ambiguous instead of unambiguously positive as the early literature suggested. As a

[22] For a more detailed discussion of the issues raised in this section see Fedderke (2000a).

generalization of the same point, our understanding of the dynamics of the investment process has also been enhanced.

Early work on the link between investment and uncertainty recognized that uncertainty would be of material concern whenever firms make irreversible commitments before the state of the world relevant to the pay off that is to be generated by the commitment is realized. The main finding from this early literature was that under constant returns to scale production technology, and assuming uncertainty to attach to output price, the marginal product of capital is convex in the uncertain output price, such that rising uncertainty raises the marginal valuation of an additional unit of capital and hence stimulates investment.[23]

The modern literature has emphasized that such a result need not hold under asymmetric adjustment costs. The discussion tends to be cast in terms of a stochastic dynamic environment. Irreversibility of investment decisions and the possibility of waiting, means that the decision not to invest at the present point in time can be thought of as the purchase of an option. The option has value since waiting to invest in an uncertain environment has information value also, and hence investing now rather than tomorrow has an opportunity cost associated with it. One of the core insights of the modern literature is that uncertainty generates a reward for waiting, and hence that increases in uncertainty will potentially lower investment. Thus the modern literature on uncertainty generates two countervailing effects on investment: a positive impulse through a rising profitability of investment (since investing may carry information), and a negative impulse arising from the opportunity cost of investing now rather than in the future (since waiting may carry information). The net effect of uncertainty on investment is thus ambiguous, and a matter to be empirically determined.[24]

Since the modern theory examines the effect of uncertainty on the threshold at which investment is triggered, the focus of the theory is strictly speaking on the dynamics of the process, rather than on the long run equilibrium. A rise in uncertainty raises the threshold at which investment will be triggered, suggesting a negative link between investment and uncertainty. However, uncertainty may also raise the *volatility* of profit flows, such that the higher threshold level of profitability is satisfied more frequently than in a certain environment, generating more frequent bursts of investment expenditure. In this case, the effect of increased uncertainty may be to raise investment expenditure on average. Thus aggregate investment expenditure during any discrete time interval may or may not increase, though it seems certain that the dynamics of the process will manifest greater lumpiness.

In the present discussion we examine the determinants of investment expenditure. The analysis presents a number of advances over the previous literature. *First*, estimation extends to an uncertainty-augmented version of the model in order to be able to identify the impact of uncertainty on investment expenditure. In doing so, it distinguishes between

[23] For a review of the early literature, such as Hartman (1972) and Nickel (1978), and Aiginger (1987).
[24] A comprehensive coverage of the modern debate can be found in Dixit (1994), while Price (1995) also provides a useful introduction to the issues.

sectoral and systemic uncertainty, and their impact. *Second*, estimation employs dynamic heterogeneous panel data analysis on the South African manufacturing sector, allowing us to explore the possibility of heterogeneous rather than uniform responses to uncertainty across economic sectors. Note the call in a recent NBER Working Paper by Mairesse (1999) for the conduct of just this type of investigation into US manufacturing investment. Given the base of modern investment theory in dynamic stochastic processes, such an extension has immediate justification. To our knowledge, such a study does not exist at present. In this sense therefore the present analysis also represents an advance on the debate as it currently stands in the US context.

Use of the South African manufacturing industry provides the opportunity for a useful extension to the debate on the investment-uncertainty nexus. South African manufacturing industry has faced both sectorally specific uncertainty imparted by the impact of substantial government intervention in the form of "strategic" investment projects, many of which proved unsustainable in the long run, and carried implications for both the user cost of capital and the level of demand for the output of manufacturing sectors.[25] But South African manufacturing has also seen strong fluctuation in the level of what we term "aggregate" or systemic uncertainty which emanated both from instability of the political dispensation,[26] and from property rights that suffered from substantial restrictions until South Africa's very recent history.[27] The present study has at its disposal unique data allowing for a clear identification of the systemic uncertainty in South Africa, both economic and institutional, thus allowing a deepening of our understanding of the impact of this type of uncertainty. To our knowledge, no other study to date has undertaken such an examination in a panel data context, and certainly not in a dynamic panel data context.

For estimation purposes we use the specification provided by:

$$\ln I_t = b_0 + b_1 d\ln Y_t^e + b_2 d\ln uc_t + b_3\sigma^2_{sct,t} + b_4\sigma^2_{sys,t} + b_5 Z_t + \varepsilon_t \tag{1}$$

Our measure of investment, lnI, is restricted to fixed capital stock strictly defined, and is given by the investment rate defined by *net* changes in the stock of machinery and equipment of South African three digit manufacturing sectors. The user cost of capital, dlnuc, is that computed for manufacturing sectors in Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000), and incorporates the impact of the real domestic short term interest rate, the depreciation rate of capital stock, and the corporate tax rate. The output measure to enter the empirical specification is the *expected* change of output (denoted $d\ln Y^e$) - an unobservable magnitude. Various studies deal with this unobservable magnitude in different ways. In some, the actual current change in output is employed (see for example Ferderer (1993). In others an econometric construct is employed in

[25] See the more detailed discussion above and in Fedderke, Henderson, Kayemba, Mariotti and Vaze (2000).
[26] Even the long-awaited democratic transition has not entirely settled such uncertainty, since any new political order requires time in order to develop and settle into the new informal and implicit rules of the game.
[27] See the discussion in Fedderke, De Kadt and Luiz (1999a).

order to represent expected changes in output. For instance, Price (1995) employs a measure of capacity utilization, defined as the deviation of actual from capacity output, such that output in excess of capacity will trigger investment. In the present study we employ a measure of the $dlnY^e$ by using the log change in the capacity utilization.

Appropriate measures of risk and estimation in their presence are again the subject of an independent literature.[28] In order to obtain a measure of user cost uncertainty Ferderer (1993) employs a risk premium imputed to market interest rate on the basis of an ARCH representation of the spot market yield. In related vein, Price (1995) employs a GARCH representation of the conditional variance of output as a measure of output uncertainty.

In the present study we employ two measures of uncertainty, one of which has not been previously available to researchers. The first constitutes a measure of sectoral uncertainty. Given the relatively small time run available for each manufacturing sector, ARCH or GARCH representations of conditional variances are of limited use. Hence we employ a sectoral measure of uncertainty given by deviations of output from potential output, specified in log scale. The sectoral measure of uncertainty is thus one that proxies for the volatility of output, and is denoted by σ_{sct}^2 .

But estimations will also include a measure of systemic uncertainty provided by an index of political instability obtained from Fedderke, De Kadt and Luiz (1999a), and illustrated in **Figure 6.1**. Justification of its use lies in the importance of political instability in South Africa over the 1970-97 period. The index is a weighted average of 11 indicators of repressive state response to pressures for political reform, adjusted in accordance with the advice of leading political scientists in South Africa.[29] The systemic measure of uncertainty is denoted by σ_{sys}^2.

[28] See for instance Engle (1987), and Pagan (1988).

[29] While this measure will be employed as the base measure of systemic uncertainty, we tested for the sensitivity of results to alternative measures of systemic uncertainty, including a range of labour unrest variables, and weighted averages of the political and labour unrest variables. Results did not prove to be sensitive to these alternative measures. One possible reason for this is that for the time period under consideration, labour unrest in South Africa was not independent of political instability.

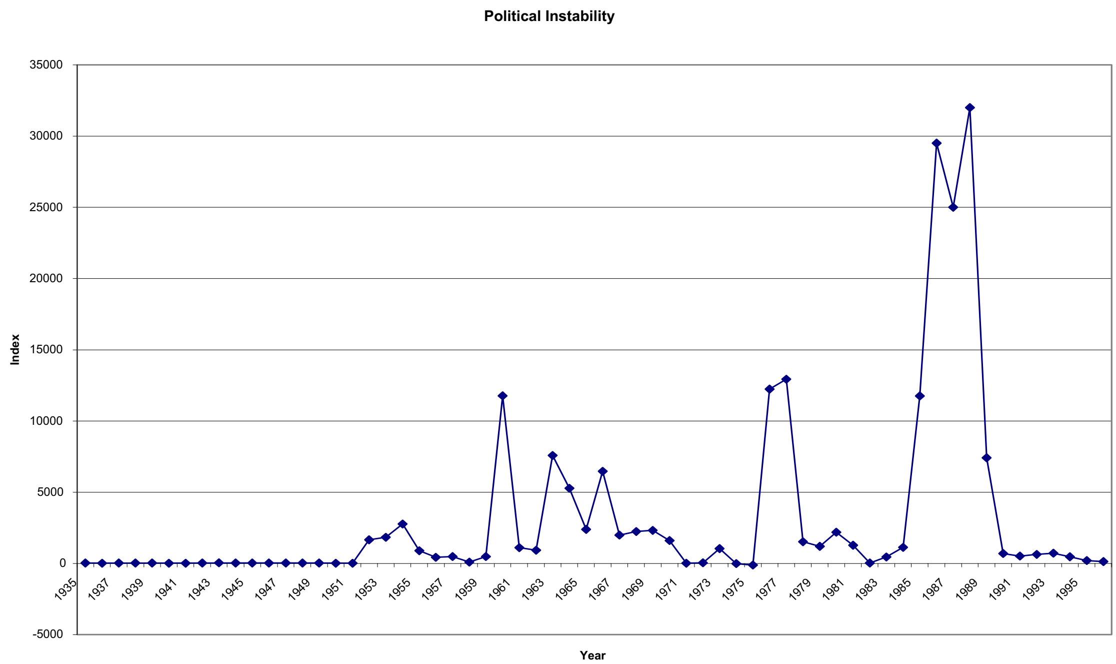

Figure 6.1: Political Instability Index. Source : Fedderke, De Kadt and Luiz (1999a)

We also test for the impact of additional factors, Z_t, deemed to be of potential importance in the South African context. We control for the impact of credit rationing by testing the significance of a proxy for the availability of internal funding. This is provided by the log of the real gross operating surplus. Openness of a sector we control for by the ratio of imports and exports to total value added of the sector. The rate of return on capital stock is proxied for by the ratio of the real gross operating surplus to total capital stock. Technological progress we obtain from a sectoral measure of total factor productivity growth, computed from factor shares in output. The skills intensity of the labour force composition, is obtained from the ratio of highly skilled and skilled workers, to unskilled workers in each manufacturing sector. Finally we test for the impact of possible government crowd-in or crowd-out by the magnitude of government investment expenditure.

In estimation we employed the dynamic heterogeneous panel estimation technique we have already employed in a previous chapter. (See the discussion in Appendix 1 of Chapter 4[30]) Results from the preferred estimation are presented in **Table 6.5.**

[30] More detailed discussion of the estimation results can be found in Fedderke (2000).

Table 6.5: PMGE Estimation Results. Figures in round parentheses denote standard errors. Statistical significance denoted by *.

	INVESTMENT
Expected Output Measure	0.75*
	(.23)
Real User Cost Measure	-0.10*
	(.03)
Sectoral Uncertainty	-0.23*
	(.11)
Systemic Uncertainty	-0.04*
	(.00)
Speed of Adjustment to Equilibrium	-0.72*
	(.10)

Our preferred results imply that:

- A 1% increase in the growth rate of capacity utilization, the proxy for the expected rate of return on capital stock, would lead to a 0.75 percentage point increase in the equilibrium investment rate.

- A 1% increase in the growth rate of the user cost of capital would lead to a 0.10 percentage point fall in the equilibrium investment rate.

- A 1% increase in the sectoral uncertainty variable would lead to a 0.23 percentage point fall in the equilibrium investment rate.

- A 1% increase in the systemic uncertainty variable would lead to a 0.04 percentage point fall in the equilibrium investment rate.

The central finding of the present section is that uncertainty exercises a statistically significant effect. Moreover, the effect of uncertainty on investment is unambiguously such as to lower investment rates. Lastly, in establishing the impact of uncertainty on investment expenditure, it is vital that the impact of sectoral and systemic uncertainty be separated. Both systemic and sectoral uncertainty appears to be pertinent for investment - though systemic uncertainty has an impact on a wider range of sectors than does sectoral uncertainty.

Finally we investigate the impact of a range of additional potential determinants of investment expenditure in the South African manufacturing sector. These are the impact of:

- *credit rationing*, proxied by the availability of internal funding, given by the log change of the gross operating surplus in the present instance;

- the impact of *trade*, controlled for by the ratio of imports and exports to total value added;

- the impact of *technological progress*, controlled for by the growth in total factor productivity on a sectoral level;

- the impact of the *skills composition* of the labour force, controlled for by the log ratio of skilled to unskilled labour;

- the *rate of return on capital*, controlled for by the log change of the ratio of real net operating surplus to total fixed capital stock;

- the *real cost of labour*, proxied by the log change of real per labourer remuneration;

- a *government crowd-in* effect, controlled for by the log of the level of real government investment expenditure.

In **Table 6.6** we present the coefficients of these additional variables.[31]

We find that technological progress *per se* does not appear to have influenced the investment rate in manufacturing industry significantly. Openness also does not appear to have significantly affected the investment rate of the South African manufacturing sector. One interpretation that can be attached to the insignificance of the openness variable is that it adds little information over and above the change in capacity utilization. Since openness serves as an indicator of demand for output, inclusion of both variables does not serve to add much additional information. Nevertheless the finding does serve to confirm that exposure of manufacturing sectors to international output markets has not served to lower investment rates.

The last insignificant Z_t variable is the log change of real labour remuneration. While there are some *a priori* grounds for supposing that it is relative factor prices that might drive the investment rate in fixed capital, we find that only the real user cost of capital exerts an influence on investment rates, while the real cost of the potential substitute factor of production proves to be statistically insignificant. The implication thus is that an increasing real cost of labour does not increase capital intensity of production in the manufacturing sector, though of course it may (and does) decrease the usage of labour in manufacturing industry.

[31] Again, full results are available in Fedderke (2000a).

Table 6.6: Coefficients of additional Z_t variables controlled for. Figures in round parentheses denote standard errors. Statistical significance denoted by *.

	Z_t Coefficients
Credit Rationing	0.05
	(.05)
Openness	0.003
	(.008)
Technological Progress	-0.02
	(.06)
Skills Ratio	-0.08*
	(.02)
Rate of Return on Capital	0.09*
	(.03)
Real Wage	-0.06
	(.21)
Government Investment	0.04*
	(.02)

The positive and significant impact of changes in the rate of return on capital conforms to prior expectations. Increasing return on capital generates higher rates of investment. The implication here is that the capacity utilization variable alone does not suffice to capture the expected rate of return on capital stock for the South African manufacturing sector. Thus the change in the rate of return on capital does appear to add information over and above that already contained in the proxy employed for $dlnY^e$.

The coefficient on the skills ratio is negative and significant for South African manufacturing industry. The most immediate implication might appear to be that skilled labour and capital goods are substitutes, such that greater skill-intensity of production requires smaller capital stocks in production. However, care should be taken in the interpretation of this variable. This arises since the long history of South African underinvestment in human capital may have come to create a supply side constraint on industries that rely on a strong complementarity between human and physical capital. The negative sign on the skills ratio may be a reflection of the fact that industries with a strong human capital requirement have not been able to hire the requisite form of labour, and have therefore maintained a lower investment rate. Thus the poorly conceived educational policies of past South African governments may have served to generate the additional negative consequence of lowering investment in knowledge intensive sectors of the economy.

Finally, we observe that the estimation incorporating government investment expenditure does find some evidence in favour of crowd-in effects. The coefficient on the variable is both significant and of positive sign. Two considerations should cause the reader to exercise caution in interpreting this result, however. First, the crowd-in effect proves to be small, and second the specification is no longer strictly comparable to others for which we report results. Moreover, full evaluation of the crowd-in would have to consider the cost of the government investment expenditure, and whether the net gain to society was positive or negative. Nevertheless, the coefficient does point toward the possibility of some effect having been present on manufacturing investment.

6.2.1 Conclusions and evaluation

Uncertainty appears to impact on investment rates in the manufacturing sector in middle income countries. In particular, *both* sectoral and systemic uncertainty (as proxied by an index of political instability) lowers investment rates in manufacturing industry in South Africa. This result is a consistent and robust finding regardless of which other variables are controlled for in estimation. The international evidence on the impact of uncertainty on investment thus finds corroboration in the instance of a middle income country. The uncertainty findings carry with them immediate policy implications. Stability at a systemic level appears crucial if investment rates in South African manufacturing industry are to rise. This carries implications both for the conduct of macroeconomic policy and the need for an emphasis on price stability in its conduct, but also for the importance of creating a stable political environment able to pursue credible policy orientations over time. By the latter we refer to the importance of creating a policy environment that renders the policy making process predictable, rather than subject to problems of time inconsistency. Past political dispensations in South Africa with their associated large discretionary power vested in the state, rendered the prospect of arbitrary state intervention ever real. The move to a liberal democratic polity has lowered this source of uncertainty and we have seen sound economic reasons for guarding this political advance jealously.

The real user cost of capital was found to be statistically significant as a determinant of investment rates in South African manufacturing industry. The implication of this is twofold. In the first instance the impact of factors that change the user cost of investment - such as high taxation rates for instance - act as a deterrent to investment. The corollary is that policy makers play a role in creating the appropriate conditions for rising investment rates through an alteration of the real user cost of capital. But equally, the real user cost of capital is only one of a number of determinants of investment. This implies that for policy makers a simple focus on the user cost of capital is not enough. Instead it is imperative that policy makers create the conditions of long term macroeconomic stability, and of sufficient rates of return on investment (see the positive and significant coefficient on the change capacity utilization variable, as well as the rate of return on capital stock variable) that create a climate conducive to high investment rates. There are no easy ways out here.

Thus far the core findings. But we found also that credit rationing appears not to have played a role in the formal manufacturing sectors[32] and technological change, openness,

[32] It may of course be a significant factor in the informal sector not included in the sample on which our data is based.

and changes in the real cost of labour are similarly insignificant as determinants of investment rates. We suggested that the finding on the negative impact of the skills ratio in the employment of manufacturing sectors is consistent with the suggestion that the poorly conceived educational policies of past South African governments may have served to lower investment rates in sectors with strong complementarities between human and physical capital. The rate of return on capital stock appears to add information on the expected payoff to investment expenditure over and above the capacity utilization proxy employed throughout the present study.

Such results carry with them some important policy implications. Uncertainty matters for investment, and it does so across all manufacturing sectors in the South African economy. The evidence presented in this study has affirmed the importance of uncertainty in *lowering* the investment rate in South African manufacturing. This confirms not only the importance of adjustment costs as determinants of investment expenditure, but also that uncertainty raises the threshold rate of return below which investment is unlikely to occur. At least two important policy implications flow from this finding. First, it implies that any policy intervention designed to stimulate investment expenditure may face serious constraints in the sense that it may appear ineffectual due to the influence of the relatively high threshold below which investment is simply not triggered. Where an industry is operating below the threshold rate of return on investment, policy intervention may be in fact altering the rate of return on investment and hence the incentive to invest, but may not trigger a physical investment response because the intervention has not been substantial enough to breach the threshold. Thus there may be considerable scope for changing investment incentives by means of policy intervention, without there following any appreciable change in the investment rate. The second policy implication then follows as a corollary. Creation of a macroeconomic as well as microeconomic environment that is stable, predictable and devoid of sudden and arbitrary intervention is an immediate policy goal that emerges from the present study, not only because uncertainty has a direct negative impact on investment rates in manufacturing, but also because it serves to lower the threshold below which investment does not occur. In effect lowering uncertainty carries both a direct positive stimulus to investment, and it serves to render other policy levers more effective in achieving their objective.

Since changes in the real user cost of capital influence the investment rate of manufacturing sectors, changes in the component cost elements that governments can influence will also carry with them long run changes in investment rates.

It is important to bear in mind that the effects identified above are long term in nature. Hence the conclusions drawn must constantly be modulated by the realization that adjustment to new equilibrium investment rates after any policy intervention will not be instantaneous, but subject to a dynamic adjustment path.

Finally we also noted that the impact of the various determinants on investment rates vary in importance across manufacturing sectors. There is thus evidence of heterogeneity within the panel, and appropriate policy intervention in industrial policy should take cognizance of such heterogeneity.

While the findings on the determinants of investment presented in this study are theoretically coherent and accord with findings from other international sources, they are unique in two important respects. The estimation techniques employed allow for not only dynamic panel estimation, but dynamic panel estimation that allows for heterogeneity across groups included in estimation. In this respect, we are not aware of any other study internationally to have preempted the findings presented in the present paper on investment determinants for South Africa or any other country. Second, the study is explicit in controlling for both systemic and sectoral uncertainty separately, and confirms that both are crucial determinants of investment expenditure.

6.3 The labour market

Employment creation in the South African labour market has been less than healthy for some period of time now. In Chapter 1 we detailed evidence indicating a sharp decline in formal sector employment across the 1990's in South Africa. Understanding conditions within South African labour markets is crucial to developing a strategy designed to improve employment creation in the future.

In this section we begin with an examination of labour market conditions, and also consider some econometric evidence on likely determinants of employment patterns in South Africa.

Two core findings emerge from the analysis. First, adherence to sound economic principles in price setting is the most conducive to long run sustainable employment creation. In short, the real wage matters in determining changing employment patterns. Moreover, the interplay between real labour productivity and the real wage is important in determining employment patterns. Technology also proves to be an important determinant of employment patterns.

It is also worth emphasizing that the descriptive evidence makes it abundantly clear that the inability of the South African economy to create employment is not new. It is an ingrained structural problem that has been with us since the 1970's.

This in turn carries with it two important implications. The first is that poor employment creation cannot be made the responsibility of any recent change in policy regime. The problem is deeper, and is likely to be structural. But second, and as corollary, it also follows that fundamental structural labour market reform is required if employment creation is to take place in the South African economy. Fundamental supply side measures are likely to be required – and such reforms are never easy to accomplish.

We begin with a brief description of employment patterns in the South African economy over the 1970-97 period, before moving on to a consideration of some of the potential determinants of employment in South Africa.

6.3.1: Employment in South African economic sectors, 1970-97[33]

The South African labour market is dominated by a relatively small number of sectors. The agricultural sector, government, gold and uranium mining and a number of service sectors provide the bulk of employment in the South African labour market. Moreover, of the large sectoral employers, only general government showed very strong tendencies to grow over the 1970 – 1997 period, widening the differential between itself and the next largest sectoral employer.

A particularly notable point is that for none of the sizeable employment-creating sectors in the South African economy has employment been growing particularly strongly – with the exception of the already identified government sector. Moreover, this lack of employment creation is evident over the full 1970-97 period.

This evidence carries with it a number of core implications for any consideration of the South African labour market:

- While current South African debates concerning the employment creating capacity of economic growth in the economy are thus fully warranted in terms of the absolute level of unemployment in the economy, the evidence just cited also makes it clear that this is not a new development. Rather, economic growth in South Africa has been poor at generating additional employment ever since the 1970's.

- Moreover, the relative importance of sectors as sources of employment in South Africa needs to be tempered by the realization that in absolute terms, changes in the four to five largest sectors in terms of employment will have a disproportionately large impact on the level of employment. By way of extension, strong changes in employment in the manufacturing sectors for instance will simply not translate into very significant employment changes in aggregate in the short term, simply because manufacturing sectors individually do not contribute a large proportion of employment in the South African labour market.

It follows that to the extent that we are concerned with the question of what impact any one determinant of employment, say trade liberalization or technological change, has had on employment in the manufacturing sector, the impact of such a factor is also likely to have had a relatively small impact on total labour market conditions. Findings of *either* a negative *or* a positive impact of trade liberalization (say) on employment in any individual manufacturing sector simply are likely to have relatively small aggregate effects on employment as a whole. On the other hand, since some of the non-manufacturing sectors contribute disproportionately large proportions to employment in the South African labour market, it also follows that strong determinants of employment in these sectors may carry disproportionately large consequences for the South African labour market in aggregate.

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[33] Sections 6.3.1, 6.3.2 and 6.3.3 draw heavily on Fedderke, Henderson, Mariotti and Vaze (2000).

In conclusion a last observation is in order. Given the preponderance of a small number of sectors in terms of employment in the South African labour market, we should note that changing conditions particularly in terms of the real wage maintained in those sectors, are likely to again carry disproportionate consequences for labour market conditions in other sectors. The government sector in particular may serve a role in determining reservation wages for other sectors in the economy.

6.3.2 The relative rate of change of employment in South African economic sectors

Implicit in the absolute levels of employment already discussed and the changes in such levels of employment, are long term rates of change in employment. In **Table 6.7** we list the average growth rate in employment both for the 1970-90 period, and the 1990-97 period, given the already noted hypothesis that 1990 marks a significant structural break in the South African labour market.

An examination of the average growth rates of employment listed in **Table 6.7** confirms that 1990 might mark a structural break in the South African labour market. The average growth rate across all sectors (unadjusted for the total level of employment in each sector) over the full 1970-97 period was 1.22% per annum. By contrast, the average growth rate in employment (again across all sectors, unadjusted for absolute levels of employment) from 1970-90, and 1990-97 was 2.16% and –1.26% per annum respectively.

It is notable that the rate of employment creation across sectors has been below average annual population growth,[34] emphasizing the observation already made of the very low capacity of the South African economy to generate employment over a very protracted time frame since the 1970's. This is further evident from the fact that of the economic sectors with employment growth rates above 3% per annum (Plastic Products, Business Services, Television, radio & etc., Finance & Insurance, Electrical Machinery, General Government) only one lies amongst the large employment creators in the economy (in absolute terms). Moreover, General Government is likely to be the single sector least susceptible to market pressures, such that the increase in employment in General Government cannot be taken to reflect improved economic or market-related employment prospects for labour. In sharp contrast, amongst the five sectors with the *strongest proportional decrease* in employment, three sectors lie amongst the top six employment creators in absolute terms.

The point generalizes. The correlation between the level of employment in 1970 and the average rate of change of employment by sector, is –0.27, indicating that the larger the contribution of a sector to employment in 1970, the less likely it was to experience strong

[34] While population growth in South Africa is the subject of some controversy, one estimate places average annual population growth over the 1970-97 period at 2.38%. The estimate are based on Sadie's demographic data.

growth in employment.[35] The suggestion is that of a long-term restructuring of the South African economy. Employment patterns in the South African economy are subject to change, with a movement from traditional employment sectors to newly emerging and as yet relatively small sectors. Such restructuring takes time, particularly given the human capital deficit of significant portions of the South African population, which acts as an additional impediment to adequate labour mobility.

But what also requires recognition is that the 1990's appear to be particularly structurally distinct from preceding time periods. It has marked a protracted period of negative growth in employment of a number of economic sectors. Of the total of 48 sectors recorded, 31 had negative growth rates in employment over the course of the 1990's. By contrast, over 1970-90 only three sectors had negative employment growth rates. The difference between the two sample periods may reflect the fact that the 1970-90 period contains a longer time run, over which cyclical variation is averaged out, while the data for the 1990's contain the impact of a severe recessionary period for the South African economy. On the other hand, seven years represents close on a full decade, and hence if the difference in the two time periods is indeed an artifact of recessionary pressures, it represents at the very least a very long and severe recession in South African labour markets.

In addition, the difference between the two time periods is sufficiently marked to suggest that the South African labour market is indeed subject to a structural break in 1990. The correlation between average employment growth rates in economic sectors over the 1970-90 period and those over the 1990-97 period is only 0.49 – suggesting that the growth rate in employment a sector maintained over the 1970-90 period constituted a relatively poor predictor of the growth rate it would maintain post-1990.

So much for the relatively gloomy general picture. But the general malaise of the labour market does hide the presence of some feel-good evidence. Of the non-government sectors with employment growth above 3%, three manufacturing industries and two service sectors have maintained very healthy growth rates.

[35] The point can be made in a number of ways from the evidence. Thus the correlation between the rank of each sector in terms of employment in 1970 and its rank in terms of average annual employment growth over the 1970-97 period is –0.21. And the correlation between the rank of each sector in terms of employment in 1970 and its average employment growth over the 1970-97 period is –0.19. The picture is consistent in its import.

TABLE 6.7: Formal Employment: average growth rate; low rank indicates low growth rate	Growth 70-97	Growth 90-97	Growth 70-90	Rank 90-97	Rank 90-97	Rank 70-90
Tobacco	-1.43	-5.65	0.12	1	1	5
Glass & glass products	-0.96	-0.99	-0.95	2	24	1
Agriculture, forestry & fishing	-0.90	-0.90	-0.90	3	26	2
Transport & storage	-0.75	-4.57	0.61	4	6	6
Gold & uranium ore mining	-0.73	-5.07	0.79	5	3	8
Textiles	-0.71	-2.91	0.03	6	15	4
Households (domestic servants)	-0.57	-0.72	-0.52	7	28	3
Water supply	-0.55	-3.73	0.79	8	10	7
Coal mining	-0.35	-4.01	1.27	9	9	12
Basic iron & steel	-0.26	-4.51	1.44	10	7	14
Non-metallic minerals	-0.20	-2.92	0.83	11	14	9
Building construction	-0.09	-4.97	1.79	12	4	20
Leather & leather products	0.00	-5.56	2.08	13	2	24
Footwear	0.11	-4.74	1.64	14	5	17
Other mining	0.13	-2.96	1.52	15	13	15
Rubber products	0.34	-1.46	1.00	16	21	10
Metal products excluding machinery	0.63	-0.62	1.29	17	29	13
Machinery & equipment	0.64	-1.67	1.25	18	18	11
Catering & accommodation services	0.66	-1.62	1.96	19	19	21
Civil engineering & other construction	0.74	-1.56	1.68	20	20	18
Basic non-ferrous metals	0.75	-4.16	2.52	21	8	29
Wholesale & retail trade	1.10	-0.60	1.62	22	30	16
Other transport equipment	1.12	-1.73	2.19	23	17	26
Food	1.19	-1.04	2.08	24	23	23
Paper & paper products	1.44	0.03	2.09	25	33	25
Beverages	1.44	-2.86	2.85	26	16	37
Other chemicals & man-made fibres	1.55	-1.22	2.86	27	22	38
Wood & wood products	1.63	1.25	1.69	28	42	19
Professional & scientific equipment	1.76	-0.26	2.55	29	32	30
Communication	1.80	-0.75	2.75	30	27	31
Motor vehicles, parts & accessories	1.92	1.44	2.41	31	43	28
Printing, publishing & recorded media	1.92	0.99	2.39	32	39	27
Wearing apparel	2.00	0.99	2.06	33	40	22
Other industries	2.11	-0.34	3.03	34	31	39
Basic chemicals	2.13	-3.33	3.72	35	11	41
Community, social & personal services: Profit	2.22	0.39	2.84	36	37	33
Other	2.22	0.39	2.84	37	34	35
Medical, dental & other health & veterinary services	2.22	0.39	2.84	38	36	34
Community, social & personal services: Non-profit	2.22	0.39	2.84	39	35	36
Electricity, gas & steam	2.27	-3.29	4.17	40	12	43
Furniture	2.39	1.02	2.79	41	41	32
Coke & refined petroleum products	2.94	-0.99	4.24	42	25	44
General government	3.41	0.59	4.37	43	38	46
Electrical machinery	3.44	3.16	3.69	44	47	40
Finance & insurance	3.52	2.45	3.97	45	46	42
Television, radio & communication equipment	3.88	3.91	4.33	46	48	45
Business services	3.96	2.09	4.72	47	45	47
Plastic products	4.33	1.71	5.39	48	44	48

Admittedly, in the case of Plastic Products and TV, Radio & Comms. Equipment, the sectors are small in absolute terms as regards employment. But the remaining sectors are mid-ranking in absolute employment levels. Moreover, the fact that these sectors proved to be robust to the shock of the 1990's (the exception is the Plastic Products sector) that affected so many other sectors in the economy negatively, suggests that these sectors may well be exploiting a comparative advantage of the South African economy, and be evidence of the restructuring of the South African labour market (and the South African economy as a whole?) already identified as a potential feature of the 1990's.[36]

6.3.3 Some possible reasons for the changing patterns of employment

In terms of economic analysis, it is not possible to separate changes of quantity in any good including labour, from changes in its price. As a consequence, we now turn to the issue of real labour remuneration, and its potential link to employment patterns.

6.3.3.1 Real labour remuneration

We examine the link between employment and the real wage rate through two mechanisms.

The first is the correlation between the level of employment and the real wage rate. The results are reported in **Table 6.8**. Two forms of information are presented. The first is the correlation between the *level* of employment by sector, and the *level* of the real wage in that sector, across the full time run available for each sector (1970-97). The second is the correlation between the *growth rate* of employment by sector, and the *growth rate* of the real wage in that sector, across the full time run available for each sector (1970-97).

An important conclusion emerges from an examination of the evidence presented: evidence collected for the aggregate South African labour market hides important sectoral differences – and indeed obscures the most striking features of the link between real labour remuneration, and employment.

While there appears to be a relatively strong *positive* association between employment and the real wage rate for the South African labour market as a whole (at +0.52), and only a very small negative correlation (of –0.07) on average across all sectors of the economy,[37] this obscures some important sectoral patterns that emerge from the data. First, the large employment sectors of the economy that have experienced strong declines in employment, also show strong negative correlations between real labour remuneration and employment. Thus:

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[36] Given a constant growth rate of 3% per annum, employment in each of these sectors would double in approximately 22 years. The implication is simply a reminder that small sectors can come to be large in time. Given appropriate conditions, such as buoyant demand conditions, such a transformation may accelerate even further.

[37] The difference arises since the correlation for the economy as a whole is the correlation between total employment and the real wage rate. By contrast, the average correlation for all sectors is the average across all individual sectors, and is thus not weighted by the size of employment.

- Agriculture Forestry & Fishing (Rank 48 in 1970; average employment growth 1970-97: -0.9 per annum; employment – real wage correlation of –0.81; employment growth – real wage growth correlation of –0.4),
- Household Servants (Rank 47 in 1970; average employment growth 1970-97: -0.57 per annum; employment – real wage correlation of –0.87; employment growth – real wage growth correlation of –0.12),
- Gold and Uranium Mining (Rank 45 in 1970; average employment growth 1970-97: -0.73 per annum; employment – real wage correlation of –0.91; employment growth – real wage growth correlation of –0.1),
- Transport & Storage (Rank 46 in 1970; average employment growth 1970-97: -0.75 per annum; employment – real wage correlation of –0.80; employment growth – real wage growth correlation of –0.3),
- and Building Construction (Rank 41 in 1970; average employment growth 1970-97: -0.09 per annum; employment – real wage correlation of –0.77; employment growth – real wage growth correlation of –0.83),

all share a negative employment – real wage nexus.

The point can be strengthened since every sector in South Africa that has showed negative growth rates in employment, also shows a negative correlation between employment and the real wage. Compare the correlation between employment and the real wage for the following sectors with negative employment growth rates in **Table 6.7**: Agriculture, Forestry & Fishing (-0.81), Glass & Glass Products (-0.62), Tobacco (-0.06), Transport & Storage (-0.8), Gold & Uranium Mining (-0.81), Textiles (-0.54), Household Servants (-0.87), Water Supply (-0.04), Coal Mining (-0.24), Basic Iron & Steel (-0.72), Non-metallic Minerals (-0.32), and Building Construction (-0.77).

Even amongst sectors that have experienced strong positive growth rates in employment (defined as above 3% per annum), in which we might have expected strong upward pressure on wages due to strong demand for labour, negative correlations persist. Thus:

- General government - though this sector is of course less likely to respond to pure market signals (1970 Rank 46; average employment growth 1970-97: 3.41 % per annum; employment – real wage correlation of –0.64; employment growth – real wage growth correlation of –0.93),
- Electrical machinery (1970 Rank 46; average employment growth 1970-97: 3.44 % per annum; employment – real wage correlation of –0.21; employment growth – real wage growth correlation of –0.39),
- Finance & Insurance (1970 Rank 46; average employment growth 1970-97: 3.52 % per annum; employment – real wage correlation of +0.38; employment growth – real wage growth correlation of –-0.06),
- TV, Radio & Communications Equipment (Rank 46; average employment growth 1970-97: 3.88 % per annum; employment – real wage correlation of –0.33; employment growth – real wage growth correlation of –0.32),
- Business Services (Rank 46; average employment growth 1970-97: 3.96 % per annum; employment – real wage correlation of –0.97; employment growth – real wage growth correlation of –0.49),

- Plastic Products (Rank 46; average employment growth 1970-97: 4.33 % per annum; employment – real wage correlation of +0.78; employment growth – real wage growth correlation of –0.40),

while not uniformly generating additional employment on the basis of falling real wages, show a strong propensity to do so. Only for Finance & Insurance, and for Plastic Products is the correlation between employment and the real wage positive, suggesting that the strong labour demand increased wages – rather than that falling wages induced labour demand.

While there are thus some sectors in the South African economy that show a positive correlation between employment and the real wage, careful examination of the evidence suggests that the negative association between employment and the real cost of labour predicted by economic theory is in fact present in the South African labour market.

No examination of the determinants of employment can thus ignore the impact of the real wage rate.

6.3.3.2 Labour productivity

One possible explanation besides changes in the real wage for changing employment trends, are changes in labour productivity.[38]

Economic theory would anticipate a link between real labour product and the real wage. **Table 6.9** reports the correlation between real labour productivity and the real per labourer remuneration by economic sector for which the relevant data is available.[39] It is noticeable that for most sectors the correlation between labour productivity and the real wage is not only positive, but frequently very strong. For eight sectors[40] the correlation lies above +0.9, for eleven[41] sectors above +0.8, for four[42] above +0.7, and for seven[43] equal to or above +0.59. Thus for 31 out of 46 sectors for which requisite data is available, the correlation conforms not only to economic theory, but is reasonably strong

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[38] We need to note here that the measure of labour productivity in the South African economy is materially affected by the measure of output that is employed. Two measures of real output are available: Real Sales (or gross output) and Real GDP (or net output). The appropriate measure is that for Real GDP, since Real Sales incorporates the value of intermediate inputs into production, and does not therefore represent a true measure of true value-added of labour.

[39] Strictly speaking, we are interested in the link between the marginal product of labour and the marginal cost of labour. For the time being, this is as close as we are likely to get.

[40] In declining order: Professional & scientific equipment, Other chemicals & man-made fibres, Communication, Plastic products, Other industries, Furniture, Printing, publishing & recorded media, Medical, dental & other health & veterinary services.

[41] In declining order: Paper & paper products, Wholesale & retail trade, Food, Basic non-ferrous metals, Finance & insurance, Wearing apparel, Other mining, Agriculture, forestry & fishing, Wood & wood products, Beverages, Rubber products.

[42] In declining order: Catering & accommodation services, Coal mining, Transport & storage, Electrical machinery.

[43] In declining order: Civil engineering & other construction, Other community, social & personal services: Profit seeking, Coke & refined petroleum products, Electricity, gas & steam, Water supply, Television, radio & communication equipment, Other transport equipment.

– if it is borne in mind that economic theory assumes all other influences on the real wage to be held constant in predicting the positive correlation.

TABLE 6.8: Correlations: Employment versus Real Labour Remuneration	**Employment vs Real Wage (levels)**	**Employment vs Real Wage (Growth Rates)**
Agriculture, forestry & fishing	-0.91	-0.1
Coal mining	-0.24	0.1
Gold & uranium ore mining	-0.81	-0.4
Other mining	-0.41	-0.49
Food	0.56	-0.21
Beverages	0.91	0.1
Tobacco	-0.06	-0.46
Textiles	-0.54	-0.53
Wearing apparel	0.66	-0.43
Leather & leather products	-0.61	-0.19
Footwear	-0.32	-0.08
Wood & wood products	-0.43	-0.27
Paper & paper products	-0.66	-0.46
Printing, publishing & recorded media	-0.48	-0.38
Coke & refined petroleum products	-0.05	0.18
Basic chemicals	-0.35	-0.08
Other chemicals & man-made fibres	0.49	-0.44
Rubber products	-0.45	-0.36
Plastic products	0.78	-0.4
Glass & glass products	-0.62	-0.14
Non-metallic minerals	-0.32	-0.34
Basic iron & steel	-0.72	-0.41
Basic non-ferrous metals	-0.39	-0.26
Metal products excluding machinery	0.3	-0.25
Machinery & equipment	0.18	0.04
Electrical machinery	-0.21	-0.39
Television, radio & communication equipment	-0.33	-0.32
Professional & scientific equipment	0.7	-0.48
Motor vehicles, parts & accessories	-0.39	-0.17
Other transport equipment	0.52	-0.08
Furniture	0.02	-0.06
Other industries	0.36	0.07
Electricity, gas & steam	-0.05	-0.51
Water supply	-0.04	-0.08
Building construction	-0.77	-0.83
Civil engineering & other construction	-0.27	-0.43
Wholesale & retail trade	0.73	-0.09
Catering & accommodation services	-0.02	-0.77
Transport & storage	-0.8	-0.3
Communication	0.55	-0.38
Finance & insurance	0.38	-0.06
Business services	-0.97	-0.49
Medical, dental & other health & veterinary services	0.86	-0.55
Other community, social & personal services: Profit seeking	0.78	0.15
Other community, social & personal services: Non-profit seeking	0.77	-0.12
Other	0.62	-0.33
Households	-0.87	-0.12
General government	-0.64	-0.93
Total labour remuneration	0.51	-0.09
AVERAGE	-0.07	-0.28

For only ten[44] sectors does the correlation lie between 0 and +0.5, and is the link predicted by economic theory thus relatively weak – and only six[45] sectors had the negative correlation between labour productivity and the real wage contradicting economic theory.

Noteworthy is the distinct performance of these groupings of economic sectors in terms of the growth of employment and the real wage they experienced over the full sample period. The strength of the correlation between labour productivity and the real wage appears to be a predictor of the strength of sustainable real wage improvements, as well as growth in employment.[46] Thus:

- For the eight sectors with the strongest correlation between labour productivity and the real wage, average growth in real per labourer remuneration was 2.56% per annum over 1970 – 1997, and average growth in employment 2.26% per annum over 1970 – 1997.
- For the ten sectors with a correlation between +0.8 and +0.9 between labour productivity and the real wage, average growth in real per labourer remuneration was 1.99% per annum over 1970 – 1997, and average growth in employment 1.15% per annum over 1970 – 1997.
- For the four sectors with a correlation between +0.7 and +0.8 between labour productivity and the real wage, average growth in real per labourer remuneration was 3.74% per annum over 1970 – 1997, and average growth in employment 0.74% per annum over 1970 – 1997.
- For the seven sectors with a correlation between +0.59 and +0.7 between labour productivity and the real wage, average growth in real per labourer remuneration was 1.57% per annum over 1970 – 1997, and average growth in employment 1.80% per annum over 1970 – 1997.
- For the ten sectors with a correlation between 0 and +0.5 between labour productivity and the real wage, average growth in real per labourer remuneration was 1.30% per annum over 1970 – 1997, and average growth in employment 0.805% per annum over 1970 – 1997.
- For the six sectors with a correlation between labour productivity and the real wage below 0, average growth in real per labourer remuneration was –0.31% per annum over 1970 – 1997, and average growth in employment 0.25% per annum over 1970 – 1997.

[44] In declining order: Motor vehicles, parts & accessories, Machinery & equipment, Metal products excluding machinery, Gold & uranium ore mining, Building construction, Basic iron & steel, Textiles, Basic chemicals, Other, Other community, social & personal services: Non-profit seeking.
[45] In declining order: Glass & glass products, Non-metallic minerals, Footwear, Leather & leather products, Tobacco.
[46] A similar relationship holds with respect to employment when we consider the correlation between changes in real labour productivity and changes in the real wage.

Table 6.9: Correlations	Y/L vs W/P	Y/L vs e	dY/dt vs dW/dt	dY/dt vs de/dt
Agriculture, forestry & fishing	0.86	-0.97	0.12	-0.40
Coal mining	0.75	-0.10	0.28	-0.09
Gold & uranium ore mining	0.41	-0.42	0.24	-0.25
Other mining	0.86	-0.19	0.18	-0.38
Food	0.88	0.73	0.48	0.00
Beverages	0.81	0.74	0.59	-0.13
Tobacco	-0.68	-0.79	0.43	-0.61
Textiles	0.22	-0.68	0.63	-0.53
Wearing apparel	0.87	0.63	0.67	-0.28
Leather & leather products	-0.49	-0.28	0.41	-0.31
Footwear	-0.34	-0.25	0.48	-0.13
Wood & wood products	0.83	0.66	0.51	0.02
Paper & paper products	0.89	0.58	0.79	-0.25
Printing, publishing & recorded media	0.91	0.74	0.69	-0.32
Coke & refined petroleum products	0.64	0.58	0.72	0.21
Basic chemicals	0.15	-0.05	0.32	-0.24
Other chemicals & man-made fibres	0.96	0.66	0.77	-0.35
Rubber products	0.81	-0.13	0.47	-0.18
Plastic products	0.95	0.91	0.62	-0.17
Glass & glass products	-0.15	-0.93	0.58	-0.03
Non-metallic minerals	-0.24	-0.31	0.52	0.09
Basic iron & steel	0.29	-0.55	0.58	-0.25
Basic non-ferrous metals	0.87	-0.31	0.85	-0.21
Metal products excluding machinery	0.42	0.61	0.28	-0.13
Machinery & equipment	0.44	0.02	0.87	0.09
Electrical machinery	0.73	-0.15	0.71	-0.15
Television, radio & communication equipment	0.60	-0.17	0.67	-0.25
Professional & scientific equipment	0.97	0.81	0.73	-0.59
Motor vehicles, parts & accessories	0.45	0.23	0.76	-0.27
Other transport equipment	0.59	0.08	0.60	-0.15
Furniture	0.94	0.83	0.72	-0.01
Other industries	0.95	0.72	0.73	-0.01
Electricity, gas & steam	0.63	-0.32	0.09	-0.58
Water supply	0.62	-0.48	0.56	-0.23
Building construction	0.32	-0.64	0.16	-0.68
Civil engineering & other construction	0.69	-0.44	0.17	-0.63
Wholesale & retail trade	0.89	0.69	0.25	-0.14
Catering & accommodation services	0.77	-0.01	0.55	-0.77
Transport & storage	0.74	-0.69	0.36	-0.35
Communication	0.95	0.65	0.53	-0.60
Finance & insurance	0.87	0.83	0.59	0.31
Business services	-0.83	-0.93	0.15	-0.67
Medical, dental & other health & veterinary services	0.91	0.83	0.42	-0.36
Other community, social & personal services: Profit seeking	0.65	0.67	-0.27	-0.67
Other community, social & personal services: Non-profit seeking	0.04	-0.10	0.34	-0.22
Other	0.04	0.10	-0.23	-0.03
Total	0.91	0.64	-0.25	-0.32
AVERAGE	0.53	0.07	0.47	-0.26

With the exception of perhaps only the sector grouping with a correlation between +0.7 and +0.8, the evidence appears to suggest the presence of a declining employment creating capacity in sectors as they conform less closely to the dictates of standard economic theory. Where the real wage is less closely linked to real labour productivity the growth in employment also tends to be lower. Moreover, the capacity for a heightened but *sustained* increase in real wages also appears to linked to the degree to which real wages are justified by labour productivity.

The immediate implication for policy intervention in South African labour markets appears to be that "well-functioning" labour markets, defined as those that link factor rewards to factor productivity in accordance with the requisites of economic theory, appear to be more likely to generate both employment, and sustained improvements in labour remuneration. In effect, to the extent that by labour market flexibility we mean the capacity of labour markets to adjust freely and rapidly to the market clearing wage suggested by labour productivity, the evidence from the link between real labour productivity and the real wage suggests that labour market flexibility is desirable. Once again, therefore, our findings tend to confirm the prior expectations that economic theory provides.

6.3.4 Some preliminary conclusions

We have seen that real wages are likely to be important in determining employment trends in South Africa's labour markets. More specifically where the growth rate in labour remuneration has outstripped growth rates in labor productivity we have observed tendency for labour inputs into production to decline.

Poor employment creation in South African labour markets has been a long-standing structural feature present since at least the 1970's. Recent macroeconomic policy changes in South Africa are therefore very difficult to identify as the cause for poor employment creation. Supply side features of the labour market are far more probable as a cause of sluggish employment growth, and real wages and labour productivity are two such candidates.

Investment in human capital, improvement in the skills base of the South African economy, is one possible response should this diagnosis be correct. Our earlier discussion suggests a host of additional reasons why this may be a good idea. Increasing the flexibility of labour markets, to allow for a range of real wages, appropriately adjusted to labour productivity is another response, perhaps most appropriate to existing unskilled labour that is struggling to enter the formal labour market.

We are aware of the fact that there may be many additional constraints to the efficient functioning of labour markets in South Africa. Asymmetric information may be a particularly severe impediment. But to say that there are further inefficiencies, is not to argue that those rigidities that we can identify should not be addressed in their own right.

6.3.5 A further investigation into determinants of labour usage in South African labour markets

The discussion thus far has been descriptive. Therefore while the initial conclusions note above may be suggestive, the relative significance of the alternative explanations for employment growth remain to be determined.

In this section we undertake an econometric investigation into the likely determinants of labour usage in South Africa over the 1970-97 period, using manufacturing sector data. Again we use dynamic heterogeneous panel estimation in order to conduct the investigation.[47] The investigation is brief, and is designed to provide a test for the suggestions that have emerged from the descriptive analysis in a multivariate context.

We begin with the consideration of a production function given by:

$$Y = F(B, K, L) \tag{3}$$

where Y denotes output, K capital, L labour, and B a vector of other relevant variables. Inversion of the production function allows us to write:

$$L = G(B, Y, K) \tag{4}$$

In the current context, we allow the B vector to include three variables:

- Openness, denoted OPEN, and defined as the ratio of imports and exports to output, reflects the extent to which a sector is exposed to international markets, and hence international technologies of production.
- A relative factor price ratio, denoted RPRICE, defined as the ratio of the user cost of capital to real per laborer remuneration, where the user cost of capital in turn is defined as the sum of the risk rate of return on government paper, the sector specific depreciation rate, and the corporate tax rate.
- The skills composition of the labor force, denoted SR, controls for any upward pressure on real wage rates due to a rising skills base in the labor force. It is defined as for the price effect estimations.

We are thus able to distinguish the determinants of labor usuage in the South African manufacturing sector using the following long run labor requirements equation:[48]

$$L = \alpha_1 Y + \alpha_2 RPRICE + \alpha_3 SR + \alpha_4 OPEN + \varepsilon \tag{5}$$

Table 6.10 presents estimation results for the labor usage equation (5). One feature of the finding is the slow correction of short-run deviations from the long-run equilibrium. This

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[47] Again the methodology is explained in Appendix 1 of Chapter 4.
[48] We drop the capital stock term due to statistical insignificance in all estimations.

is indicated by the estimate of the error correction coefficient which is negative but relatively small.[49] Estimation results suggest:

- a positive and statistically significant impact of output on labour usage,
- a positive and statistically significant impact of the relative factor price ratio on labour usage, suggesting declining labor usage in the face of rising real wages relative to the real user cost of capital.
- in addition, the SR coefficient is significant and negative, implying a declining usage of labor in the face of a rising skills composition of the South African manufacturing labor force.

Table 6.10: Labour Requirements Equation. Dependent variable is employment. Figures in round parentheses are standard errors. Statistical significance is denoted by *.

	Employment
Output	0.51*
	(.03)
Relative Factor Prices	0.92*
	(.16)
Skills Ratio	-0.29*
	(.05)
Openness	-.001
	(.01)
Speed of Adjustment	-0.19*
	(.05)

The labor requirements equation suggests that the dominant influences on labor usage in the South African manufacturing sector were the requirements on labor inputs generated by output supply levels, and the relative factor price of labor to capital stock. In this sense, the labor requirements equation confirms the earlier suggestion emerging from the descriptive analysis that South Africa's persistent and substantial unemployment levels may be attributable to inappropriate factor prices.

An additional consideration that might be considered more seriously is the impact of the process of globalization on South African labour markets. It is often alleged that trade liberalization has harmed South Africa’s labour markets. Fortunately, this proposition is both testable, and in fact carries with it the added benefit of allowing us to pinpoint whether technological progress has had any additional impact on labour usage.

The standard framework within which the impact of globalization on labour markets is addressed is Heckscher-Ohlin trade theory. Indeed, work on the developed countries has gone some way toward attempting to understand the impact of trade liberalization on labour markets.

[49] Only 19% of any disequilibrium is eliminated in the following period.

The empirical work on the impact of trade on labor markets has concentrated on developed countries. In Europe and the US, growing unemployment amongst the unskilled and rising wage inequality between the skilled and the unskilled led some to attribute the phenomenon to increased trade liberalization. The fear was that unskilled jobs were going to low-wage economies as a result of the lifting of trade barriers. Such an argument is plausible in terms of Heckscher-Ohlin (henceforth HO) trade theory. In the simplest case, skilled and unskilled labor are two factors of production, with developed countries showing a comparative advantage in skills-intensive goods due to greater relative supplies of skilled labor, while developing countries have a comparative advantage in labor-intensive goods due to greater relative supply of unskilled labor. Removal of trade barriers would strengthen the impact of comparative advantage, with developed countries experiencing contraction in unskilled labor intensive sectors, and expansion in skilled labor intensive sectors, leading to widening inequality in the labor market.[50] This migration of jobs thesis would have quite different implications for a less developed country. For poorer countries, the situation for unskilled labor should be reversed, with the position of the unskilled laborer improving with liberalization. By contrast for skilled labor in developing countries, the premium extracted by their scarcity is put at risk as developing countries increasingly import skilled labor intensive products from the developed countries, thus lowering wage inequality.

However, testing these implications of HO trade theory is not a trivial task. As a consequence empirical modeling has provided checks on whether changes in labor markets are *consistent* with the predictions of trade theory, rather than proof that the changes in labor markets are the consequence of trade liberalization. At the heart of the Heckscher-Ohlin story lies an interaction of the Heckscher-Ohlin and the Stolper-Samuelson theorems, providing the comparative advantage induced relative shift in demand and the change in relative factor price components of the tale respectively. Yet as Deardorff (1994) has pointed out the Stolper-Samuelson theorem (hereafter SST) has assumed at least six different formulations. Only two of these mention international trade at all. The reason for this is that the essence of the SST is the existence of a link between product and factor price changes. This makes clear the difficulty of directly testing HO trade theory, since domestic product price changes can be brought about by many factors, and cannot be exclusively attributed to international trade. Isolating the impact of international trade is thus difficult, particularly so since international trade is likely to be an endogenous outcome of differences in tastes, technology, endowments, domestic and international barriers to trade. Thus trade and product price changes are simultaneously brought about - trade does not bring about product price changes.

A further difficulty in testing the validity of HO trade theory concerns dimensionality. The predicted impact of trade liberalization on skilled and unskilled labor is couched in a two-factor-two-product world. While an instructive simplification, the result does not generalize unambiguously to multi-factor and multi-product contexts. See for instance Leamer (1996). For this reason the most prevalent test of the trade impact on labor

[50] An alternative Heckscher-Ohlin story would not rely on the lowering of protection, but instead posit a strong expansion of world production of unskilled-labour intensive goods, driving down world prices in unskilled labour intensive sectors and hence the factor reward for unskilled labour.

markets has adopted what Deardorff terms the *correlation version* of the SST, which relates any vector of relative product price changes to relative factor intensity of production. It predicts that *on average* factors used intensively in rising (falling) price industries will experience relative price increases (declines).[51]

But again, the correlation version of the SST provides no more than a consistency check of the trade theory since the source of product price changes remains difficult to unambiguously associate with trade effects. Moreover, empirical application has frequently linked product price changes to factor proportions rather than relative factor price changes. Thus for industrialized countries, a common check is whether observed price changes of unskilled labor intensive goods after liberalization are consistent with factor scarcity, i.e. whether unskilled labor intensive product prices fell.

Perhaps the most important difficulty with this simple consistency check is that in order to be interpreted as a test of the impact of international trade, it must assume all domestic prices to be exogenously set internationally. Only by arguing that for a small economy domestic industries are international price takers can all domestic price changes be argued to be the outcome of trade-induced changes. Yet the assumption is legitimate only if tariff changes are not altering the wedge between domestic and international prices, and only as long as we ignore the impact of technological progress, particularly its industry and factor specific impacts. Some authors abandon the HO framework entirely. Feenstra and Hanson (1995) employ a Ricardian framework instead, allowing them to drop the assumption that all countries are in the same cone of diversification. Others extend the HO framework to incorporate the process of technological know-how. See for instance Wood (1997, 1999) and Wood and Ridao-Cano (1999) and Tang and Wood (2000). Yet there is no *a priori* reason to suppose that technological progress will be factor-neutral, and where it is not relative factor prices would change. Leamer (1996) demonstrates the importance of explicitly introducing technological improvements in mandated factor share estimations.

Full derivation of the model demonstrates the need to estimate three fundamental relationships.[52] First, the price change equation under the assumption of zero technology pass-through is given by:

$$\Delta p = \theta_{\ell}\ell + \theta_k k + \eta \tag{6}$$

where Δp denotes the percentage change in product prices, ℓ the share of labour in value-added output, k the share of capital in value added output, and η an error term. Second, and similarly, the price change equation under the assumption of perfect technology pass-through becomes:

$$\Delta p + \Delta TFP = \theta_{\ell}\ell + \theta_k k + \eta \tag{7}$$

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[51] For a fuller discussion of these issues and an application of the consistency check to South African data, see Fedderke, Shin and Vaze (2000).

[52] For a complete discussion of the derivation of this model, as well as the estimation issues involved in applying the model to the South African instance, see Fedderke, Shin and Vaze (2000).

where ΔTFP denotes technological progress as measured by TFP. Finally, we estimate the technology equation:

$$\Delta TFP = \theta_{\ell}\ell + \theta_{k}k + \eta \tag{8}$$

Factor price changes can now be separated into those due to technology, and those due to trade liberalization. Note that the changes mandated by what Leamer terms *globalization* are the factor price changes required to maintain the zero-profit condition after accounting for the impact of technology. Hence the identification problem of associating product price changes with trade (and liberalization) effects remains, and the Leamer specification remains a consistency check rather than a direct empirical test of the SST.

Estimation of the three equations (6) through (8) places us in a position to identify factor earnings growth mandated by technological change, and those mandated by globalization.[53] Results from estimation for the South African manufacturing industry are presented in **Table 6.11**.[54]

We find that both labor and capital demonstrate positive average annual growth rates in earnings due to the impact of globalization, though the impact on the abundant factor of production labor is stronger than that on capital stock. Moreover, the globalization related earnings changes are greater for labor than capital, as is consistent with the SST. Second, the impact of technology on mandated factor earnings is negative for both factors of production, though in this instance the impact on capital is stronger than it is on labor.[55]

Table 6.11: Mandated Earnings Growth of Factors of Production. Figures denote the decomposition of factor earnings growth mandated by demand factors, those mandated by the impact of technology, and total mandated earnings growth. Figures are obtained from the resolution of the implied identification problem of equations (6) through (8), and are the implied average annual percentage changes.

	Mandated Earning Growth Unrelated to Technology
Labour	0.21
Capital	0.06
	Mandated Earning Growth Related to Technology
Labour	-0.57
Capital	-0.69
	Total Mandated Earnings Growth
Labour	-0.36
Capital	-0.63

[53] The temptation is to identify this directly with trade effects. However, recall that this continues to be a composite effect of all demand-related factors, of which trade is only one.
[54] Please note that these results are in highly condensed form. Full results can be found in Fedderke, Shin and Vaze (2000).
[55] Even the results based on the full technological pass-through assumption (not reported here) suggest that any negative impact of globalization on mandated labor (and capital) earnings is very much weaker than the change mandated by technology.

The results from the Leamer specifications estimated confirm the positive impact of globalization on mandated labor earnings, with the magnitude of the impact exceeding that on capital. However, a new piece of evidence points to the fact that total *mandated* earnings growth particularly for labor in South Africa was negative over the 1972-97 period. Given the strength and persistence of real wage increases in South Africa over this period, the evidence thus suggests that an important possible source of the persistent and high levels of unemployment in South Africa's labor markets may well lie with relative factor prices. This finding thus confirms the implication from the inverted production function reported above: that real wage increases on labour have negatively impacted on employment.

We thus find that relative factor prices dominate any impact of openness or reductions in the effective rate of protection of South African manufacturing sectors. But we also find a negative impact of technological progress on labour usage. The implication is that the nature of technological change in South Africa has been labour replacing.

6.3.6 Conclusions

The evidence examined above with respect to the South African labour markets suggests that the problem is primarily one of an inappropriate real price of labour, as well as labour market rigidities.

We have seen that the strongest employment performance of the South African economy has been in sectors where real price changes of labour have been consonant with the changes in real labour productivity. Econometric evidence has confirmed both the negative impact of the real wage on employment, and has shown that output growth is positively associated with labour usage. The impact of technology has been such as to emphasize the importance of getting labour prices right.

References

[1] Abramovitz, M., (1956), Resource and Output Trends in the United States since1870, *American Economic Review*, 46 (2), 5-23.

[2] Abramovitz, M., (1986), Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, 46(2), 385-406.

[3] Abramovitz, M., (1993), The Search for the Sources of Growth: Areas of Ignorance, Old and New, *Journal of Economic History*, 53(2), 217-43.

[4] Aiginger, K., (1987), *Production Decisions under Uncertainty*, Oxford: Basil Blackwell.

[5] Arrow, K.J., (1962), The Economic Implications of Learning by Doing, *Review of Economic Studies*, 29, 155-73.

[6] Arrow, K.J., (1994), The Production and Distribution of Knowledge, in G.Silverberg and L.Soete, eds., *The Economics of Growth and Technical Change: Technologies, Nations, Agents*, Edward Elgar, 9-19.

[7] Barro, R.J., and Sala-i-Martin, X., (1992), Convergence, Journal of Political Economy, 100(2), 223-51.B

[8] Barro, R.J., and Sala-i-Martin, X., (1995), Economic Growth, New York: McGraw-Hill.

[9] Bank Boston, MIT: *The Impact of Innovation*, http://web.mit.edu/newsoffice/founder/summary.html.

[10] Case, A., and A. Deaton, "School Inputs and Educational Outcomes in South Africa," *Quarterly Journal of Economics,* (1998), Forthcoming.

[11] Denison, E.F.,(1964), The Unimportance of the Embodied Question, *American Economic Review*, 54, 90-4.

[12] Dixit, A.K., and Pindyck, R.S., (1994), *Investment under Uncertainty*, Princeton: University Press.

[13] Durlauf, S., and Quah, D., (1998), The New Empirics of Economic Growth, *Centre for Economic Performance*, Discussion Paper 384.

[14] Engle, R.F., Lilien, D.M., and Robins, R.P., (1987), Estimating time varying risk premia in the term structure: the ARCH-M model, *Econometrica,* 55,391-407.

[15] Fagerberg, J., (1988), International Competitiveness, *Economic Journal,* 98, 355-74.

[16] Fagerberg, J., Technology and International Differences in Growth Rates, *Journal of Economic Literature*, 32(3), 1147-75.

[17] Fedderke, J.W., (1999), So Weber was right all along, *Theoria*, 93,133-59.

[18] Fedderke, J.W., (2000a), Investment on Fixed Capital Stock: the South African Manufacturing Industry 1970-97, *ERSA Working Paper No. 16, University of the Witwatersrand.*

[19] Fedderke, J. W., (2000b), From Uneducating to Educating South Africa: some thoughts on new policy imperatives in education, *Keynote Address at the 1999 Kenton Conference, ERSA, Policy Paper No. 8, University of the Witwatersrand.*

[20] Fedderke, J.W., de Kadt R., and Luiz, J., (1999a), Indicators of Political Liberty, Property Rights and Political Instability in South Africa: 1935-97, forthcoming in the *International Review of Law and Economics*, *ERSA, Working Paper No. 4, University of the Witwatersrand.*

[21] Fedderke, J.W., de Kadt, R., and Luiz, J., (1999b), Growth and Institutions: a study of the link between political institutions and economic growth in South Africa – a time series study, 1935-97, Forthcoming in Studies in Economics & Econometrics, *ERSA, Working Paper No. 6, University of the Witwatersrand.*

[22] Fedderke, J.W., de Kadt, R, and Luiz, J., (2000a), Uneducating South Africa: The Failure to address the 1910-1993 legacy, *International Review of Education*, 46 (3/4), 257-81, *ERSA Working Paper No 2, University of the Witwatersrand.*

[23] Fedderke, J.W., de Kadt R., Luiz, J., (2000b), A Capstone Tertiary Educational System: Inefficiency, Duplication and Inequity in South Africa's Tertiary Education System, 1910-93, *ERSA, Working Paper No. 14, University of the Witwatersrand.*

[24] Fedderke, J.W., Henderson, S., Kayemba, J., Mariotti,M., and Vaze, P., (2000), Changing Factor Market Conditions in South Africa: The Capital Market – A sectoral description of the period 1970-1997, *ERSA, Policy Paper No. 7, University of the Witwatersrand.*

[25] Fedderke, J.W., Henderson, S., Mariotti M., and Vaze, P., (2000) Changing Factor Market Conditions in South Africa: The labour market – A sectoral description of the period 1970-1997, *ERSA, Policy Paper No. 5, University of the Witwatersrand.*

[26] Fedderke, J.W., and Klitgaard, R.E., (1996), Economic Growth and Social Indicators: An Exploratory Analysis, *City University: Department of Economics and Applied Econometrics Research Unit Discussion Paper No. 45.*

[27] Fedderke, J.W., and Klitgaard, R.E., (1998), Economic Growth and Social Indicators, *Economic Development and Cultural Change,* 46(3), 455-90.

[28] Fedderke, J. W., and Liu, W., (1999), South African Capital Flows and Capital Flight over the 1960-95 period, *ERSA, Working Paper No. 5, University of the Witwatersrand.*

[29] Fedderke, J.W., and Luiz, J., (1999a), Production of Educational Output: time series evidence from socio-economically heterogenous populations – the case of South Africa 1910-1993, *ERSA, Working Paper No 7, University of the Witwatersrand.*

[30] Fedderke, J.W., and Pirouz, F., (2000), The Role of Mining in the South African Economy, *ERSA, Policy Paper No. 9, University of the Witwatersrand.*

[31] Fedderke, J.W., Shin, Y and Vaze P., (2000), Trade and Labour Usage: An Examination of the South African Manufacturing Industry, *ERSA Working Paper No 15, University of the Witwatersrand.*

[32] Fedderke, J.W., and Vaze, P., (2000), The nature of South Africa's trade patterns by economic sector, and the extent of trade liberalization during the course of the 1990's, *ERSA, Policy Paper No. 3, University of the Witwatersrand.*

[33] Ferderer, J.P., (1993), The Impact of Uncertainty on Aggregate Investment Spending: An Empirical Analysis, *Journal of Money, Credit and Banking,* 25(1), 49-61.

[34] *Growth, Employment and Redistribution, 1996*

[35] Gerschenkron, A., 1962, *Economic backwardness in historical perspective,* Cambridge: Harvard University Press.

[36] Grilliches, Z., (1994), Productivity, R&D, and the Data Constraint, *American Economic Review*, 84(1), 1-23.

[37] Harberger, A.C., 1998, A Vision of the Growth Process, *American Economic Review*, 88(1), 1-32.

[38] Hartman, R., (1972), The Effects of Price and Cost Uncertainty on Investment, *Journal of Economic Theory*, 5, 258-66.

[39] Hulton, C.R., (1992), Growth Accounting when Technical Change is Embodied in Capital, *American Economic Review*, 82(4), 964-80.

[40] Habermas, J., (1981), *Theorie des kommunikativen Handelers*, Frankfurt-am-Main: Suhrkamp.

[41] Irish Council for Science Technology and Innovation., (1999), *Benchmarking School Science, Technology and Mathematics Education in Ireland Against International Good Practice: Benchmarking Database.*., URL: http://www.forfas.ie/st/sti.htm.

[42] Irish Council for Science Technology and Innovation., (1999), *Benchmarking School Science, Technology and Mathematics in Ireland Against International Good Practice: Presentation of Findings and Recommendations.*

[43] Jorgenson, D.W., (1988), Productivity and Postwar U.S. Economic Growth, *Journal of Economic Perspectives*, 2(4): 23-41.

[44] Jorgenson, D.W., and Grilliches, Z., (1967), The Explanation of Productivity Change, *Review of Economic Studies*, 34, 249-83.

[45] Joshi Aksha: Information Technology – Advantage India. www.idsa-india.org.

[46] Kornai, J., (1992), The Socialist System: The Political Economy of Socialism, *The Clarendon Press, Oxford.*

[47] Lall S., (1997), Coping with New Technologies in Emerging Asia. Mimeo

[48] Landes, D., (1990), Why are we so rich and they so poor?., *American Economic Review,* 80(2), May, 1-13.

[49] Landes, D., (1998), *The Wealth and Poverty of Nations*, London: Little, Brown and Co.

[50] Lim, D., (1994), Explaining the Growth Performances of Asian Developing Economies, *Economic Development and Cultural Change,* Vol 42, Number 4.

[51] Lucas, R.E., (1988), On the Mechanics of Economic Development, *Journal of Monetary Economics*, 22, 3-42.

[52] Mairesse, J., Hall, B.H., and Mulkay, B., (1999), Firm-Level Investment in France and the United States: An Exploration of What We Have Learned in Twenty Years, *NBER Working Paper No. W7437.*

[53] Maddison, A., (1987), Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment, *Journal of Economic Literature,* 25,649-698.

[54] Malia, Martin., (1994), The Soviet Tragedy, *The Free Press, New York.*

[55] Mansfield, E., Schwartz, M., and Wagner, S., (1981), Imitation Costs and Patents: An Empirical Study, *Economic Journal*, 91, 907-18.

[56] Meyer-Stamer, J., (1995), New Departures for Technology Policy in Brazil, *Science & Public Policy,* Vol 22, No. 5, pp. 295-304.

[57] Mankiw, N. Gregory, Romer, D., and Weil, D.N., (1992), A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics,* 107(2), 407-37.

[58] Moll, T., (1992), Essays on Growth & Structural Change in South Africa., P.h.D.Thesis , University of Cambridge.

[59] Nelson, R.R., (1964), What is the Matter with Neoclassical Growth Theory? In G. Silverberg and L. Soete, eds., *The Economics of Growth and Technical Change*, Edward Elgar, 290-324.

[60] Nelson, R.R., and Winter, S.G., (1982), *An Evolutionary Theory of Economic Change,* Cambridge Mass: Belknap Press.

[61] Nelson, R.R., and Wright, G., (1992), The Rise and Fall of American Technological Leadership: The postwar era in historical perspective, *Journal of Economic Literature*, 30, 1931-64.

[62] Nickell, S.J., (1978), *The Investment Decisions of Firms*, Cambridge: University Press.

[63] Nove, A., (1983) *The Economics of Feasible Socialism*, Allen and Unwin, London.

[64] Ochoa, O.A., (1996), Growth, Trade and Endogenous Technology, Macmillian.

[65] Olson, M., (1982), *The Rise and Decline of Nations*, New Haven and London: Yale University Press.

[66] Pagan, A., and Ullah, A., (1988), The econometric analysis of model with risk terms, *Journal of Applied Econometrics*, 3, 87-105.

[67] Pesaran, M.H., and Smith, R.P., (1995), Estimating Long-Run Relationships from Dynamic Heterogeneous Panels, *Journal of Econometrics,* 68,79-113.

[68] Pesaran, M.H., (1997), The Role of Economic Theory in Modelling the Long Run, *Economic Journal*, 107, 178-91.

[69] Price, S., (1995), Aggregate uncertainty, investment and asymmetric adjustment in the UK manufacturing sector, Unpublished manuscript, City University London.

[70] Rawls. J., (1970), A Theory of Justice, *Oxford: University Press.*

[71] Republic of Ireland, Department of Commerce, Science and Technology, White Paper, (2000), *Science and Technology and the Policy Process.*

[72] Republic of Ireland, *State Expenditure on Science and Technology, (1999),* Forfas, Wilton Place, Dublin. www.forfas.ie

[73] Romer, P.M., (1986), Increasing Returns and Long-Run Growth, *Journal of Political Economy*, 94(5), 1002-37.

[74] Romer, P.M. (1990), Endogenous Technological Change, *Journal of Political Economy,* 98(5), S71-S102.

[75] Sen, A., (1999), *Development as Freedom*, New York: Alfred A Knopf.

[76] Schultz, T.W., (1993), *Origins of Increasing Returns*, Blackwells.

[77] Schumpeter, J.A., (1912), *Theorie der Wirtschftlichen Entwicklung*, Leipzig: Dunker & Humboldt, translated by Redvers Opie.

[78] Schumpeter, J.A., (1943), *Capitalism, Socialism & Democracy*, London: Routledge.

[79] Shell, K., (1966), Towards a Theory of Inventive Activity and Capital Accumulation, *American Economic Review*, May, 62-8.

[80] Solow, R.M., (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, 312-20.

[81] Teece., D.J., (1977), Technological Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How, *Economic Journal*, 87, 242-61.

[82] Walker, M., (1994), *The Cold War*, Collins, London.