International Association for Management of Technology
IAMOT 2007 Proceedings

AN INNOVATION MANAGEMENT FRAMEWORK TO IMPROVE NATIONAL COMPETITIVENESS IN DEVELOPING COUNTRIES

VUYANI LINGELA*
Department of Engineering and Technology Management, University of Pretoria, Pretoria 0002, South Africa
* National Advisory Council on Innovation, Private Bag X894, Pretoria 0001, South Africa
Vuyani.Lingela@dst.gov.za

ANDRÉ BUYS
Department of Engineering and Technology Management, University of Pretoria, Pretoria 0002, South Africa
Andre.Buys@up.ac.za

This paper introduces the new Innovation Management (IM) Framework for better articulation, identification of gaps and challenges to help improve national competitiveness. The two basic inputs of the proposed IM Framework are innovation actors and innovation activities. Innovation actors are defined as industry, government, education institutions, research institutions and financial institutions. Innovation activities are human resource development activities, research and development (R&D) activities, and business development activities pursued by innovation actors in the national system of innovation (NSI).
Using a 20 year time series data covering the period from 1985 to 2005, this paper demonstrates the use of the IM Framework as a national innovation management tool for the innovation actors: to determine and manage their contribution in the NSI; to assess and manage functional relationships among their activities in the NSI; and to identify and manage factors limiting competitiveness in the NSI. Finally, this paper examines the contribution of human resource development, R&D and business development activities in South Africa, Japan and Korean on national competitiveness.

Keywords: Innovation management framework, national system of innovation, human resource development, research and development, business development

Introduction

The aim of this paper is to introduce a new innovation management framework for use by innovation actors collectively to identify and manage failures in the national system of innovation (NSI) to improve national competitiveness. National competitiveness is the ability of a nation's industry to command high prices in foreign markets; and the ability of a nation to create jobs that support high wages, not merely employment of citizens at low wages. The achievement of these objectives depends on the productivity with which a nation's resources (labour and capital) are employed. The only meaningful concept of national competitiveness is the value of the output produced by a unit labour and capital (Porter, 1990, pp. 5-7).

Niosi et al. (1993, p. 212) define the NSI as the system of interacting private and public firms, universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology. Freeman (1996, p. 30) emphasises that innovation should not be viewed as a linear process, whether led by demand or by technology, but a complex interaction linking potential users with new developments in science and technology.

The South African government has adopted the NSI as a policy intervention to promote coordination in the NSI to ensure that South Africa has a set of institutions, organisations and policies which give effect to a national system of innovation; that there is constructive interaction among those institutions, organisations and policies; and that there is an agreed upon set of goals and objectives which are consistent with an articulated vision of the future which is being sought (DACST, 1996a, p. 11).

The Innovation Management Framework

The evidence presented by Schumpeter (1934), Porter (1990), Romer (1990), IDRC (1993), Callon et al. (1992), Kim (1993), Odagiri and Goto (1993), Håkansson and Snehota (1995), Buys (2001) and UNDP (2001) confirms that the rate of technological progress determines the ability of a nation's industry to open new markets, develop new products and services that command high prices in domestic and international markets. Following this approach, many competitive nations were able to create jobs that support high wages, not merely employment of citizens at low wages.

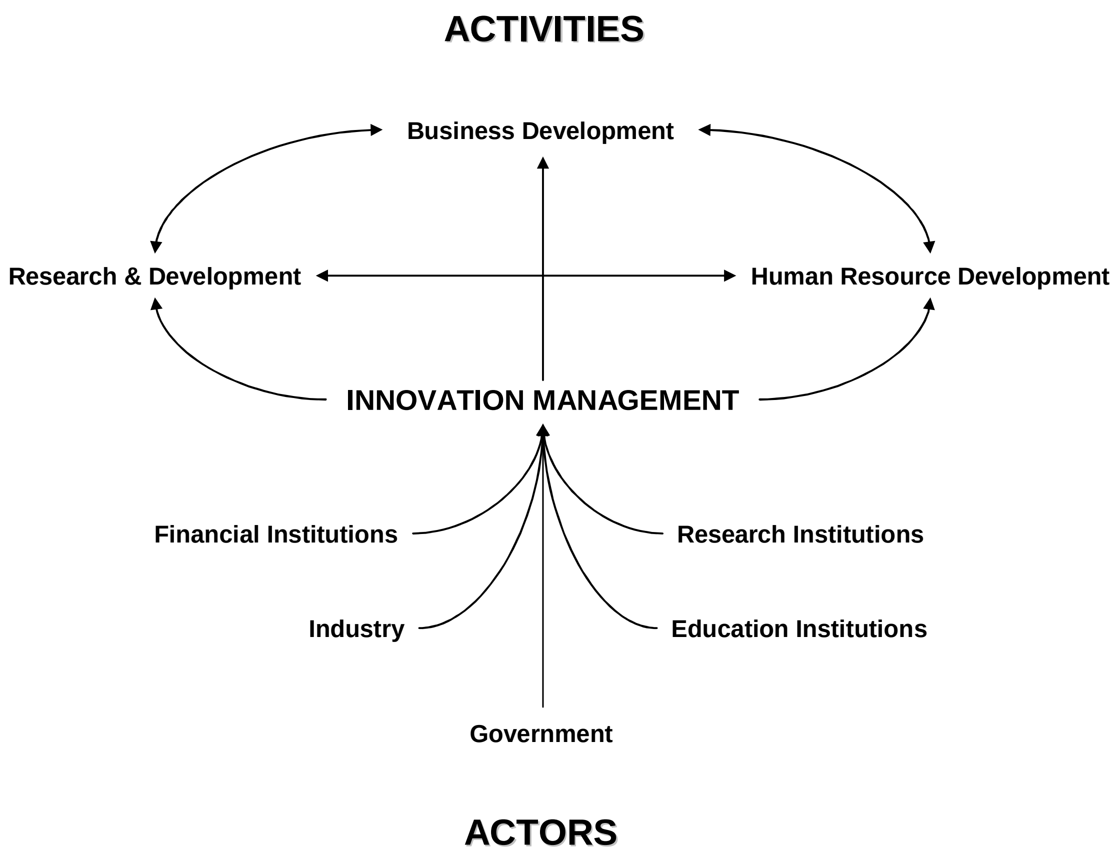

Figure 1. The Innovation Management Framework

Niosi et al. (1993, p. 212), Freeman (1996), Porter (1990), World Bank (1991), Senker (1996), Bell and Pavitt (1997) and UNDP (2001) emphasise the presence of linkages between supporting and competing companies, universities, and research organisations that supply and transform outputs of science and technology, together with public and private financial institutions that provide substantial resources as an essential characteristic of the NSI. This notion shows a shift away from implicit acceptance of a linear model of innovation towards a balanced approach.

Integrating various perspectives on innovation systems, the new Innovation Management Framework presented in Figure 1 was developed for better articulation, identification of gaps and challenges to help improve national competitiveness. The two basic inputs of the proposed Framework are innovation actors and innovation activities. Innovation actors are defined as industry, government, education institutions, research institutions and financial institutions. Innovation activities are research and development (R&D) activities, human resource development activities and business development activities pursued by innovation actors.

The proposed Framework is based on the assumption that the development of functional relationships among innovation activities in the system of innovation will improve national competitiveness. We propose the new Innovation Management Framework for the following three objectives: to provide a framework for innovation actors to determine and manage their contribution in the NSI; to provide a framework for innovation actors to assess and manage functional relationships among their activities in the NSI; and to provide a framework for innovation actors to identify and manage factors limiting competitiveness in the NSI.

Edquist (1994, pp. 71-77) proposes an empirical analysis of the NSI, for the purposes of policymaking, which he calls problem-identifying analysis. He maintains that the problem-identifying analysis must be comparative to be able to determine whether a level is high or low by comparing it to other countries. For comparative analysis, this paper includes time series data on innovation activities in South Africa, Japan and Korea. The choice of the three countries is motivated by the fact that South Africa represents a successful developing country, while Korea represents a successful newly industrialised country and Japan represents a successful developed country.

In other words, Korea is a reflection of South Africa in the future, while Japan is a reflection of Korea in the future. Over the past 130 years, Japan has gone through all the stages of economic development that South Africa and Korea are experiencing. Korea on the other hand has gone through the stages of economic development that South Africa is experiencing. South Africa is aspiring to attain the level of economic development that Korea has achieved. South Africa, Korea and Japan together represent three stages of national economic development for comparative analysis.

Unlike Japan and Korea, South Africa is a multi-national, multi-ethnic, multi-linguistic and multi-religious country. South Africa is also a country of two nations: one well resourced with the potential to compete; and the other marginalized, lacking the necessary infrastructure and with limited access to economic assets and opportunities (DTI, 2002, p. 8). In most respects, South Africa falls far short of qualifying as a scientifically highly developed country and conforms to standards typical of middle-income countries, but it also complies with characteristics of the sub-Saharan continent (Marais, 2000, p. 46).

Table 1. Growth in innovation activities

Country	Year	HG	SES	UGN	UGP	SE	RDE (million Yen)	SP	IP	C/LF	CI/LF	GDP (billion Yen)	Population
Japan	1985	11,167,864	16,568,138	2,806,256	69,688	462,891	8,890,299	33,958	13,351	2,917,939	1,523,768	327,433	120,754,000
	1986	11,365,056	16,901,476	2,912,770	71,465	489,100	9,192,932	35,740	13,864	2,985,564	1,578,674	341,921	121,492,000
	1987	11,456,437	17,386,838	3,075,228	71,873	504,008	9,836,641	35,983	17,294	3,065,834	1,726,688	359,509	122,091,000
	1988	11,429,473	17,989,602	3,195,520	76,421	530,495	10,627,571	40,279	16,989	3,213,319	1,922,834	386,736	122,613,000
	1989	11,263,673	18,911,182	3,322,459	82,121	553,336	11,815,482	41,627	21,106	3,408,843	2,088,286	414,743	123,116,000
	1990	10,992,498	20,258,332	3,457,112	90,238	579,552	13,078,315	44,334	20,743	3,620,431	2,294,263	449,997	123,537,000
	1991	10,643,243	21,292,743	3,598,014	98,650	603,548	13,771,524	46,087	22,401	3,824,710	2,273,320	472,261	123,921,000
	1992	10,255,337	22,334,916	3,734,496	109,108	620,014	13,909,493	52,027	23,164	3,872,706	2,246,102	483,838	124,229,000
	1993	9,860,609	23,050,901	3,834,568	122,360	644,977	13,709,139	51,808	23,411	3,940,951	2,100,314	480,662	124,536,000
	1994	9,543,891	23,043,851	3,895,483	138,752	664,855	13,596,030	55,786	23,517	3,989,542	2,070,340	491,268	124,961,000
	1995	9,295,335	23,766,348	3,914,746	153,423	682,590	14,408,236	58,589	22,871	4,043,596	2,093,845	499,984	125,439,000
	1996	9,074,897	23,895,790	3,925,893	162,485	698,280	15,079,315	61,331	24,059	4,084,135	2,183,622	514,227	125,761,000
	1997	8,852,840	23,841,818	3,925,830	171,547	720,560	15,741,499	61,929	24,191	4,137,227	2,133,960	520,535	126,091,000
	1998	8,638,989	24,018,325	3,902,174	178,901	731,017	16,139,925	67,630	32,118	4,064,684	2,003,463	512,503	126,410,000
	1999	8,455,824	23,922,858	3,889,132	191,125	757,244	16,010,588	69,393	32,514	4,024,295	1,969,315	508,005	126,650,000
	2000	8,270,853	24,295,968	3,875,241	205,311	761,857	16,289,336	68,636	32,922	4,076,003	2,002,937	513,170	126,870,000
	2001	8,055,833	24,136,873	3,864,340	216,322	750,739	16,527,998	71,083	34,891	4,031,678	1,873,085	500,968	127,140,000
	2002	7,795,221	24,020,494	3,876,025	223,512	756,336	16,675,053	69,672	36,339	3,969,438	1,780,360	497,203	127,399,000
	2003	7,562,882	23,635,832	3,898,008	231,489	757,339	16,804,155	75,581	37,248	3,937,408	1,797,649	501,254	127,573,000
	2004	7,388,612		3,893,801	244,024	787,264	16,937,584	68,568	37,032				127,764,400
	2005	7,239,113		3,927,349	254,480	790,932			31,834				127,956,000
Country	**Year**	**HG**	**SES**	**UGN**	**UGP**	**SE**	**RDE (million Won)**	**SP**	**IP**	**C/LF**	**CI/LF**	**GDP (billion Won)**	**Population**
Korea	1985	5,002,781	2,491,673	1,277,828	68,178	41,473	1,237,074	559	50	2,045,934	1,471,942	84,061	40,806,000
	1986	5,102,415	2,766,011	1,332,455	69,962	47,042	1,606,910	660	55	2,299,263	1,644,153	98,110	41,184,000
	1987	4,970,703	3,125,648	1,361,949	70,364	52,783	1,985,224	884	105	2,643,656	1,918,179	115,164	41,575,000
	1988	4,900,616	3,692,875	1,387,170	75,117	56,545	2,454,152	1,030	126	3,186,615	2,271,201	137,112	41,975,000
	1989	4,811,342	4,336,102	1,630,374	81,171	66,220	2,817,256	1,342	183	3,678,621	2,679,517	154,753	42,380,000
	1990	4,662,781	6,856,021	1,691,429	86,911	70,503	3,349,864	1,582	290	4,382,941	3,617,486	186,691	42,869,000
	1991	4,534,447	5,549,376	1,761,775	91,304	76,252	4,158,441	1,867	449	5,323,503	4,490,774	226,008	43,268,000
	1992	4,534,331	6,462,736	1,981,970	96,577	88,764	4,989,031	2,398	586	5,955,817	4,769,689	257,525	43,663,000
	1993	4,536,722	7,397,248	2,099,021	103,974	98,764	6,152,983	2,962	830	6,638,445	5,224,299	290,676	44,056,000
	1994	4,612,204	8,241,341	2,196,895	109,983	117,446	7,894,746	3,948	1,008	7,559,050	5,959,751	340,208	44,453,000
	1995	4,674,749	9,738,027	2,342,786	112,728	128,315	9,440,606	5,365	1,240	8,756,840	6,969,016	398,838	45,093,000
	1996	4,654,799	11,029,826	2,540,209	126,358	132,023	10,878,051	6,417	1,567	9,834,728	7,712,425	448,596	45,525,000
	1997	4,548,166	12,067,851	2,790,734	151,358	138,438	12,185,807	7,851	1,965	10,146,047	7,833,623	491,135	45,954,000
	1998	4,369,493	12,130,975	2,950,826	179,773	129,767	11,336,617	9,830	3,362	9,879,947	6,689,762	484,103	46,287,000
	1999	4,178,626	11,417,942	3,154,245	204,773	134,568	11,921,752	11,307	3,679	10,255,439	7,082,230	529,500	46,617,000
	2000	3,960,856	12,704,300	3,363,549	229,437	159,973	13,848,501	12,455	3,472	10,968,943	7,951,883	578,665	47,008,110
	2001	3,770,544	17,868,600	3,500,560	243,270	178,937	16,110,522	14,856	3,763	11,780,634	8,005,279	622,123	47,353,520
	2002	3,663,512	18,726,300	3,577,447	262,867	189,888	17,325,082	15,799	4,009	12,584,003	8,505,864	684,264	47,615,130
	2003	3,646,806	20,749,700	3,531,721	272,331	198,171	19,068,682	18,730	4,132	13,664,226	9,260,951	724,675	47,849,230
	2004	3,702,338	22,112,700	3,515,603	276,918	209,979	22,185,343	19,217	4,671	14,286,719	9,543,385	779,381	48,082,160
	2005	3,777,918		3,492,207	282,225				4,591	14,838,708	9,700,103	806,622	48,294,140
Country	**Year**	**HG**	**SES**	**UGN**	**UGP**	**SE**	**RDE (thousand Rands)**	**SP**	**IP**	**C/LF**	**CI/LF**	**GDP (million Rands)**	**Population**
South Africa	1985	2,079,000	6,753	297,695	17,241	20,274	1,077,304	2,665	97	5,312	2,323	127,598	31,307,880
	1986	2,245,000	8,112	328,558	19,002	22,005	1,203,215	3,138	91	5,968	2,270	149,395	32,121,290
	1987	2,411,000	9,745	362,621	19,950	23,736	1,329,125	3,371	113	6,819	2,347	174,647	32,933,080
	1988	2,743,000	10,753	396,083	20,619	21,984	1,551,786	3,267	107	7,772	2,990	209,613	33,728,500
	1989	2,743,000	13,641	429,544	21,476	20,232	1,774,447	3,243	143	9,064	3,641	251,676	34,490,550
	1990	2,743,000	17,157	439,007	22,517	21,545	2,280,267	3,155	122	10,360	3,862	289,816	35,200,000
	1991	2,939,270	20,192	467,129	23,730	22,857	2,786,087	3,347	111	11,586	3,849	331,980	35,933,110
	1992	3,101,000	23,227	490,112	24,367	20,727	2,690,098	3,272	101	12,768	3,813	372,225	36,690,740
	1993	3,314,000	26,335	552,948	24,769	18,596	2,594,108	3,303	101	13,883	3,984	426,133	37,473,800
	1994	3,571,395	30,856	617,897	25,886	110,536	2,971,331	3,391	109	15,032	4,534	482,120	38,283,220
	1995	3,756,000	33,517	621,902	27,003	202,477	3,348,554	3,392	127	16,639	5,273	548,100	39,120,000
	1996	3,802,000	41,782	625,908	27,669	294,417	3,725,777	3,369	116	18,246	5,959	617,954	40,000,250
	1997	3,943,032	43,933	629,913	29,353	386,358	4,103,000	3,317	114	19,627	6,534	685,730	40,926,060
	1998	4,084,064	44,726	633,918	31,127	478,298	4,505,250	3,487	132	20,957	7,139	742,424	41,899,680
	1999	4,078,846	46,437	632,911	33,592	570,238	4,907,500	3,665	127	22,183	6,898	813,683	42,923,480
	2000	3,943,618	50,811	644,763	35,624	662,179	5,712,000	3,501	125	23,738	7,495	922,148	44,000,000
	2001	4,029,272	54,912	658,588	40,619	754,119	7,488,075	3,672	137	24,994	8,098	1,020,007	44,812,420
	2002	4,108,709	61,280	677,913	47,072	388,221	7,830,813	3,944	123	27,226	9,185	1,168,778	45,345,290
	2003	4,186,882	69,252	717,793	52,333	22,323	10,082,600	3,828	131	29,609	10,320	1,257,026	45,828,700
	2004	4,317,903	74,688	744,488	54,437	27,875	12,010,000	3,906	115	32,712	11,802	1,386,658	45,509,240
	2005		80,179						108	35,953	13,821	1,523,255	45,192,000

In the following sections, we apply the Innovation Management Framework to examine the contribution of human resource development, R&D and business development activities on national competitiveness. The data used in this paper to examine innovation activities over a 20-year period from 1985 to 2005 are presented in Table 1. While Table 1 presents the best time series data currently available from various national and international sources indicated in Appendix 1, many gaps and reliability problems remain in measuring the contribution of innovation actors to human resource development, research and development and business development activities in Japan, Korea and South Africa. We interpolated the data by constructing average values of the immediately preceding and following years from existing years to obtain missing values particularly for South Africa.

The Function of Human Resource Development Activities

The data presented in Figure 2 show declining growth rates in the South African population from its record high growth rate of 46.38% in 2003 to 44.35% in 2005, which account for a population of 45.82 million and 45.19 million respectively. The population growth rates of 5.96% and 18.35% in the past 20 years account for the Japanese and Korean population of 128 million and 48.23 million respectively. The low population growth rates in Japan and Korea are seen as a threat to the national social security system in both countries, particularly in Japan which faces even lower population growth prospects than Korea.

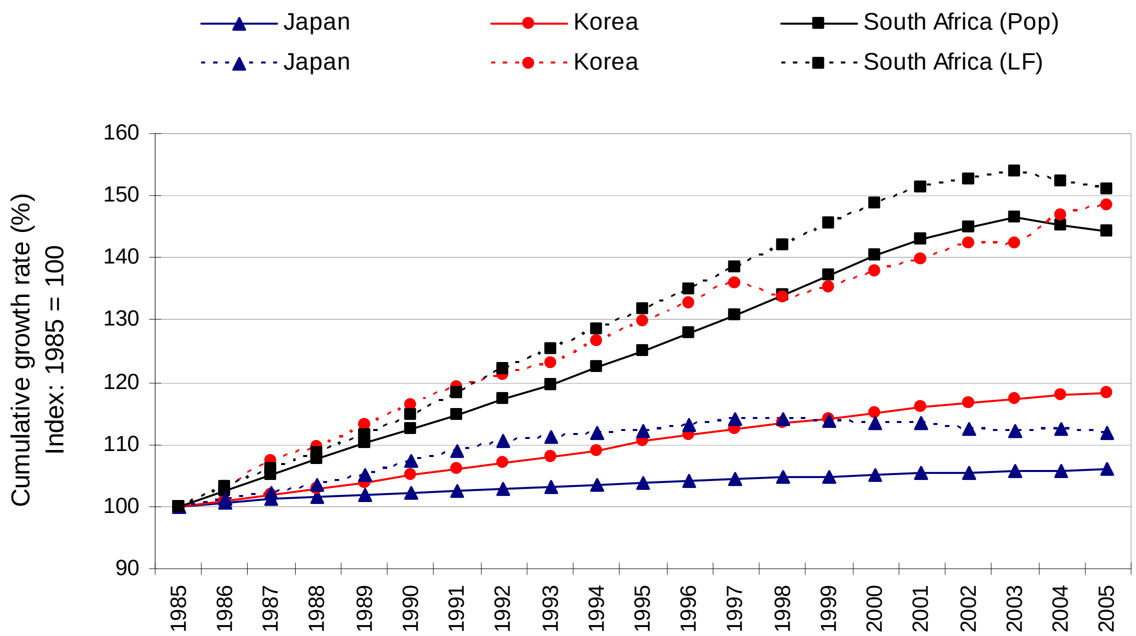

Figure 2. Growth in population (Pop) and labour force (LF)

These population growth trends have implications for human resource development and subsequent growth in labour force. This is apparent in South Africa, where the declining population growth rate is associated with a declining growth rate in labour force. Whereas low birth-rate is associated wit low population growth rate in Japan, infectious diseases are associated with the declining population growth rate in South Africa. Statistics South Africa (2006c, p. 39) indicates that the natural causes of death such as tuberculosis, cerebrovascular diseases, diabetes mellitus and the human immunodeficiency virus (HIV) disease were underlying causes of death in over 90% of the deaths in which they were mentioned in 2003 and 2004.

Expenditure on education

Bell and Pavitt (1997, p. 85) argue that the conventional focus on investments in physical capital is no longer adequate to achieve economic growth based on technological development. They maintain that such an approach completely ignores the investment in intangible capital that is necessary, not just to operate machines, but to choose them in the first place, to improve their performance and to replicate them once acquired and further develop both them and the products they produce to lay the basis for higher value activities in the future.

The data presented in Figure 3 show the growth rate of 23.64% in Japanese public expenditure on education in the past 18 years, which accounts for 26.6 trillion Yen (US$ 203 billion) or 4.72% of GDP expenditure on education in 2003. The record high growth rate of 787% in public expenditure on education in Korea in the past 19 years accounts for 22.11 trillion Won (US$ 19.00 billion) or 2.84% of GDP in 2004. The amount of 80.18 billion Rands (US$ 12.27 billion) or 5.26% of GDP spent on education in South Africa in 2004 is about half the amount of money spent on education in Korea.

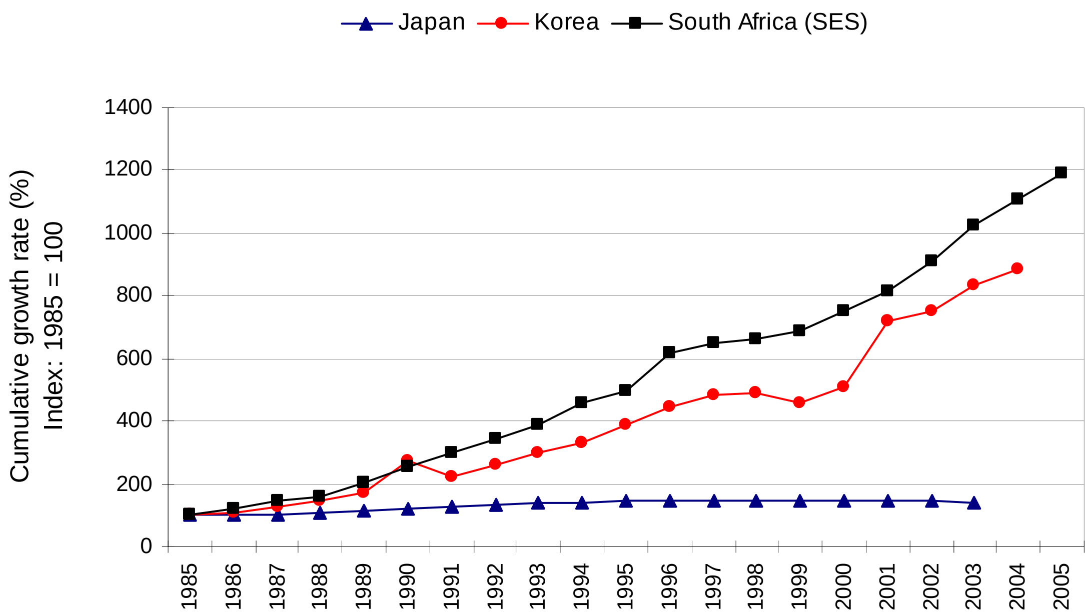

Figure 3. Growth in public expenditure on education (SES)

3.2 Secondary school enrolment

The impact of the low population growth rates is apparent in Figure 4 which shows declining growth rates of -35.18% and -24.48% in secondary school enrolment in the past 20 years in

Japan and Korea respectively. Although Japan saw a record high number of 11.46 million students enrolled in secondary school in 1987, only 7.24 million students were enrolled in 2005. Like Japan, Korea saw a record high number of 5.10 million students enrolled in secondary school in 1986, but only 3.78 million students were enrolled in 2005.

Unlike Japan and Korea, South Africa saw positive growth in secondary school enrolment, as indicated by the growth rate of 108% in the past 19 years. As a result of this growth trend, South Africa saw a record high number of 4.32 million students enrolled in secondary school in 2004 compared to 2.08 million students in 1985. Although the number of secondary school students in South Africa is lower than the number of student in Japan, South Africa has more secondary students than Korea.

In South Africa, there is broad agreement about the extent of the problem of the quality of education for black students at a secondary level. The survey conducted by South Africa's Foundation for Research Development reveals that more than 80% of all black students who completed secondary school in 1993 did not register for mathematics or physical science, and of those that did, only about 20% passed these subjects on higher grade. In contrast, 61% of white students completed secondary school with mathematics as subject (FRD, 1996, p. 2).

This is a major reason for concern in South Africa, considering that the character and effectiveness of a nation's system of schooling, training and retraining affects the attitude of workers towards technical advancement and determines the supply of skills from engineer to machine tender (Nelson and Rosenberg, 1993, p. 13).

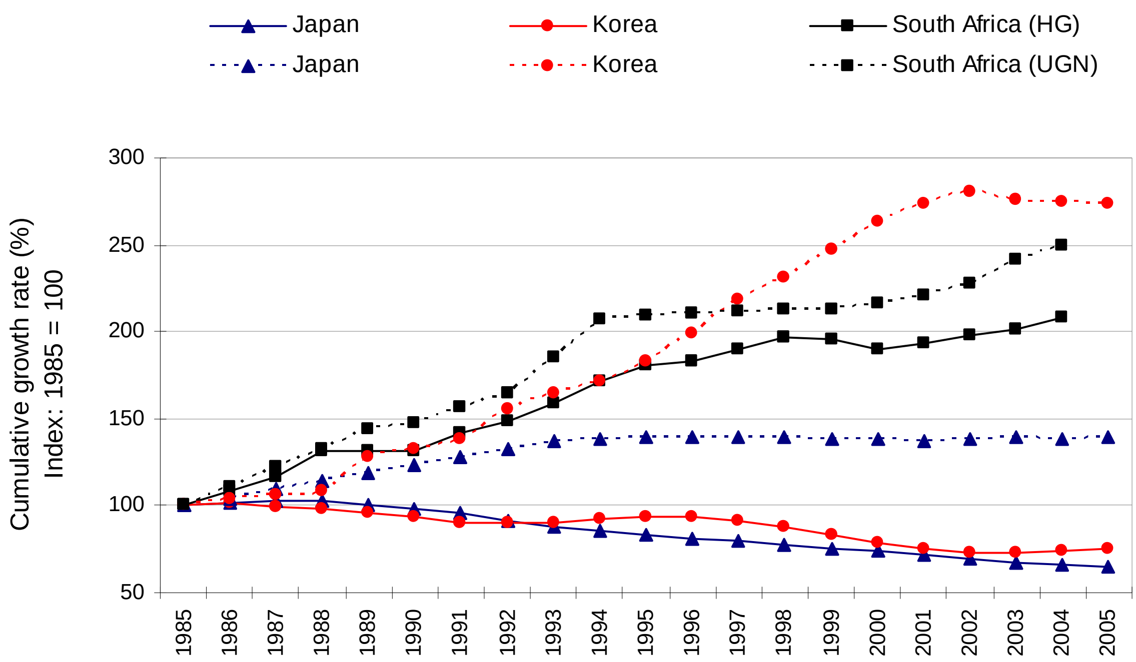

Figure 4. Growth in secondary school (HG) and higher education enrolment (UGN)

Higher education enrolment

The growth rate in secondary school enrolment has an influence on enrolment into higher education institutions. Countries with high numbers of students in secondary school are expected to have high numbers of students in higher education institutions if all other factors remain constant. For example, the ratio of Japanese higher education students to secondary school students was 25.13% in 1985 and 54.25% in 2005, while the same ratio in Korea was 25.54% in 1985 and an outstanding 92.44% in 2004. In South Africa, the ratio of higher education students to secondary school students was 14.32% in 1985 and only 17.24% in 2004. These data show that higher education enrolment in Korea is four times greater relative to South Africa.

The data presented in Figure 4 show growth rates of 39.95% and 173% in higher education enrolment in the past 20 years, which accounts for 3.93 million students in Japan and 3.49 million students in Korea respectively in 2005. In South Africa, the record high growth rate of 108% was achieved from 1985 to 1994, resulting into a total of 618 thousand higher education students in 1994. However, since 1994 the growth rate in higher education enrolment in South Africa levelled off until 2000. South Africa saw a growth rate of 20.49% in higher education enrolment from 1994 to 2004, which accounts for 744 thousand students in 2004.

In 1994 only 11% of black South African students in higher education institutions were enrolled in science and engineering fields compared with 57% of white students enrolled in science and engineering (FRD, 1996, p. 3). These results are worrying, considering that human resource development in science and technology is the most basic and crucial determinant for the rapid acquisition of technological capability, as technological capability is embodied in people (Kim, 1993, p. 358).

The account by Odagiri and Goto (1993, pp. 80-104) of the Japanese experience in building the automotive industry presents some important lessons for other nations. One is the presence of engineers and entrepreneurs who were willing to take risks and sustain efforts under adversity. The other is the general ability of engineers to absorb foreign technology and the ability of workers to absorb new production processes. Major firms in the automobile electrical equipment and steel industries remained Japanese-owned and the stakes foreign firms owned in Japanese electrical and communication equipment companies decreased during the post-war period. The Japanese government emphasised engineering education since the 1880s, at the time when most developed countries regarded pure science as superior to engineering.

Graduate school enrolment

In the same way that secondary school enrolment influences higher education enrolment, countries with a high number of students in higher education are expected to have a high number of students in graduate schools. Porter (1990, pp. 78-80) expresses a strong need for scientists and engineers specialised in fields similar to emerging innovation opportunities in the local environment, above and beyond the simple availability of trained scientists and engineers.

Figure 5 shows growth rates of 265% and 313% in graduate school enrolment in the past 20 years in Japan and Korea respectively. The number of graduate school students in Japan grew from 70 thousand in 1985 to 254 thousand in 2005, while the number of Korean graduate students grew from 68 thousand to 282 thousand in 2005. South Africa's graduate school enrolment rate grew by 215% in the past 19 years from 17 thousand in 1985 to 54 thousand students in 2003. These data indicate that Korea has five times more graduate students than South Africa.

Researchers

The data presented in Figure 5 show growth rates of 406% and 70.87% in the number of researchers in Korea and Japan in the past 19 and 20 years respectively. These data account for the total of 210 thousand and 790 thousand researchers in Korea and Japan in 2004 and 2005 respectively. The growth rate of 10.11% accounts for the total number of 22 thousand researchers in South Africa in 2003 compared to 20 thousand researchers in 1985. These data suggest that Korea has 8 times more researchers than South Africa

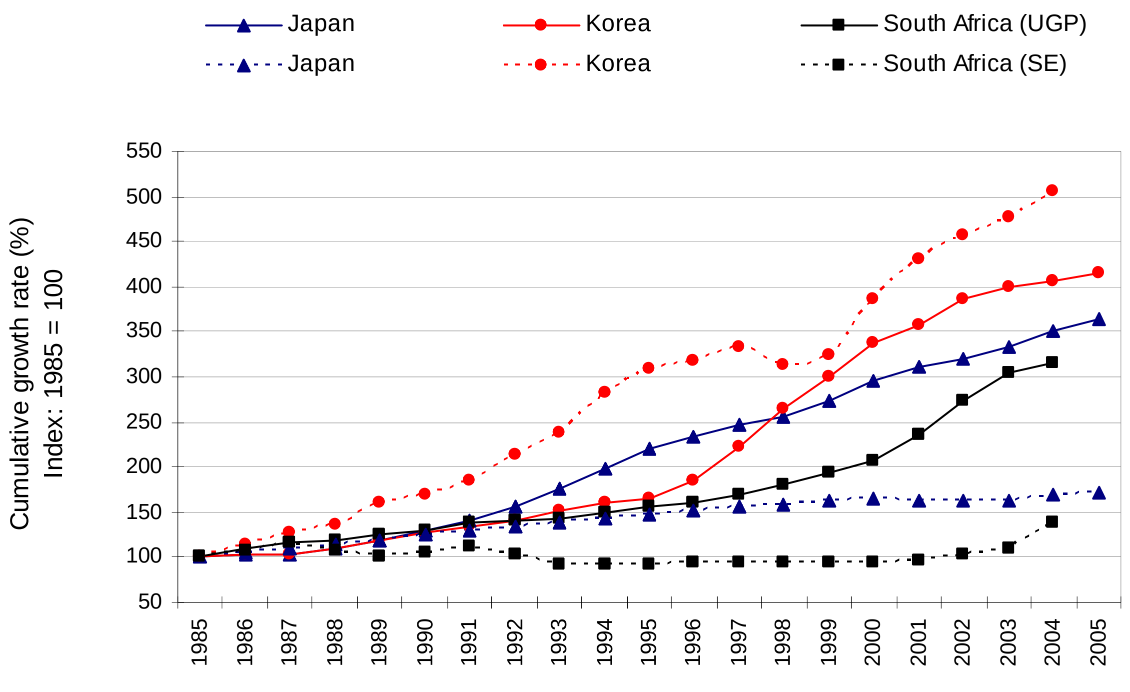

Figure 5. Growth in graduate school enrolment (UGP) and the number of researchers (SE)

Even though South Africa saw an increase in the number of researchers to 27 thousand in 2004, these data indicate low growth rates in human resource development activities in South Africa in the past 18 years. Marais (2000, p. 88) argues that the policy of apartheid directly contributed to a skewed distribution of R&D capacity in South Africa's science and technology sector. He explains that the well-established capacity of the white minority is in stark contrast with the needs of the black majority. These aspects have often rendered the evolution of science and technology in South Africa unpredictable and made it seem quite erratic.

The Function of Research and Development Activities

Expenditure on research and development

Investments in technology, like investment in education, can equip people with better tools and make them more productive and prosperous (UNDP, 2001, p. 2). Romer (1990, pp. S72-S75) explains that technological change provides the incentive for continued capital accumulation, and together, capital accumulation and technological change account for much of the increase in output per hour worked. For example, the Japanese firms found their world export market share in high-technology products increasing from 7.2% in 1965 to 19.8% in 1986 (Odagiri and Goto, 1993, pp. 81-89).

De Wet (1998, pp. 1-2) maintains that even though many countries in the world gained political independence, they essentially remained "technology colonies". He indicates that in technology colonies the predominant industrial business activity is at the manufacture and trade-in-final-products end of the product life cycle, while activities in the industrialised country tend towards a continuum over the whole life cycle. Technology colonies have a small group of activities at the research end of the life-cycle, representing the R&D activities of higher education institutions, some research development done in local industry and some funded by government.

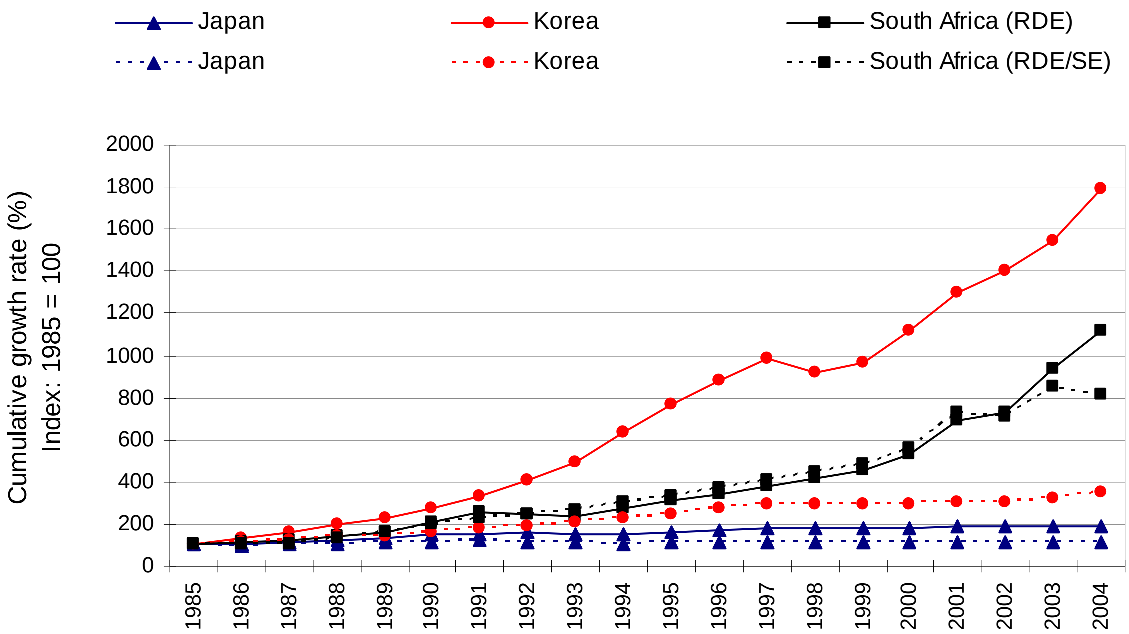

Figure 6. Growth in research and development expenditure (RDE)

He explains that there is a large flow of technology from the developed world into the colony in the form of licensed product designs, processes, subassemblies and final products, often implemented in the colony in the form of a subsidiary of a multi-national corporation. There is an almost insignificant flow of technology from the local R&D to the local industrial sector, mainly because the relevant R&D is done "back home"; but there is some communication between the local and foreign R&D communities. More than 80% of the value of the South African business activity is done under foreign licence (De Wet, 1998, pp. 1-2).

Archibugi and Michie (1997, pp. 125-128) maintain that even if leading nations were willing to share their technology with catching-up countries, the latter would still have to devote substantial energies to attempt to assimilate it, including the development of their own endogenous scientific and technological capabilities. The World Bank (1991, p. 35) insists that the intangible investment in knowledge accumulation is the decisive factor for development, rather than physical capital investment.

Japan and Korea exemplify two countries whose industry and government provide substantial resources to promote innovation through R&D activities. The data presented in Figure 6 show growth rates of 90.52% and 1,693% in R&D expenditure in the past 19 years in Japan and Korea respectively. Japan's growth rate accounts for 16.93 trillion Yen (US$ 154 billion) or 3.38% of GDP expenditure on R&D in 2004. Korea's growth rate accounts for 22.19 trillion Won (US$ 19.06 billion) or 2.85% of GDP expenditure on R&D in 2004.

The growth rate in national expenditure on R&D (RDE/SE), weighted by the number of researchers, provides new insights on national research capacity as presented in Figure 6. These data suggests that a large amount of money for R&D is shared by a large number of researchers in Korea and Japan, whereas a relatively small amount of money is shared by a small number of researchers in South Africa. However, there is a noticeable decline in R&D expenditure per researcher in 2004 whereas R&D expenditure maintains high growth. These data suggest an increase in the number of researchers, which calls for a dramatic increase in R&D expenditure in South Africa to promote R&D activities of the growing number of researchers.

South Africa is experiencing positive growth rates of 835% in R&D expenditure in the past 19 years. However, this growth rate accounts for a total of 12.01 billion Rands (US$ 1.84 billion) or 0.87% of GDP expenditure on R&D in 2004. These data suggest that South Africa would have to invest a total amount of 124 billion Rands or 8% of GDP in 2005 to achieve a level of R&D investment comparable to the level in Korea, because Korea spends twelve times more money on R&D than South Africa.

Scientific papers

The primary objective of research is to uncover information about a specific subject to generate new knowledge which can be applied by universities, research institutions, financial institutions, companies, governments and non-governmental organizations to realize their objectives. Although research results are published in several media, the results of scientific research are mostly published in peer reviewed scientific journals. The total number of scientific papers published by researchers of a particular country represents the intensity or level of scientific research in that specific country or region within a specific country.

The data presented in Figure 7 show growth rates of 102% and 3,338% in the number of scientific papers published by researchers in Japan and Korea respectively in the past 19 years. These growth rates account for 68,568 and 19,217 scientific papers published by researchers in Japan and Korea respectively in 2004. The growth rate of 46.57% in the number of scientific papers published in the past 19 years accounts for 3,906 scientific papers published by researchers in South Africa in 2004. These data indicate that researchers in Korea publish five times more scientific papers than researchers in South Africa.

These data show that researchers in South Africa have been publishing more scientific papers than researchers in Korea until 1993. However since 1994 the numbers of scientific papers published by researchers in Korea have surpassed the number of papers published by South African researchers. Since 1994 Korea has achieved the growth rate of 387% in the number of scientific papers, while South Africa has only achieved the growth rate of 15.19% since 1994.

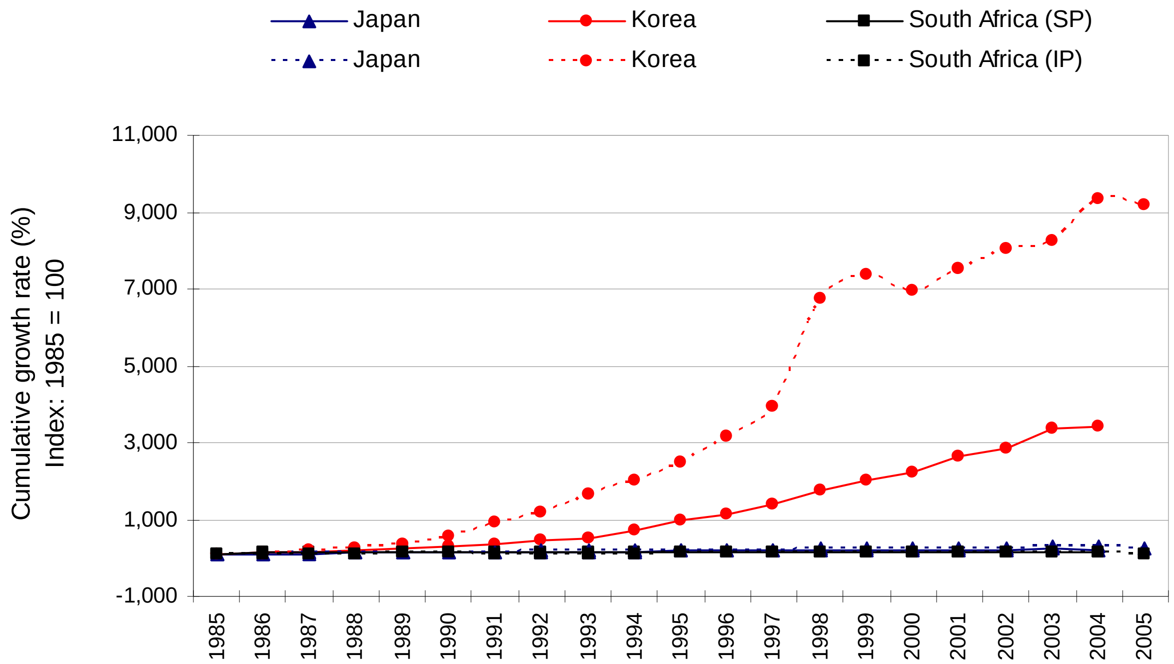

Figure 7. Growth in number of scientific papers (SP) and patents (IP)

The South African government acknowledges that reliance solely on the past basis for competitiveness, such as abundant natural resources and cheap labour, will create an increasingly low value economy, and unable to address the country's socio-economic legacy (DTI, 2002, pp. 3-7). However, the government accepts that South Africa's capacity to respond to new areas of technology that are regarded as critical in the global economy, such as information and communications technology and biotechnology is limited at present (DST, 2002, p. 32).

Patents

Obtaining exclusive legal rights in the form of patents is one way in which organisations protect and exploit the intellectual property (IP) embodied in their products or services. However, the economic reality is that not all patents can be developed into commercial products or services and it is often not possible to foresee with certainty patents or other forms of IP that can be developed to create commercially viable products and services. Despite these uncertainties, the total number of patents granted to individuals and organisations in a particular country represents the intensity of R&D as well as economic potential in that specific country.

The data presented in Figure 7 show growth rates of 138% and 9,082% in the number of patents granted to individuals and organizations in Japan and Korea in the past 20 years, which accounts for 31,834 and 4,591 patents granted to Japanese and Koreans respectively by the United States Patent and Trademark Office (USPTO) in 2005. South Africans have been granted more patents than Koreans until 1987, since 1988 Koreans started to obtain record high number of patents. The low growth rate of 11.05% in the number of patents granted in the past 19 years accounts for 108 patents granted by the USPTO to individuals and organisations in South Africa in 2005. These data indicate that Koreans receive 42 times more patents than South Africans.

The Function of Business Development Activities

Compensation of employees

Porter (1990, pp. 5-7) insists that national competitiveness is the ability of a nation to create jobs that support high wages, not merely employment of citizens at low wages. He maintains that the ability to create jobs that support high wages depends on the productivity with which a country uses labour and capital. Japan and Korea show labour force growth rates of 5.57% and 25.34% respectively in the past 20 years, where labour force is weighted by population size. These growth rates account for the employment rate of 52.12% and 50.47% in Japan and Korea respectively in 2005. South Africa on the other hand shows growth rate of 4.63% in the past 20 years which accounts for the relatively low employment rate of 41.86% in 2005.

The data presented in Figure 8 show growth rates of 34.94% and 625% in compensation per worker in the past 18 years and 20 years in Japan and Korea respectively. These growth rates account for a compensation of 3.94 million Yen (US$ 33,784) and 14.84 million Won (US$ 14,687) per worker in Japan and Korea in 2003 and 2005 respectively. The growth rate of 577% in compensation per worker in the past 20 years accounts for 35,953 Rands (US$ 5,501) in compensation per worker in South Africa in 2005. These data suggest that workers in South Africa on average receive three times less compensation than workers in Korea.

The South African government (DTI, 2002, pp. 18-24) acknowledges that the South Africa will not sustain growth and competitiveness when human and economic resources are underdeveloped. The government indicates that South Africa’s current industrial policies do not have the desired impact in particular areas, most notably on the growth rate, employment creation, small business development, income distribution and equity. Consequently, the data presented in Figure 8 suggest that while individual workers in South Africa continue to realize high growth rates in salaries, the South African economy is creating jobs that support low wages with limited capacity to create jobs that support high wages.

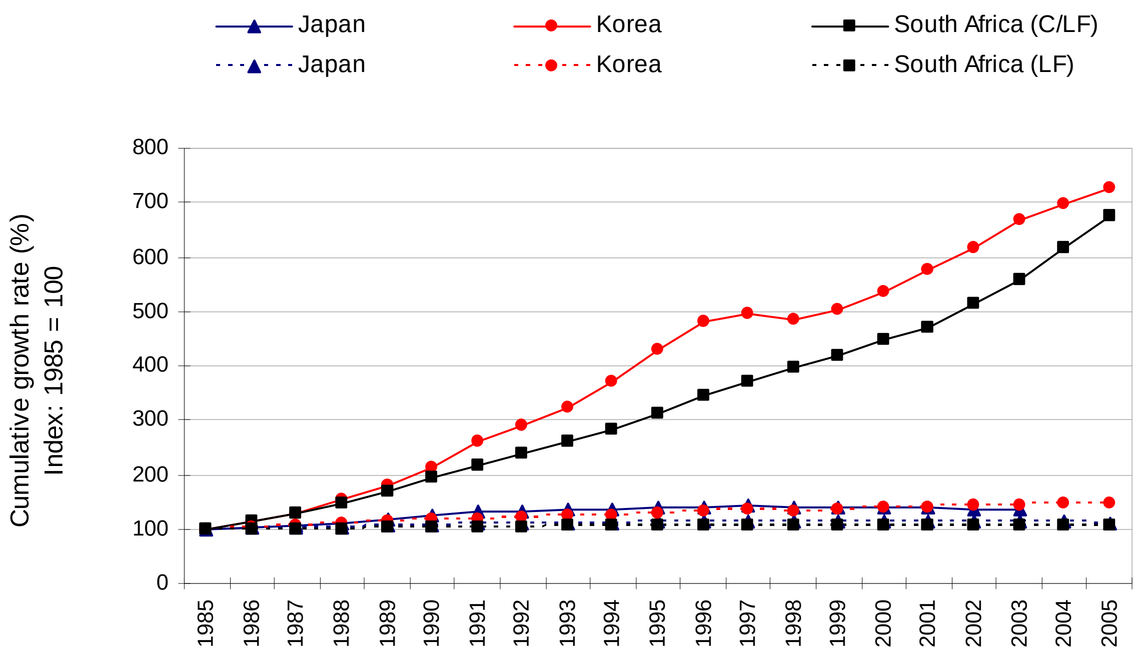

Figure 8. Growth in compensation per worker (C/LF) and labour force (LF)

These data show that the growth rate in labour force started to level off in South Africa since 1994 and the country has been facing declining employment growth rates since 1999. On the other hand, these data suggest that Korea continues to create new job opportunities that support high wages while individual workers continue to realise high growth in salaries. These data indicate that the Korean economy is creating five times more new jobs than the South African economy.

It is understood that companies generally do not set about to increase employment; rather, they sell products in order to survive, make profits and grow. Companies that succeed at selling some types of products create economic growth and employment as a side effect of going about their business (Edquist et al., 2001, p. 158). South Africa is ranked 23rd out of 31 countries according to the rate of new firms that have paid wages and salaries for 3-42 months in 2003. Compounding this problem is a low proportion (33%) of South Africans who believe that they have the skills and experience necessary to start a new business compared to 66% in the other developing countries included in the survey (Orford et al., 2003, pp. 1-3).

The South African Department of Trade and Industry indicates that labour-intensive sectors are showing a tendency to decline in labour demand and are growing less rapidly than the non-labour intensive sectors. There is also a shift in demand from semi- and unskilled labour towards skilled labour, in some cases creating a shortage in the supply of particular skills such as science and technology. The economically active population grew by 2.5% between 1988 and 1992 and the size of the workforce in the formal sector declined by 1% per year, while the science and technology workforce increased marginally by 0.2% (FRD, 1996, p. 4).

Developing countries facing high levels of unemployment can learn from the Korean experience, where the rapid expansion of education caused serious unemployment problems for the graduates in the 1950s and 1960s. However, the formation of educated human resources, despite low per capita income, laid an important foundation for the subsequent adaptation of imported technologies and development of indigenous technologies. The rapid expansion of the Korean economy soon absorbed the surplus of educated workers (Kim, 1993, p. 360).

Fixed capital investments

The data presented in Figure 9 show growth rates in gross fixed capital formation, which measures the total value of new investments on physical assets by industry and additions to the value of non-produced capital goods. Investments by industry in the form of manufactured capital goods such as machines, equipment, buildings, vehicles and the value of land improvements, which are used in the production of other goods and services, are some of the most important drivers of the national economic growth.

The growth rate of 17.97% in fixed capital investment, when weighted by the size of labour force in the past 18 years, accounts for 1.80 million Yen (US$ 15,424) in Japan in 2003. The growth rates of 559% and 495% in fixed capital investment, when weighted by the size of labour force in the past 19 years, account for capital investment of 9.70 million Won (US$ 9,601) in Korea and 13,821 Rands (US$ 2,115) in South Africa respectively in 2005. These data indicate that Korea's investment on fixed capital is four times greater than South Africa's investment on fixed capital.

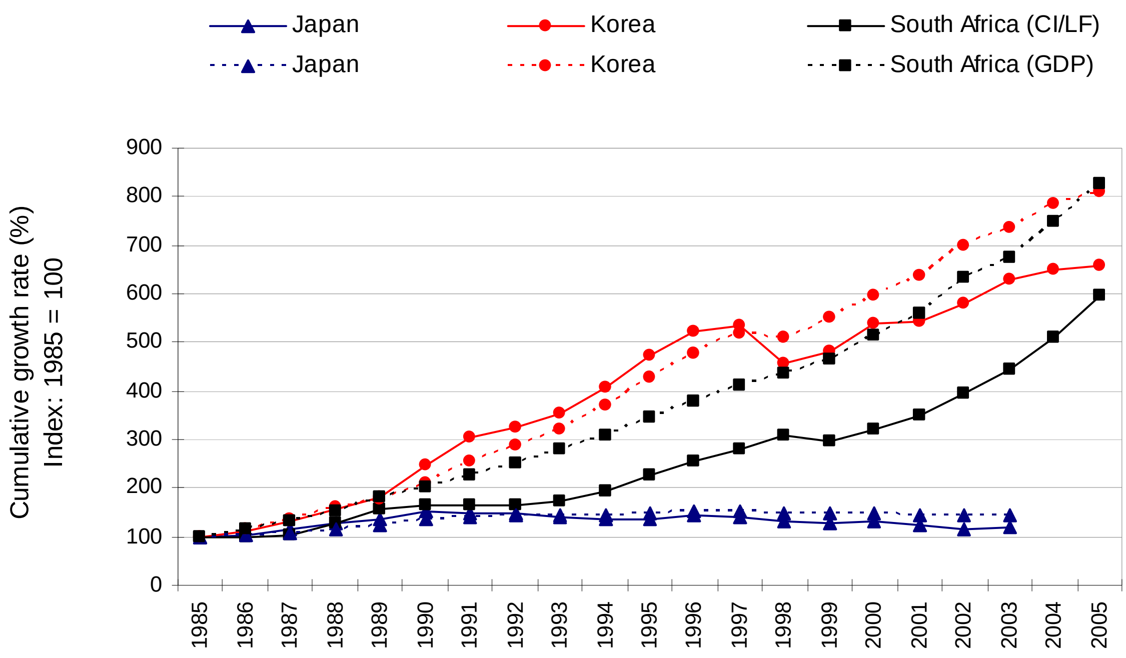

Figure 9. Growth in fixed capital investments per worker (CI/LF) and GDP

These data show a relatively low growth rate of 17.97% in fixed capital investment in Japan which corresponds to a low growth rate of 44.90% in GDP per capita in the past 18 years which accounts for the GDP per capita of 3.93 million Yen (US$ 33,713) in 2003. The high growth rates of 559% and 494% in fixed capital investment in the past 20 years corresponds to high growth rates of 710% and 727% in GDP per capita in South Africa and Korea. With the GDP per capita of 16.70 million Won (US$ 16,532), Korean economy is three times bigger than the South African economy with the GDP per capita of 33,706 Rands (US$ 5,157) in 2005.

The UNDP (2001, p. 3-8) argues that even though high-tech start-ups have thrived on venture capital in developed countries, there is little prospect of such financing in many developing countries, where even basic financial services are underdeveloped. Private investors can be discouraged by the lack of intellectual property protection in developing countries. The UNDP stresses that technology is created in response to market pressures – not the needs of the poor people, who have little purchasing power. The heart of the problem is that technology may be both a tool for development and also a means for competitive advantage in the global economy.

In Korea the government intentionally created large firms, *chaebols*, as instruments to bring about the economy of scale in mature technologies and to develop "strategic industries" in turn to lead exports and economy. The government helped more significantly with the formation of *chaebols* by allocating scarce foreign exchange and preferential financing. The government gave *chaebols* large import-substitution projects, for which they imported production technology on turnkey basis with foreign loans guaranteed by the state. Three of the largest *chaebols* in 1965, Samsung, Lucky-Goldstar and Ssangyong remained on the same list 10 years later (Kim, 1993, p. 363).

Conclusions

This paper introduced the new Innovation Management Framework for better articulation, identification of gaps and challenges to help improve national competitiveness. Using a 20 year time series data covering the period from 1985 to 2005, this paper demonstrated the use of the new Framework as a national innovation management tool for the innovation actors: to determine and manage their contribution in the NSI; to assess and manage functional relationships among their activities in the NSI; and to identify and manage factors limiting competitiveness in the NSI.

This paper examined the contribution of human resource development, R&D and business development activities in South Africa, Japan and Korea on national competitiveness. Comparative analysis of human resource development, R&D and business development activities in both Japan and Korea enhanced the capacity of this new Framework to distil factors limiting competitiveness in the South African NSI.

The case of South Africa and Korea presented in this paper provides further evidence to confirm the results of other studies presented in this paper suggesting that population size is not important for national competitiveness if the country does not have a large pool of skilled people to promote national productivity. Korea and South Africa for example, the two countries with comparable population sizes are leading different development trajectories. Korea has a relatively low but stable population growth rate while South Africa is beginning to realise a declining trend in population growth rate. Further studies forecasting the impact of the declining population growth rate on national competitiveness are recommended.

In Japan, the consequences of the negative growth rate in secondary schools enrolment are made obvious by the stagnant growth rate in higher education enrolment and graduate school enrolment since 1993. In Korea, the negative growth rate in secondary school enrolment is manifested in the declining growth rate in higher education enrolment since 2003 and the stagnant growth rate in graduate school enrolment.

The negative growth rate in secondary school enrolment is very important for Japan and Korea, as both countries are characterised by very high enrolments rates of 54% and 92% in higher education. This means the higher the number of secondary school students in Japan and Korea, the higher will be the number of students in higher education institutions in both countries. Despite the promising high growth rate in secondary school enrolment in South Africa, the country is facing an acutely low enrolment rate of 17% in higher education. South Africa saw a dramatic decline in the growth rate in higher education enrolment since 1994.

South Africa shows a relatively low growth rate in graduate school enrolment but the numbers of graduate students are much lower than Japan and Korea. Even further, more than 80% of all South African black students who complete secondary school do not have mathematics or physical science as subjects (FRD, 1996, p. 2). Based on these factors, this paper concludes that a very high proportion of black students cannot pursue science and technology related studies as well as career opportunities in science and technology related fields.

The data presented in this paper suggests that the South African economy is creating jobs that support low wages, with limited capacity to create jobs that support high wages while a limited number of skilled workers continue to realize high growth in salaries. Based on these factors, it seems obvious that the aim of the South African government to achieve national competitiveness and to create jobs that support high wages is unattainable in the near future if these trends continue.

Another important aspect, ensuing from low human resource development activities in South Africa, is the under-representation of researchers in the South African labour force. The data presented in this paper shows that Korea has nine times more researchers than the number of researchers in South Africa. The noticeable lack of research capacity is further marginalised by very low investment on R&D in South Africa. Consequently, South Africa's research output as indicated by the number of scientific papers and patents are very low. This paper also presented data showing that Koreans are granted thirty one times more patents by the USPTO than South Africans.

Based on these results, this paper concludes that South Africa's capacity to respond effectively to opportunities presented by the global knowledge economy will remain limited as long as the country does not implement financial and budgetary provisions supporting an increase in expenditure on R&D in the NSI. As indicated in this paper, South Africa would have to invest a total amount of 124 billion Rands or 8% of GDP of 2005 to achieve a level of R&D investment comparable to the level of investment in Korea.

Increasing expenditure on R&D would be a costly for South Africa. However it is necessary to help achieve the objective of the South African government to promote South Africa into a globally competitive nation. As Romer (1990, p. S72-S75) explains, technological change - improvement in instruction for mixing together raw materials - lies at the heart of economic growth. Technological change provides the incentive for continued capital accumulation, and together, capital accumulation and technological change account for much of the increase in output per hour worked.

The assumption that increased competitiveness and innovation would create employment opportunities that would just flourish should not be overestimated. It is understood that companies generally do not set about to increase employment; rather, they sell products in order to survive, make profits and grow. Companies that succeed at selling some types of products create economic growth and employment as a side effect of going about their business (Edquist et al., 2001, p. 158). South Africa's science and technology policy must be aligned and articulated with other forms of industrial, labour, financial and skills development policies otherwise the country will continue to create a divided society.

Science and technology driven employment creates opportunities for the skilled people but the poor majority, who are outside the knowledge society with no means of getting into it, drift into informal activities and crime for survival. Stronger linkages between the science and technology, education, industrial, labour and financial policies are essential to bring the growing unskilled and unemployed people into employment.

Acknowledgements

The National Research Foundation of South Africa and the University of Pretoria funded this study. We are especially grateful to Hiroyuki Odagiri for guidance.

Appendix 1: Sources of Data

Population (Pop), Total population including all residents
Labour force (LF), Total number of workers per country
Source: *South Africa, Japan and Korea*: World Bank (2006). EdStats Database of education statistics, http://devdata.worldbank.org/edstats/

Secondary school enrolment (HG), Number of students enrolled in secondary schools
Source: *South Africa*: Association for the Development of Education in Africa (2006) - Statistical Profile of Education in sub-Saharan Africa (SPESSA) Database, http://www.adeanet.org/spessa99/index.html; Department of Education (2002). Education Statistics in South Africa at a Glance 2000; Department of Education (2003). Education Statistics in South Africa at a Glance 2001; Department of Education (2004). Education Statistics in South Africa at a Glance 2002; Department of Education (2005). Education Statistics in South Africa at a Glance 2003; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2006). Higher Education Management

Information Systems (HEMIS) Database, http://education.pwv.gov.za/; World Bank (2006). EdStats Database of education statistics, http://devdata.worldbank.org/edstats/
Japan: Ministry of Education, Culture, Sports, Science and Technology (2006). Statistical Abstract 2006 Edition, http://www.mext.go.jp/english/statist/
Korea: Korea National Statistical Office (2006). Statistical DataBase (KOSIS), http://www.nso.go.kr/eng2006/emain/index.html

Higher education enrolment (UGN), Number of students enrolled in higher education institutions

Source: South Africa: Foundation for Research Development (1996). SA Science and Technology Indicators; Department of Education (2002). Education Statistics in South Africa at a Glance 2000; Department of Education (2003). Education Statistics in South Africa at a Glance 2001; Department of Education (2004). Education Statistics in South Africa at a Glance 2002; Department of Education (2005). Education Statistics in South Africa at a Glance 2003; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2006). Higher Education Management Information Systems (HEMIS) Database, http://education.pwv.gov.za/; World Bank (2006). EdStats Database of education statistics, http://devdata.worldbank.org/edstats/ (2006)
Japan: Ministry of Education, Culture, Sports, Science and Technology (2006). Statistical Abstract 2006 Edition, http://www.mext.go.jp/english/statist/
Korea: Korea National Statistical Office, Statistical DataBase (KOSIS) (2006), http://www.nso.go.kr/eng2006/emain/index.html

Graduate school enrolment (UGP), Number of masters and PhD students enrolled in higher education institutions

Source: South Africa: Foundation for Research Development (1996). SA Science and Technology Indicators; Department of Education (2002). Education Statistics in South Africa at a Glance 2000; Department of Education (2003). Education Statistics in South Africa at a Glance 2001; Department of Education (2004). Education Statistics in South Africa at a Glance 2002; Department of Education (2005). Education Statistics in South Africa at a Glance 2003; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2005). Education Statistics in South Africa at a Glance 2004; Department of Education (2006). Higher Education Management Information Systems (HEMIS) Database, http://education.pwv.gov.za/
Japan: Ministry of Education, Culture, Sports, Science and Technology (2006). Statistical Abstract 2006 Edition, http://www.mext.go.jp/english/statist/
Korea: Korea National Statistical Office (2006). Statistical DataBase (KOSIS), http://www.nso.go.kr/eng2006/emain/index.html

Researchers (SE), Total number of researchers

Source: South Africa: Department of National Education (DNE): Resources for Research and Development (1983 to 1992); Department of Arts, Culture, Science and Technology (DACST), Resources for Research and Development 1993/94 and 1997/98; Department of Science and Technology (2004). South African National Survey of

Research and Experimental Development (R&D) (2001/02 Fiscal Year). High-Level Key Results, 2nd Edition; Department of Science and Technology (2005), South African National Survey of Research and Experimental Development (R&D) (2003/04 Fiscal Year). High-Level Key Results; Department of Science and Technology (2006), South African National Survey of Research and Experimental Development (R&D) (2004/05 Fiscal Year). High-Level Key Results

Japan: Ministry of Education, Culture, Sports, Science and Technology. National Institute of Science and Technology Policy (2004). Science and Technology Indicators: 2004 - A Systematic Analysis of Science and Technology Activities in Japan

Korea: Korea National Statistical Office (2006). Statistical DataBase (KOSIS), http://www.nso.go.kr/eng2006/emain/index.html

Public expenditure on education (SES), Expenditure on education at school and higher education level

Source: *South Africa*: Department of Education: Information on the State Budget for Higher Education 2005, http://education.pwv.gov.za/; World Bank (2006). EdStats Database of education statistics, http://devdata.worldbank.org/edstats/

Japan: Ministry of Education, Culture, Sports, Science and Technology (2005). Survey of Local Educational Expenditure, http://web-japan.org/stat/stats/16EDU12.html

Korea: Ministry of Planning and Budget (2006). The data provided by courtesy of Ministry of Planning and Budget

Patents (IP), Number of patents granted to residents

Source: *South Africa, Japan and Korea*: United States Patent and Trademark Office (2006). Patents by Country, State, and Year - All Patent Types (December 2005), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.pdf

Scientific papers (SP), Number of scientific papers published by residents

Source: *South Africa, Japan and Korea*: Thomson Scientific (2006). Number of Papers by Publication Year. National Science Indicators, 1981-2004, Standard Version. The data provided by courtesy of Thomson Scientific.

R&D Expenditure (RDE), Expenditure on R&D activities

Source: *South Africa*: Foundation for Research Development (1996). SA Science and Technology Indicators; Department of National Education (DNE). Resources for Research and Development (1983 to 1992); Department of National Education (1993). Resources for R&D in the Republic of South Africa 1991/92); Department of National Education (1996). Resources for Research and Development 1993/94; Department of Arts, Culture, Science and Technology (DACST). Resources for Research and Development 1993/94 and 1997/98; Department of Science and Technology (2004). South African National Survey of Research and Experimental Development (R&D) (2001/02 Fiscal Year). High-Level Key Results, 2nd Edition; Department of Science and Technology (2005), South African National Survey of Research and Experimental Development (R&D) (2003/04 Fiscal Year). High-Level Key Results; Department of Science and Technology (2006), South African National

Survey of Research and Experimental Development (R&D) (2004/05 Fiscal Year). High-Level Key Results

Japan: Ministry of Education, Culture, Sports, Science and Technology (2004). Science and Technology Indicators: 2004. A Systematic Analysis of Science and Technology Activities in Japan

Korea: Korea National Statistical Office (2006). Statistical DataBase (KOSIS), http://www.nso.go.kr/eng2006/emain/index.html

Gross Domestic Product (GDP), National currencies
Compensation of labour force (C), Compensation of employees
Physical capital investment (CI), Gross fixed capital formation at current prices

Source: South Africa: South African Reserve Bank (2006). Quarterly Bulletin Time Series, http://www.reservebank.co.za/

Japan: Economic and Social Research Institute (ESRI) (2006). Gross Domestic Product classified by Economic Activities. Cabinet Office, Government of Japan, http://www.esri.cao.go.jp/index-e.html

Korea: Korea National Statistical Office, Statistical DataBase (KOSIS) (2006), http://www.nso.go.kr/eng2006/emain/index.html

REFERENCES

Archibugi, D. & Michie, J. (1997). Technological globalisation or national systems of innovation? *Futures*, Vol. 29, pp. 121-137.

Bell, M and Pavitt, K (1997). Technological Accumulation and Industrial Growth: Contrasts between Developed and Developing Countries". In Archibugi, D. and Michie, J. (Eds.), *Technology, Globalisation and Economic Performance*. Cambridge: Cambridge University Press, pp. 83-137.

Buys, A.J. (2001). Technological decolonisation of South Africa by backwards integration of the national system of innovation. Department of Engineering and Technology Management, University of Pretoria, South Africa. ITI Working Paper, June, Vol. 4.

Callon, M., Laredo, P., Rabeharisoa, V., Gonard, T. and Leray, T. (1992). The management and evaluation of technological programs and the dynamics of techno-economic networks: The Case of the AFME. *Research Policy*, Vol. 21, pp. 215-236.

DACST (1996a). White Paper on Science & Technology: Preparing for the 21st Century. Pretoria.

De Wet, G. (1998). Emerging from the Technology Colony: A view from the South, Department of Engineering and Technology Management, University of Pretoria, South Africa. Working Paper ITB2001/1.

DST (2002). South Africa's National R&D Strategy. Department of Science and Technology (DST), Government of South Africa, Pretoria.

DTI (2002). Accelerating Growth and Development: The Contribution of an Integrated Manufacturing Strategy. Department of Trade and Industry (DTI), Government of South Africa, Pretoria.

Edquist, C. (1994). *Technology policy: the link between governments and market. In Technology Policy: Towards Integration of Social and Ecological Concerns*. Edited by G. Aichholzer and G. Schienstock. Berlin, Walter de Gruyter & Co.

Edquist, C., Hommen, L. and McKelvey, M. (2001). *Innovation and Employment: process versus product innovation.* Cheltenham: Edward Elgar.

FRD (1996). SA Science and Technology Indicators 1996, Pretoria.

Freeman, C. (1996). The greening of technology and models of innovation. *Technological Forecasting and Social Change*, 53, 27-39.

Håkansson, H., Snehota, I. (1995). (Eds.), *Developing Relationships in Business Networks*. London: Routlegde.

IDRC (1993). Towards a Science and Technology Policy for a Democratic South Africa: Mission Report. Canada, IDRC.

Kim, L. (1993). National system of industrial innovation: Dynamic of capability building in Korea. In Nelson, R.R. (Ed.), *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Marais, H.C. (2000). *Perspectives on Science Policy in South Africa*. South Africa: Network Publishers.

Nelson, R.R. and Rosenberg, N. (1993). Technical innovation and national systems. In *National Innovation Systems: A Comparative Analysis*. Edited by R.R. Nelson. Oxford: Oxford University Press.

Niosi, J., Saviotti, P., Bellon, B. and Crow, M. (1993). National Systems of Innovation: In Search of a workable concept. *Technology in Society*, 2, 207-227.

Odagiri, H. and Goto, A. (1993). The Japanese system of innovation: past, present and future. In Nelson, R.R. (Ed.), *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Orford, J., Wood, E., Fischer, C., Herrington, M., and Segal, N. (2003). Global Entrepreneurship Monitor: South African Executive Report 2003. University of Cape Town Graduate School of Business.

Pianta, M. and Meliciana, V. (1994). Technological Specialisation and National Performance. Paper presented at the Conference on Technological Performances and Economic Performances, 14 October 1994. GREGI, BETA, and CERETIM, Le Mans.

Porter, M.E. (1990). *The Competitive Advantage of Nations*. New York: Free Press.

Romer, P.M. (1990). Endogenous Technological Change. *Journal of Technological Economy* 98, S71-S102.

Schumpeter, J.A. (1934). *The Theory of Economic Development*. Cambridge: Harvard University Press.

Senker, J. (1996). National systems of innovation, organisational learning and industrial biotechnology. *Technovation*, 6, 219-229.

UNDP (2001). Human Development Report 2001: Making new technologies work for human development. New York, UNDP

World Bank (1991). *World Development Report*. New York: Oxford University Press