SSH8-CT-2009-225368
INGINEUS
Impact of Networks, Globalisation and their Interaction with EU Strategies

Type of funding scheme: Collaborative Project (large-scale integrating project)
Programme addressed: FP7 Theme 8 "Socio-economic Sciences and the Humanities" (SSH)

Deliverable D3.2 – Synthesis Report on "National Innovation systems and global innovation networks"

Due date of deliverable: Month 18
Actual submission date: Month 18

Start date of project: 1st January 2009 Duration:36 months

Name of lead contractor for this deliverable:
Norwegian Institute for Studies in Innovation, Research and Education (NIFU STEP, Participant no.10)

Revision:

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	**PU**
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CP	Confidential, only for members of the consortium (including the Commission Services)	

Table of contents

Chapter 7: Sweden

Cristina Chaminade, Jon Mikel Zabala, and Adele Treccani, University of Lund (ULUND)

7.1 Introduction

Sweden is considered to be one of the most advanced countries in terms of innovation worldwide. Sweden always ranks high in all international reports on Science and Technology indicators such as the ones regularly published by the OECD or Eurostat. In 2009 Sweden invested a 3.75 percent of the GDP in R&D well above US (2.8 percent) and slightly higher than Japan (2.4 percent)[1] (OECD, 2010). The number of full time R&D employees per 1000 employees was 17 in 2000, only below that of Finland (22.4) and Iceland (17.5) in the ranking of OECD countries.

As we will argue in this chapter, the high performance in terms of innovation is due, among other things to the industrial structure of Sweden, dominated by large R&D intensive multinational groups (such as Ericsson) as well as a strong specialization in high-tech industries and services. Both the National Innovation System as well as the Global Innovation Networks in which Sweden participation is highly influenced by the industrial structure of Sweden.

The outstanding performance in terms of S&T has not been in parallel to an equally high performance in terms of growth, productivity and competitiveness (Marklundet al., 2004) for the whole economy. This mismatch between innovation performance and growth has been labeled the *Swedish Paradox* and it is still today the focus of many discussions on the innovation system of Sweden and its performance (Edquist et al., 2008; Ejermo et al 2008; Kander and Ejermo, 2009). Among the possible reasons for the relatively poor economic performance is the dominance of large R&D intensive multinational groups, the lack of support for SMEs or the strong focus on basic research.[2]

As many small countries, the Sweden economy has a strong international orientation and this is also reflected in the national innovation system. Internationally oriented industrial firms and universities dominate the Swedish innovation system. Furthermore, since 1988, the country has experienced a growing trend of mergers and acquisitions of technology intensive firms by foreign companies (Vinnova, 2006) whose presence, particularly in certain industries, is very noticeable.

The aim of this chapter is to explore the links between the NIS in Sweden and the participation of Swedish firms and Swedish universities in Global Innovation Networks. More specifically, it attempts to answer the following questions: a) To what extent are Swedish actors participating in GINs? b) To what extent is the Swedish NIS attracting GINs? c) What is the role of the Swedish NIS in supporting the participation of Swedish Universities and

[1] Data of 2008

[2] While it is not the objective of this paper to discuss the relationship between innovation and economic performance in Sweden, the previous discussion in important to highlight why, in this paper, we will try to move beyond R&D indicators (and other S&T-based indicators) to try to provide an accurate picture of the NIS and its relationship with GINs.

Swedish firms in GINs? d) What is the role of the Swedish innovation system in attracting actors in GINs into Sweden?

GINs are defined as “globally organized networks of interconnected and integrated functions and operations by firms and non-firm organizations engaged in the development or diffusion of innovations” (Chaminade, 2009:12). They embrace three forms of globalization of innovations: global research collaboration, global sourcing of technology and innovations and global generation of innovations (technology based FDI) (Archibugi and Mitchie, 1995; Plechero and Chaminade, 2010). The global research collaboration alludes to the collaboration of different partners from different countries in the development of know-how or innovation. This collaboration can take a variety of forms, including R&D joint-ventures, R&D alliances, contractual R&D, etc. and can involve a variety of organizations, including firms, research centres, universities, government, etc. The global sourcing of technology refers to the acquisition or import of technology (machinery, patents, know-how, etc) from a different country. The global generation of innovations refers mainly to the location of R&D activities in a different country and it is associated with R&D related foreign direct investment.

In this chapter, we also make a distinction between global innovation networks (GINs) and regional innovation networks (RINs) (Chaminade, 2009). GINs have a global geographical spread and engage actors beyond the traditional Triad (in our case, we are interested in the involvement of organizations from CIBS). RIS are international networks confined to a specific supra-national region – for example, within the European Union. In this paper, we consider North-North networks –that is, networks within the Triad as RINs and those involving actors outside the Triad as GINs.

7.2 Main actors in the Swedish innovation system and their international dimension

In international comparison, one could say that Sweden industrial structure is characterized by a comparatively large knowledge-intensive and export-oriented manufacturing sector, a relatively small private service sector but a comparatively large public service sector. Both the public and the private sector are dominated by large organizations.

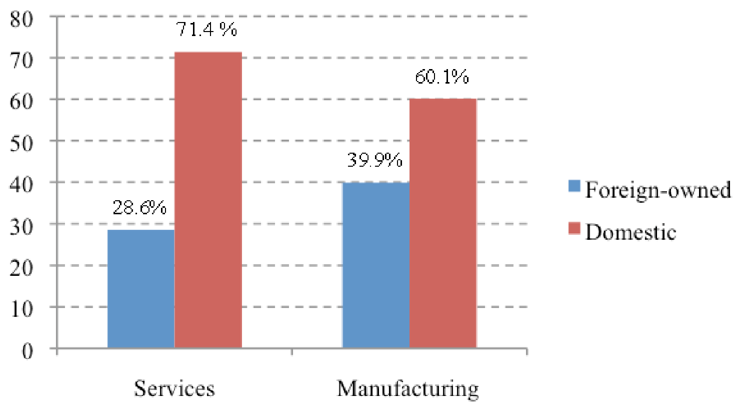
The Swedish Innovation System is quite polarized into two main groups of actors: on the one hand, about 10 large multinational groups and, on the other hand, a similar number of universities. These two groups are responsible for a larger part of the R&D performed in Sweden (Marklund et al, 2004).

Enterprises. In relation to the size of its economy Sweden has a broad industrial structure with world-leading international companies such as Ericsson (ICT), AstraZeneca (Pharmaceuticals), Volvo, Scania and Autoliv (Automotive), Industrial machinery (ABB), Packing (Tetrapack), Household appliances (Electrolux). These large multinational companies have a great impact on the functioning of the NIS and, at the same time, are responsible for the high degree of participation of the Swedish innovation system in GINs, They use extensively GINs in their innovation strategy, including global collaboration, sourcing and generation of innovations.

Figure 7.1 shows the percentage distribution of national turnover of domestic and foreign-affiliated companies in services and manufacturing for 2004. In 2004, there were 9,273 foreign affiliates in Sweden, which represents barely a 1.2 percent of the national total. They are concentrated in Telecommunications (15 percent of the units) followed by air transport (10 percent of the units) and electricity, gas and water supply. Despite their marginal importance in terms of number, they contribute significantly to the country's turnover, as figure 7.2 plots.

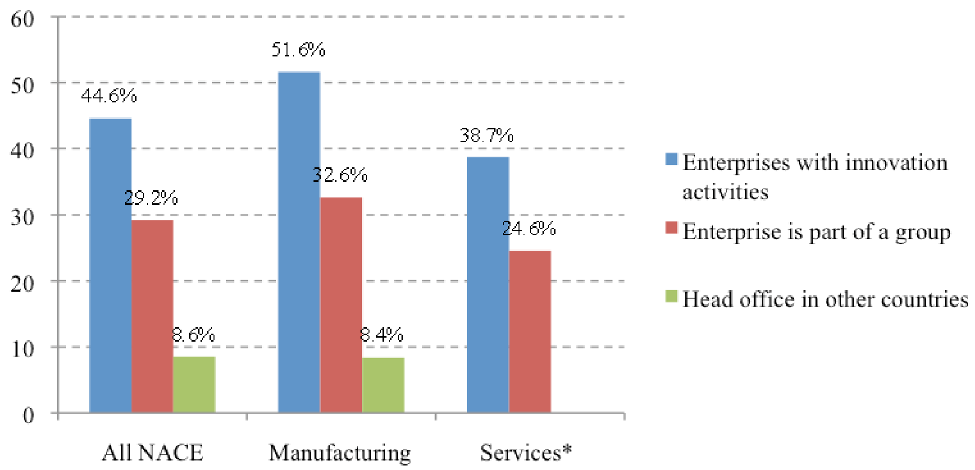
Around 7,217 firms have introduced product or process innovation in the period 2004-2006 (Eurostat, 2007), which represents 44.6 percent of the sampled population. The proportion of innovative firms is higher in manufacturing than in services, reflecting also the presence of large multinational companies in manufacturing. As it would be expected the proportion of innovative firms to total population is directly related to the size of the firm. The proportion of innovative firms in large firms is higher than in small firms. Yet the proportion of SMEs that are innovative in Sweden is quite high, particularly in manufacturing as figure 7.3 shows.

Figure 7.1. *Percentage distribution of national turnover of domestic and foreign-affiliated companies in services and manufacturing (2004).*



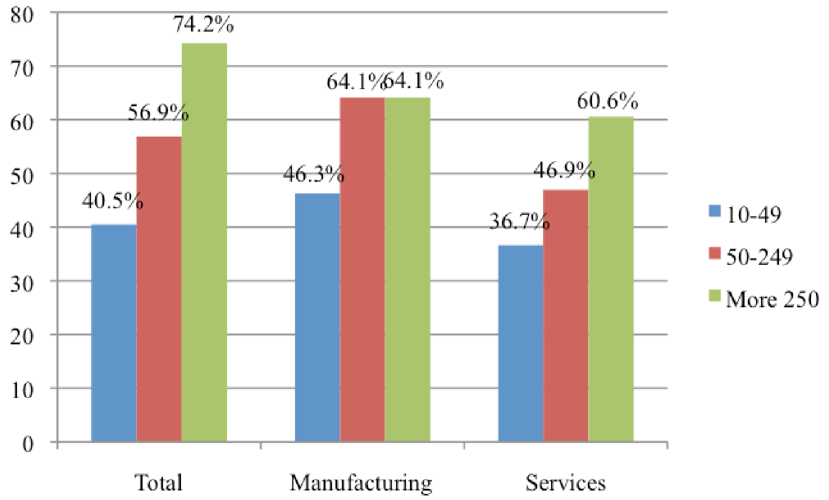
Source: OECD (2008)

Figure 7.2. - *Enterprises in Sweden – percentage (2004-2006).*



Note: Excluding public administration –
Source: Eurostat (2007) – CIS (2004-2006)

Figure 7.3. *Enterprises with innovation activities in Sweden, percentage distribution by size of the firm (2004-2006).*



Source: Eurostat (2007) – CIS (2004-2006)

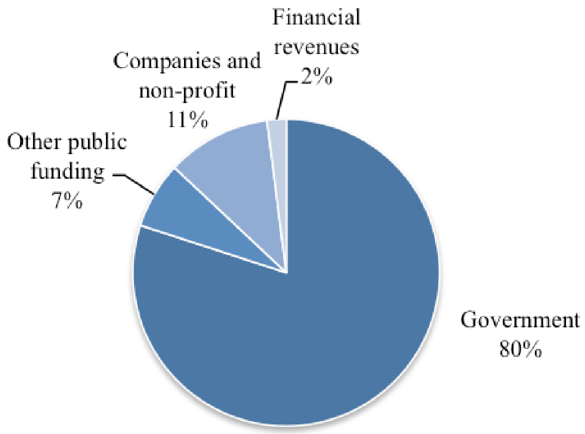
Universities and research centers. Similarly to the business sector, the university sector is dominated by approximately 10 universities which are responsible for almost all R&D performance in the country: The Karolinska Institute, Chalmers University of Technology, Uppsala University, Lund University, Gothenborg University, the Royal Institute of Technology (KTH), Stockholm University, Linköping University and Luleå University being the most important ones. Table 7.1 presents the size of the universities in terms of the number of students (FTE) in 2008. With few exceptions (Karolinska Institute and the Royal Institute of Technology), most of the funding of Swedish Universities comes from the public sources (regional and national government and EU). Private firms and foundations fund only a small proportion (approximately 11%), as shown next:

Table 7.1. - *Number of students enrolled in the 10 largest Swedish Universities (2008).*

University	Number of Students FTE
Lund University	24,600
Gothenburg University	24,100
Stockholm University	22,400
Uppsala University	19,900
Linköping Univ.	16,900
Umeå	15,600
Linnaeus Univ.	15,000
Royal Institute of Technology (KTH)	11,700
Chalmers	8,471

Source: Swedish Higher Education Authority (2009)

Graph 4. - *Sources of funding of Swedish universities.*



Source: Authors’ with data from SNAHE (2010).

Additionally, Sweden has a number of University Colleges (Swedish Högskola) that provide degrees at graduate (University diplomas and Bachelor degrees) and post-graduate level (Master and Doctorate). In comparison with Universities, University colleges are usually specialized in just one academic discipline. For example, Blekinge Institute of Technology and Mälardalen University are specialized in Engineering, while Stockholm School of Economics is in Business and Economics and Malmö University (although is currently diversifying) has a strong focus on Medicine.

With regards to Research Institutes, the Swedish R&D institute sector is one of the smallest in the OECD, mostly due to the fact that almost all public R&D investments go to the Universities in Sweden (Marklund et al, 2004). Despite their small size, they are active in a variety of industries. Some of the most important ones are the Swedish Defense Research Agency (FOI) (approx. 1,250 employees), the industrial research institutes (jointly owned by the government and industrial associations, employing approx. 2,100 employees) and other government research institutes and agencies like the Swedish Institute for Infectious Disease Control or the National Institute for Working Life, employing approx. 430 full time researchers (VINNOVA, 2006).

7.3 Competences in the Swedish NIS and their potential role in GINs

Tertiary education in Sweden. Although the proportion of higher educated people in Sweden is high, Sweden is not at the top of the OECD rankings that measure the proportion of higher educated people to the total population. Table 7.2 summarizes the number of students participating in tertiary education in 2006 in total and as a proportion of the population between 20-26.

Since 2008, tertiary education in Sweden has been divided into three cycles: Bachelor, Master and PhD, which are showing different trends over time. While the number of degrees awarded to the first and second cycle has decreased over time, the number of doctorates awarded has slightly increased, particularly in the last year for which data is available (2008). Figure 7.5 shows the number of degrees awarded in tertiary education from 1990 to 2008.

The declining trend observed in the first and second cycle is not a good indicator, particularly taking into account the role that competences play in the emergence and development of Global innovation networks: we may expect, that countries and regions with higher proportion of qualified human resources will be also the ones better positioned to attract GINs and to participate in GINs. However, one may expect this negative trend to reverse in the next future as 2008 showed, for the first time since 2003, an increase in the number of FTE in first and second cycles which may translate into an increase in the number of graduates in the coming years. Figure 7.6 illustrates the number of FTE in first and second cycle of tertiary education from 1993 to 2008.

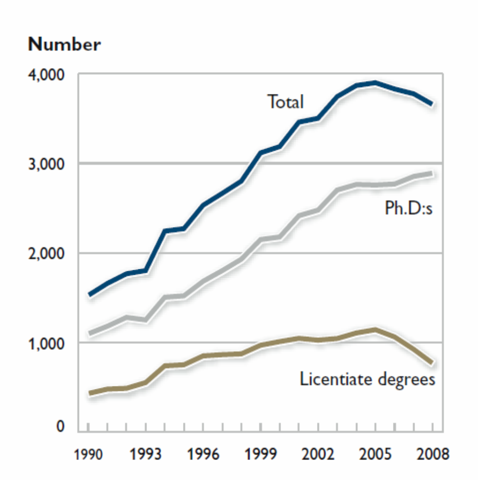
International mobility of students. The higher education system in Sweden has very strong international linkages. About 13 percent of the Swedish students enrolled in tertiary education studied abroad in 2008 (SNAHE, 2010). In the same year, more than 31000 foreign students came to Sweden, almost tripling the amount of foreign students one decade ago. The result is that since 2005/2006 the number of foreign students coming to Sweden has exceeded the number of outward students (Swedish students going abroad). Figure 7.7 shows the number of Outgoing and Incoming students for the period from 1997/98 to 2007/2008.

Table 7.2. *Number of students enrolled in Tertiary education (all cycles) and number of Graduates (2006)*

	Students enrolled in tertiary education		*Graduates 2006*	
	Total numbers	Percent of population 20-29	Total numbers	Percent of population 20-29
In any field	422,614	39.1	60,762	5.6
In Science, Maths and Computing	43,910	3.8	--	--
In Engineering, Manufacturing and Construction	68,846	6.4	--	--

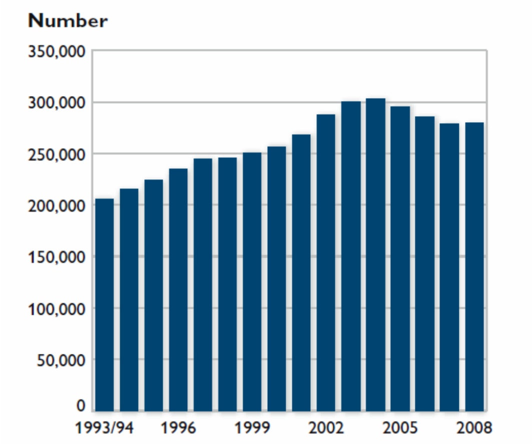
Source: Eurostat (2009)

Figure 7.5. *Number of degrees awarded in tertiary education (1990-2008).*



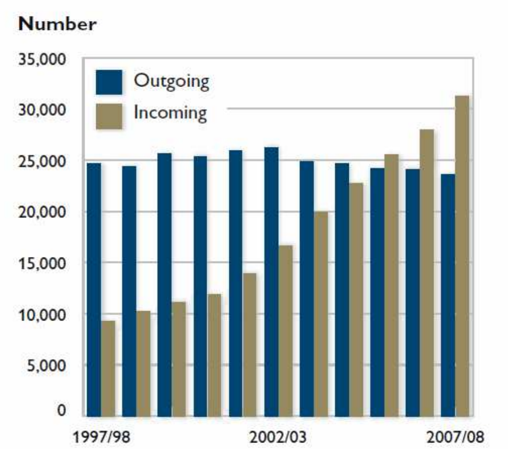
Source: SNAHE (2010)

Figure 7.6. *Number of FTE in first and second cycle of tertiary education (1993-2008).*



Source: SNAHE (2010)

Figure 7.7. *Number of Outgoing/Incoming students (1997/98-2007/2008)*



Source: SNAHE (2010)

The geographical spread of the student exchange has also varied over the last years. Although still two out of three Swedish students that go abroad travel to Europe, the proportion of students that chose to go to Asia in the last year is six times higher than in 2001/02. Similarly, about 35 percent of the students that had arranged their own studies in Sweden came from Asia. Table 7.3 summarizes the countries of origin and destination of students in tertiary education. The proportion of students to and from the CIBS countries is also included when available.

Researchers and R&D personnel in the Swedish innovation system. The decline in the number of students enrolled in tertiary education in Sweden over the last years has had an impact on the proportion of researchers and R&D personal in the Swedish innovation system, as it could be expected. This, again, is not a good sign if one takes into account that one of the most important determinants in the location of innovation activities in a certain country or region is the availability of competences (qualified human capital).

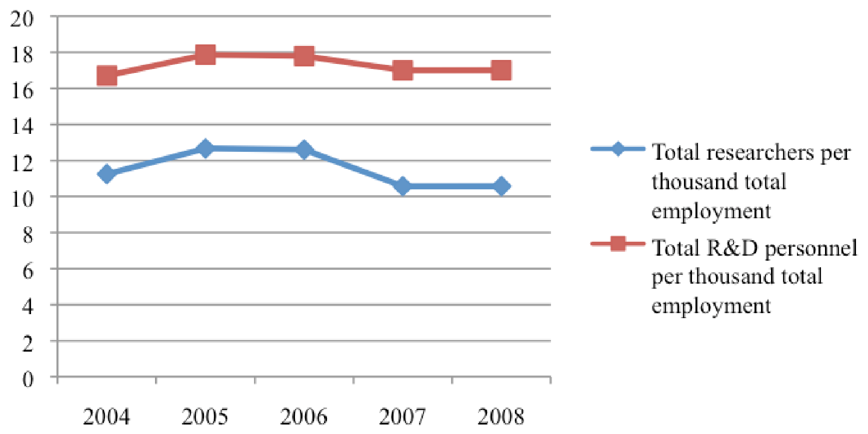
The business sector has traditionally the most important employer of R&D personnel in general and of researchers in particular and its importance in relative terms has increased over time, as next graphs show:

Table 7.3. *Number and percentage distribution of students in Tertiary education*

Country of destination/Origin	*Swedish students abroad-Foreign students in Sweden*		*Foreign students in Sweden*	
	Number	Percent	Number	Percent
Nordic countries	2,890	11.90	2,714	8.69
Europe excl. Nordic countries	12,273	50.55	11,266	36.08
Africa	260	1.07	1,314	4.21
South Africa	107	0.44	0	…
North and Central America	4,621	19.03	1,580	5.06
South America	406	1.67	385	1.23
Brazil	0	…	109	0.35
Asia	1,789	7.37	7,709	24.69
China	595	2.45	2,253	7.22
India	0	0.00	866	2.77
Oceania	2,038	8.39	455	1.46
TOTAL	24,277	100	31,224	100

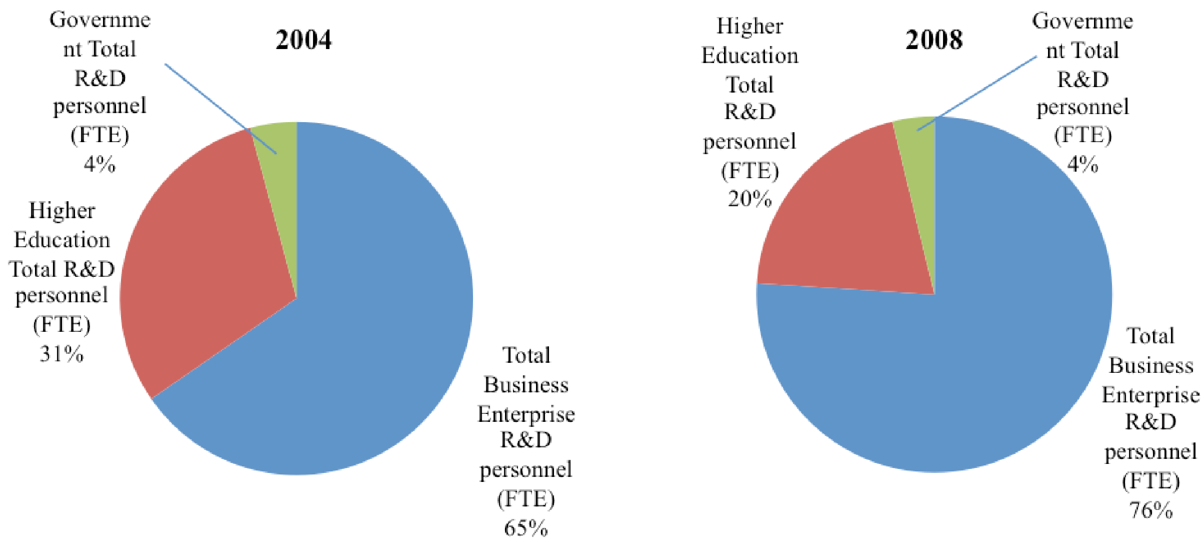
Source: Table elaborated by authors with data from SNAHE (2010)

Figure 7.8. *Total Researchers and R&D personnel per thousand total employment, 2004/2008.*



Source: Authors' own elaboration with data from OECD (2010)

Figure 7.9. *Percentage distribution of R&D personnel (FTE) between Business enterprises, Higher Education and Government in Sweden (2004 and 2008).*



Source: Authors' own elaboration with data from OECD (2010)

Human capital in firms. One of the most important sources of innovation for any firm is its employees and one of the most conventional indicators of the qualification of human resources in firms is the proportion of employees with a university degree. People with a higher education degree in Sweden are to be found mainly on the high-tech manufacturing groups (usually the large MNCs that dominate the Swedish NIS), some knowledge intensive services (KISs) and Universities, once again reflecting the polarized structure of the system of innovation. The proportion of scientists and engineers that are currently employed in KISs has increased very rapidly in the last years and currently employ more scientist and engineers than in the manufacturing industry (Marklund et al, 2004).

Table 7.4 provides information on the country of origin of the R&D personnel employed in major Swedish groups. It is worth pointing out at the increase in the number of R&D personnel from China between 1997 and 2007, from 2 to 2046 R&D employees. None of the other groups have experienced such a dramatic increase.

The level of education provides an indication of the stock of knowledge but not about how the firm uses that knowledge. In a recent study, Lorenz and Lundvall (Forthcoming) discuss the proportion of creative workers in a selection of European firms and its impact in innovation. As it can be observed in table 7.5, the Scandinavian countries, which are also the ones that perform better in terms of innovation in Europe, are also the ones showing a higher proportion of firms with creative workers in striking contrast with countries in the South and East of Europe. This is particularly relevant, when one see that the proportion of creative workers seems to be positively correlated with the innovation performance of firms (Lorenz and Lundvall, Forthcoming).

R&D in firms. As indicated earlier, the R&D system in Sweden is concentrated in a small number of large multinationals and some of the oldest universities in the country. Furthermore, the industry is, by far, the main financing and performing actor when it comes to gross domestic expenditure in R&D (GERD) as figure 7.10 shows:

Table 7.4. *Number R&D person-years (full-time annual equivalents) in major international Swedish groups*

Country/region	R&D person-year					
	1997	*1999*	*2001*	*2003*	*2005*	*2007*
Total in world	*45,135*	*38,846*	*40,037*	*30,803*	*38,204*	*45,614*
Sweden	27,517	22,022	20,923	19,085	21,720	23,239
Abroad	17,618	16,824	19,114	11,718	16,484	22,375
EU15	10,013	8,814	10,475	7,053	8,902	11,983
China	2	107	313	388	974	2,046
India	30	9	286	2	120	429
South America	332	216	401	256	323	398
USA	3,865	4,440	4,249	1,814	3,421	3,838

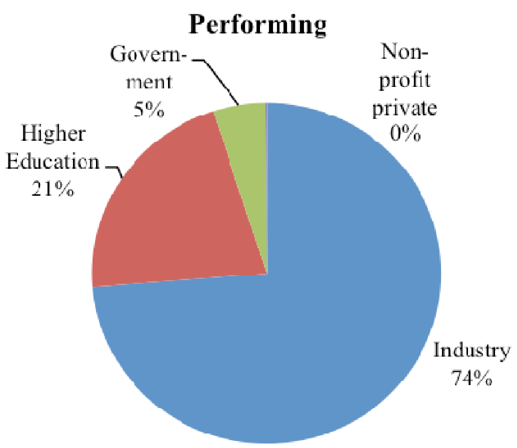
Source: ITPS (2007)

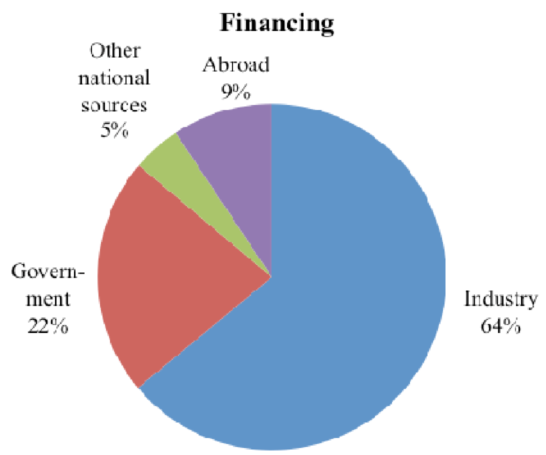
Table 7.5. *National differences in types of learners in firms (EU 27) (percent of occupied persons by country and type of learner)*

	Creative Worker	Routine problem solvers	Taylorized workers	Total
		NORTH		
Sweden	82	10	8	100
Denmark	70	15	14	100
Finland	66	21	13	100
		SOUTH		
Greece	39	33	28	100
Italy	37	29	34	100
Spain	35	30	36	100
		EAST		
Lithuania	35	27	38	100
Romania	35	38	27	100
Slovakia	33	22	35	100
EU-27	**51**	**24**	**25**	**100**

Source: Lorenz and Lundvall (forthcoming)

Graph 10. - *R&D expenditure; Performing and Financing (2007)*

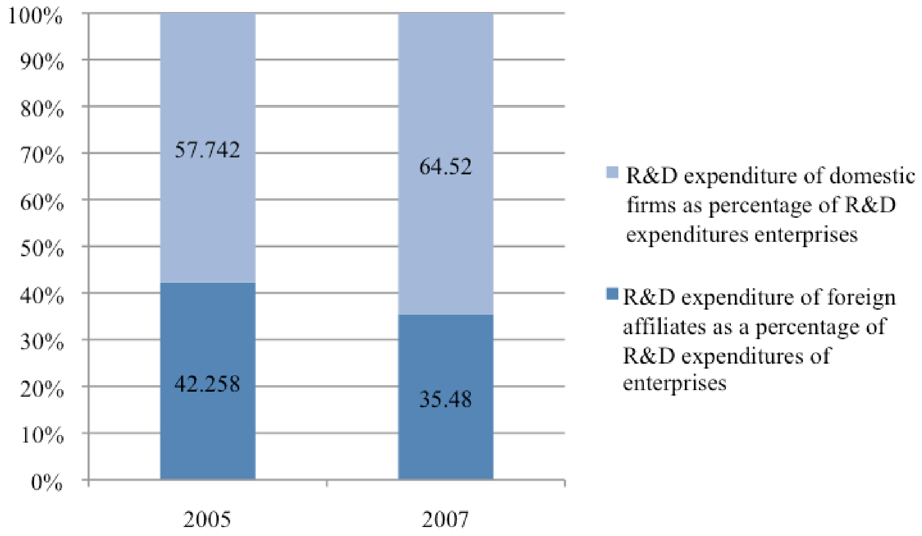




Source: Authors' based on OECD (2010)

Foreign firms have traditionally played a major role in the R&D expenditures of the country (GERD) however their importance has been diminishing over time. The country of origin of the largest R&D investors in Sweden is USA and the United Kingdom. The statistics do not provide specific information on the R&D investment of MNCs from any of the BICS countries part of INGINEUS however, the amount of investments that comes from MNCs whose headquarter is in USA and Europe is barely 1.9 percent of the total R&D investments of foreign firms in Sweden, giving an indication of the regionalization (and not globalization) of inward R&D.

Figure 7.11. - *R&D expenditure of domestic vs. foreign affiliates. Percentage (2005 and 2007).*



Source: Authors' based on OECD (2010)

Specialization/clusters. Global innovation and production activities are attracted to certain regions or clusters which have accumulated competences in a particular industrial area. It is therefore important to understand which are the clusters in which the country (and the national innovation system) is specialized. In the case of Sweden, those areas of specialization are cleantech, automotive, ICT, materials science and life sciences (ISA, 2009):

Cleantech: One of the newest clusters in Sweden is the one of Clean or Green Technologies (Cleantech) and, particularly of Biofuels, wind power and solar cell manufacturing. Somehow, the cleantech cluster has built upon the accumulation of competences of Sweden in engineering. The cluster is located in Stockholm (including Uppsala) to the north.

Automotive: Sweden has a long tradition in automotive innovation which is built on a long specialization in the production of passenger and commercial vehicles. Although the industry is currently under re-structuration (Volvo cars has been acquired by the Chinese Geely and Saab by the dutch Spyker), some of the most innovative companies worldwide in car safety (for example Autoliv) and Intelligent transport systems have their headquarters in Sweden, like Autoliv. The cluster has attracted production and innovation activities worldwide, including MNCs subsidiaries from BICS countries like Bharat Forge from India. The cluster is located around Gothenburg.

Information and Communication Technologies (ICT): One of the most important clusters in Sweden is that of ICT, particularly mobile communications, media (IPTV) and computer games. Three are the main factors that explain the specialization of Swedish NIS in ICTs: the presence of world leaders in communication technologies, like Ericsson; the pool of qualified human resources in related communication technologies; and the demand of the customers. One of the main drivers of innovation in the ICT industries is the proximity to the customer (Pavitt, 1984). Swedish customers are among the quickest in the world to adopt new applications and services (ISA; 2009: 8), which makes Sweden a good test market for new applications. This clusters has attracted a large number of R&D centers from MNCs all over the world, including some from BICS countries, like TCS and Infosys from India or ZTE, Huawei and Lenovo from China. The cluster is mainly located in Kista, in the outskirts of Stockholm although there are two emerging clusters in Skåne (for computer games) and Linköping (for web servers and IPTV).

Materials science: The specialization of the Swedish NIS in materials science can be explained by the combination of research specialization at the University and the accumulation of industrial know-how in paper and pulp and packaging technologies based on cellulose fiber –like Tetrapack- (another offspring of the forestry past of Sweden). Sweden will be hosting the largest European research facility for materials research – the European Spallation Source (ESS). In contrast with the previous clusters, the materials science cluster is spread all over the country: e.g. materials research on packaging in Lund and Stockholm and material research related to textiles in Borås (close to Gothenburg).

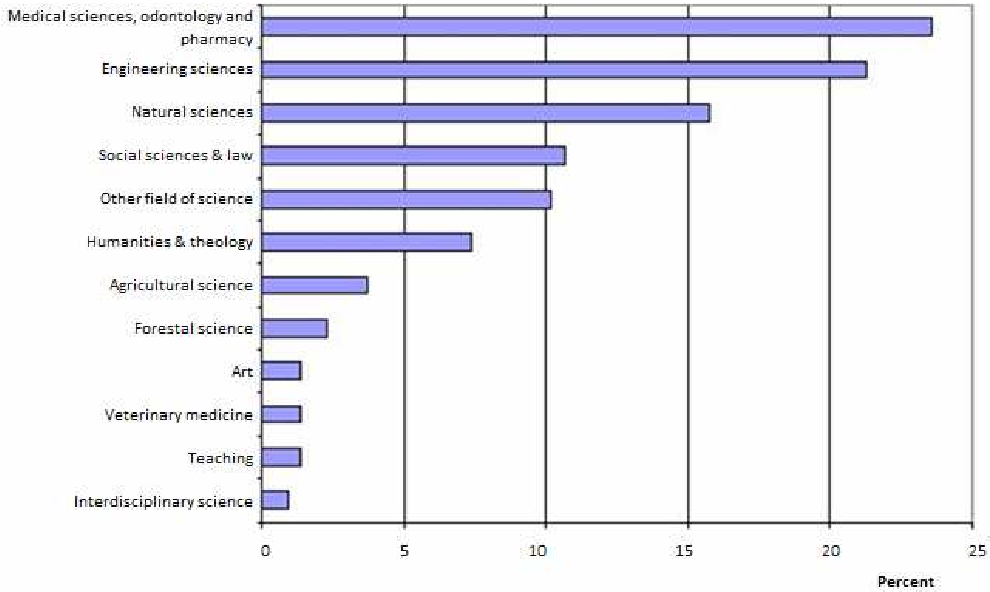
Life sciences: As in the previous case, the specialization in life sciences is based on the combination of world class research institutions (for example. The Karolinksa Institute in Stockholm) and medical universities and a cluster of large multinational companies in biotechnology (including biomed) and pharmaceuticals like Astra Zeneca, Elektra, Gambro or Pharmacia. There are two main clusters in Life Sciences, one in the South of Sweden – the Medicon Valley- and another one in Stockholm, which have specialized in biotech tools, diagnostics, medical devices, biomaterials and regenerative medicine.

Knowledge base in universities and research centers. Higher education institutions are responsible of 20 percent of the R&D performed in Sweden as shown in figure 7.9. Although it is not possible to find the breakdown of that R&D investment by subject areas, it is possible to have a rough idea by looking at the distribution of R&D employees by subject areas in Swedish Universities. As can be observed, most R&D personnel are concentrated in medicine, engineering and live sciences.

4. Innovation networks and their international dimension

As indicated in the introduction to this report, we distinguish between 3 forms of globalization of innovation and, as a consequence, global innovation networks: global research collaboration, global sourcing of technology and global generation of innovations. For analyzing these three forms, we use the information on collaboration in innovation from the innovation survey, the imports of high-tech products and the R&D FDI respectively.

Figure 7.12. *Proportion of R&D man-years (FTE) at Swedish universities in 2003 distributed by subjects.*



Source: SCB, Forskning och utveckling inom universitet och högskolesektorn 2005

Global research collaboration. The innovation survey provides information on the collaboration in innovation by partner and by the country of origin of the partner separately. As can be observed in figure 7.13, about 78 percent of Swedish innovative firms have cooperated with suppliers in their innovation process and 64 percent have done so with clients and customers. This result is different from the average in Europe at least in one respect: the most important partner for collaboration in innovation in Europe is the customer, while in Sweden is the supplier. This difference can be explained by the industrial specialization of Sweden in industries in which suppliers of technology play a fundamental role in the innovation process: automotive, clean tech, ICT, etc. These are also the industries that concentrate a larger proportion of the R&D in manufacturing and host some of the largest companies as well.

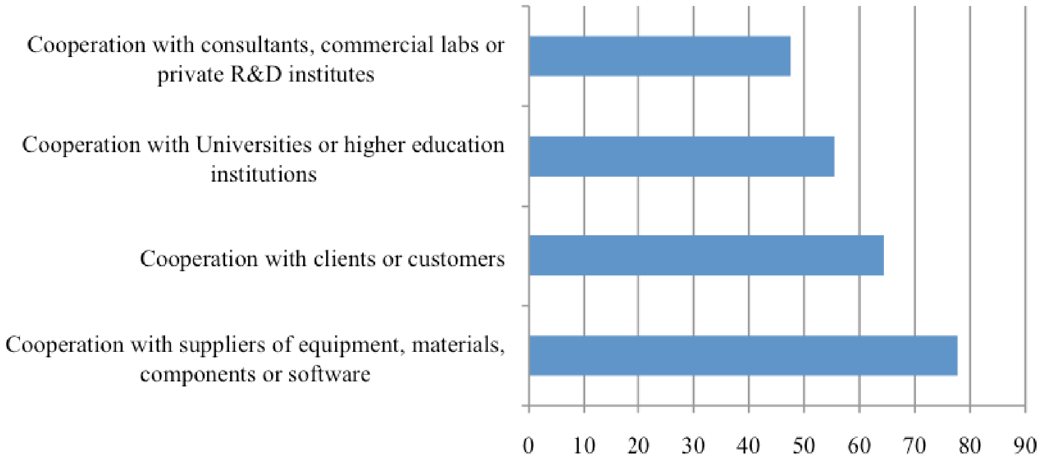
Looking at the origin of the partners, table 7.6 shows that most of the research & innovation networks are either national or European; that is, we are mainly talking about regional innovation networks (RINs) and not about global ones (GINs). However it is worth mentioning that about 20 percent of the SMEs (less than 250 employees) and 30 percent of the large firms have some form of collaboration in innovation with China and India.

Table 7.6. - *Percentage of firms that cooperate in innovation by size and location of the partner.*

	Total	Sweden	Other Europe	USA	China and India	Other
Below 10 employees	40	94	63	30	18	22
10-49 employees	37	94	58	28	16	21
50-249 employees	43	96	69	29	20	23
More 250 employees	65	95	83	43	31	28

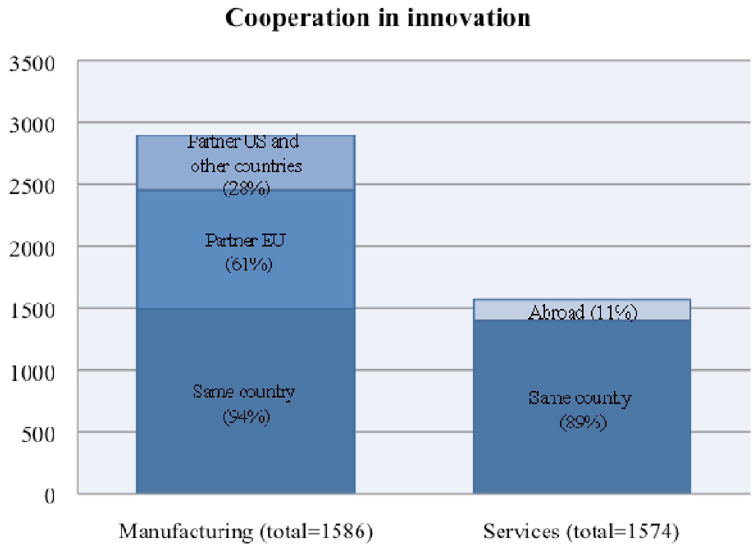
Source: Authors' own elaboration with CIS data (Eurostat, 2007)

Figure 7.13. - *Percentage of innovative firms that have collaborated in innovation by partner (2004-2006).*



Source: Authors' with CIS data (Eurostat, 2007)

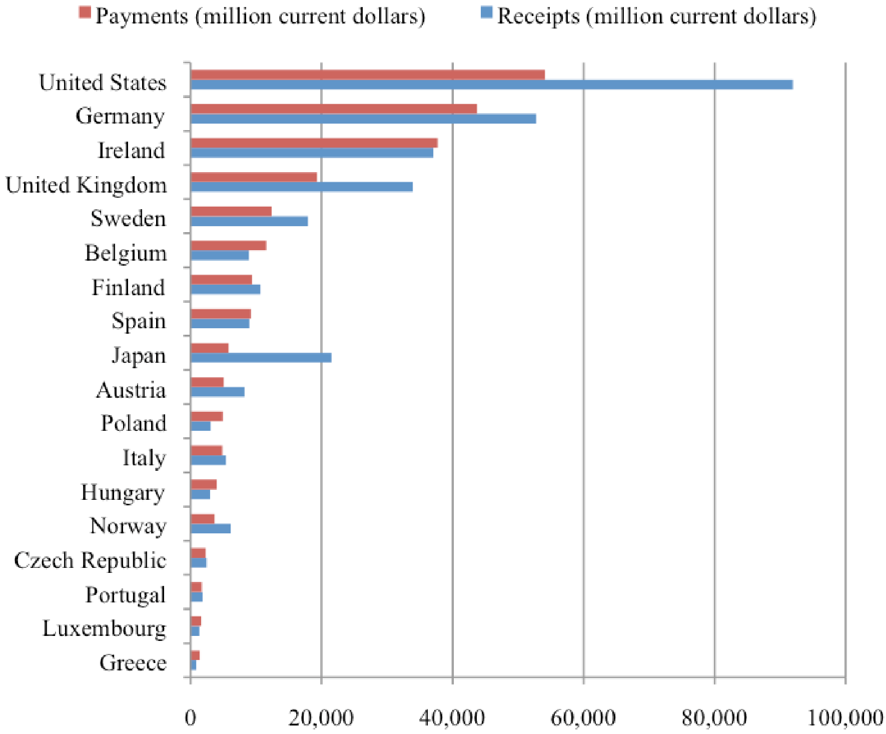
Figure 7.14. *Cooperation in innovation by origin of the partner*



Source: Authors' own elaboration with CIS data (Eurostat, 2007)

Global sourcing of technology. As a proxy of the global sourcing of technology we will use the technology balance of payments (TBP) data published by the OECD (2009). The TBP informs about the trade of disembodied technology between one country and the rest of the world. It includes the receipts and payments for the transfer of techniques (through patents, licenses, know-how), the transfer of designs, trademarks and patterns, trade of services with a technical content (like technical and engineering studies or technical assistance) and industrial R&D. It does not include information on the acquisition of embodied technology, such as machinery.

Figure 7.15. – *Technology balance of payments, 2009.*



Source: OECD (2010)

As it can be observed in figure 7.15, Sweden has a positive technology balance of payments, receiving more payments for technology licensing and services abroad than what the country pays for technology and services acquired from abroad. The global sourcing of (disembodied) technology in Sweden[3] is relatively small as compared to USA, Germany, Ireland and the United Kingdom but still quite superior to many other European countries.[4]

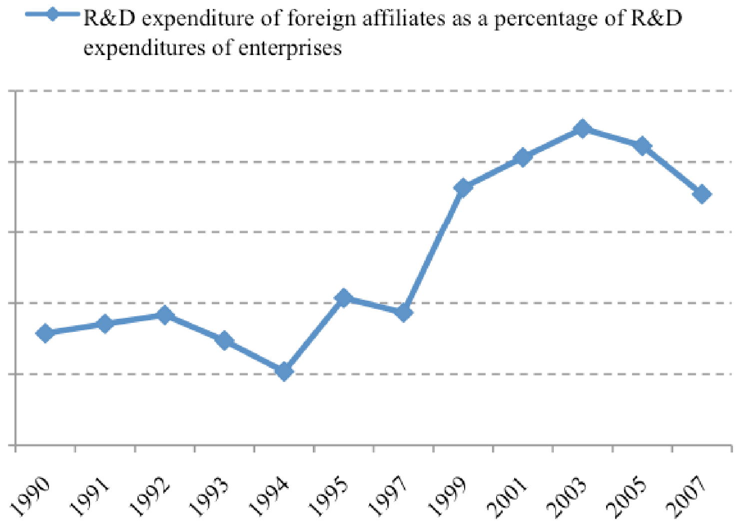
R&D international funding flows. Inward R&D investment is measured by the R&D expenditure of foreign-owned affiliates in a certain country. As shown in Graph XX, in 2007 foreign affiliates were responsible for about 35.5 percent of the total R&D expenditure in Sweden, which is very high. However, inward R&D has decreased in the past few years, both in absolute terms (expenditure in million SEK) as well as a percentage of the R&D expenditures of the business sector, as graph 16 shows.

The latest available data on the distribution of R&D expenditures of foreign enterprises in Sweden by country of origin which is dated in 2005, shows the predominance of R&D investments from UK and USA foreign affiliates as compared to affiliates from other parts of the world. Once again, the predominance of European affiliates is clear.

[3] Measured by the payments

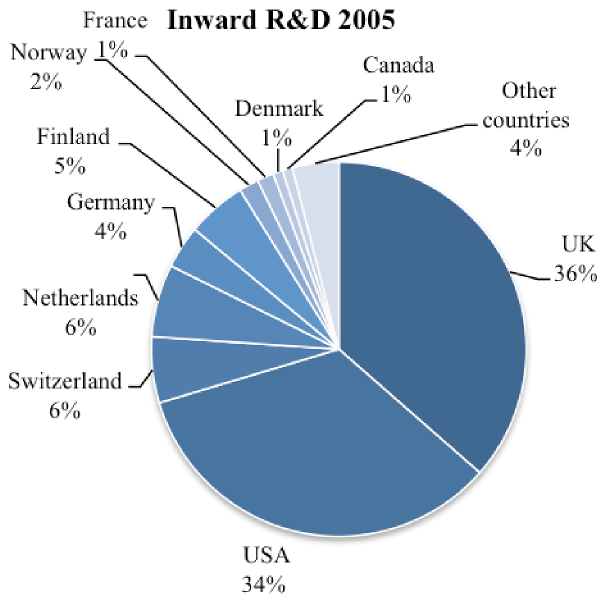
[4] Regretfully, the data published by the OECD does not include information on the origin and destination of the technology payments to assess the geographical spread of the global sourcing of technology.

Figure 7.16. *Inward R&D – R&D expenditure by foreign-owned affiliates in Sweden, 1990-2007.*



Source: OECD MSTI database, 2009:2

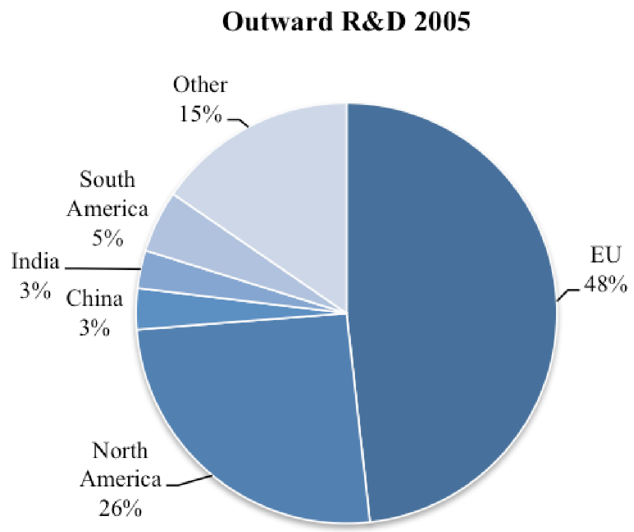
Figure 7.17. - Distribution of R&D expenditures of foreign affiliates in Sweden by country of origin, 2005.



Source: ITPS (2007)

The distribution of outward R&D by country of destination is very similar to inward R&D in terms of the predominance of Europe. However, it is important to note that about 3 percent of the outward R&D is to China and another 3 percent to India. Figure 7.18 shows the outward R&D from Sweden in 2005.

Figure 7.18. *Outward R&D in Sweden (2005).*



Source: ITPS (2007)

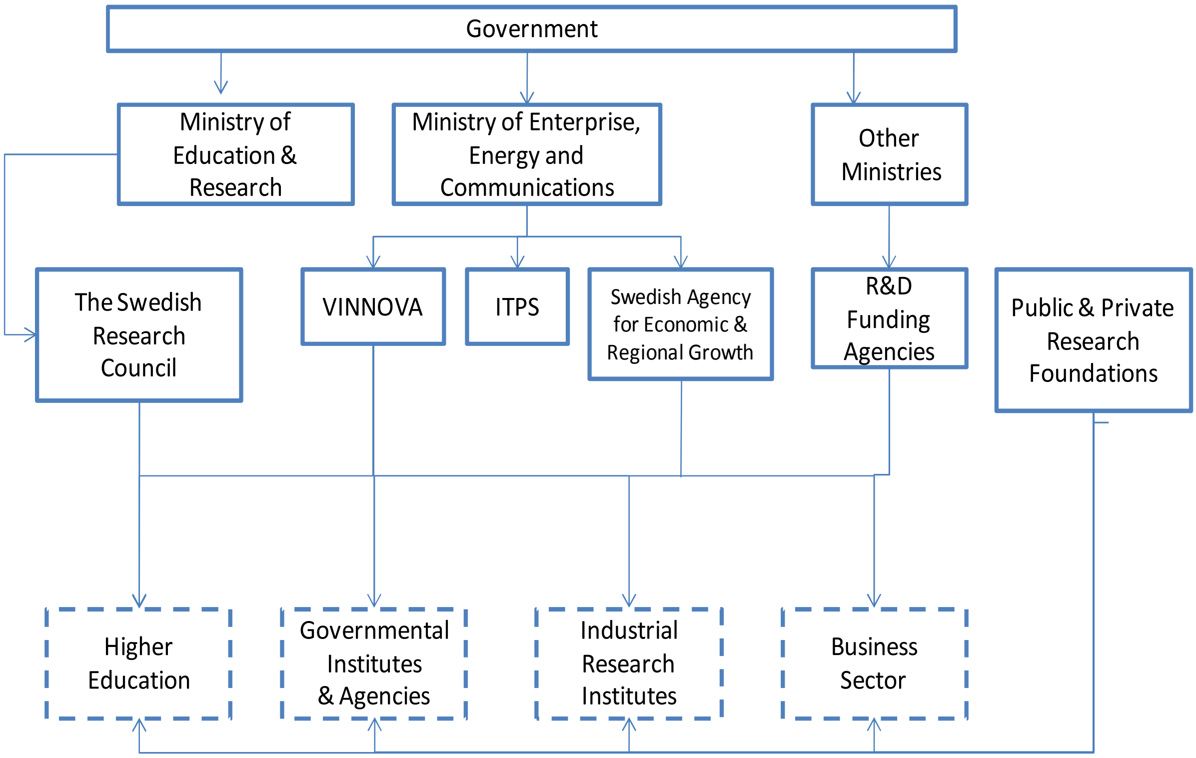
In sum, Sweden has strong international linkages in innovation, particularly with regards to global scientific collaboration and global generation of innovations. However, the geographical spread of these networks is still more regional (confined to Europe and USA) than truly global. With the data available, it is too early to say if this trend will reverse in the near future, although we can see a growing role of China as partner in research and innovation as well as a destination of global R&D, which could be interpreted as an increasing globalization (as opposed to regionalization) of Swedish firms.

7.5 Institutional frameworks and GINs

In Sweden the private sector is the main source of R&D funding. Public funds for R&D are usually directed towards Higher Education Institutions (HEIs) or through research councils, publics foundations or sectoral agencies (Forskning.se, 2009). Public research institute play a minor role except in the area of Defense (Vinnova, 2006).

As in many other countries the Ministry of Research and Education and the Ministry of Industry (in Sweden called Ministry of Enterprise, Energy and Communications) are responsible for most of the public agencies and research council that finance research in Sweden. The Swedish innovation policy went through a major reorganization in the year 2000, with the creation of new agencies and the reorganization of some of the sectorial research funding agencies like NUTEK. One of this new agency was VINNOVA. Figure 7.19 illustrates the structure of the Swedish research funding system.

Figure 7.19. - *Structure of the Swedish research funding system.*



Source: Adapted (and updated) from Roos et al (2005).

VINNOVA's main task is to "promote sustainable growth and development for the business community, society and individuals by developing effective innovation systems …" (VINNOVA, 2001). The general objective is translated into three main functions (Jacobs, 2004): Advising the Government on innovation policy issues; Commissioning and conducting in-house research on innovation related issues; Design and implement (national, regional and sectoral) policy programmes to support and stimulate innovation.

VINNOVA has adopted very specifically the system of innovation approach in policy making. Policy actions deployed by VINNOVA aim at promoting problem solving research and develop *effective* innovation systems. VINNOVA defines *effective innovation systems* "as consisting of actors from science, business and politics, which interact to develop, exchange and apply new technologies and new knowledge in order to promote sustainable growth by means of new products, services and processes" (VINNOVA, 2002:3). VINNOVA aims to promote the effective interaction of these actors to facilitate the transformation of new knowledge into products, services and processes as well as ensuring the effective links with other innovation systems (national, regional and sectoral).

The regional programme VINNVÄXT is the best example of how network problems are being addressed by VINNOVA. All initiatives funded at the regional level have to involve all relevant actors at that level, including policy-makers. To increase the cooperation between the organisations VINNOVA trains "innovation system developers", that is, facilitators that can "mobilise the level of commitment and resources needed to create efficient groups and processes which will produce concrete results" (VINNOVA, 2001:11).

The industrial research institutes focus on applied research and are jointly funded by the government and the industry. The institutes were created with the aim of providing some research capabilities to industries that were fundamentally dominated by SMEs (Arnold et al, 2007). The institutes, therefore, in principle tackle two of the problems of the Swedish NIS- the low participation of SMEs in R&D investments and the focus on basic research. However, in contrast to some other countries, the industrial research institutes (often called IRECO institutes) play a minor role in the Swedish innovation system, with even decreasing budgets over time (Vinnova, 2006). An example of some of the industrial research institutes are the Institute for Electronic, Optics and Communication Technologies (ACREO), the Institute for Manufacturing Technology (SWEREA IVF) or the Swedish Institute for Food and Bio-Technology (SIK).

A very particular feature of the Swedish innovation system is that university teachers have the right to own their inventions (the so-called teacher's exemption). Currently a new IPR system is being discussed, which gives the Universities the right to commercialize the patents generated by their researchers. The purpose of this measure is to solve what is considered to be a systemic problem of over focusing on basic research and the low level of commercialization of research results.

Sweden has a series of programs supporting R&D in certain strategic areas that are particularly targeted to foreign actors. For example, in the automotive sector, the Swedish government has the Strategic Vehicle Research and Innovation Initiative that supports applied research in energy and the environment, transport efficiency, vehicle and traffic safety, vehicle development and sustainable production (ISA, 2009). Funding is eligible to any foreign company with subsidiary in Sweden and with an established agreement with a Swedish company or to any university or research institute from abroad that has unique competences not available in Sweden.

7.6 Performance of the system or impact of the NIS on GINs?

This chapter focused on the major features of the Swedish national innovation system and the influence it has had on the emergence of Global Innovation Networks in the country. This last section is intended to provide an overall perspective on these two issues, providing a set of indicators related to the performance of an innovation system on the one hand, and other related to the characteristics of Global Innovation Networks. Regarding the performance, we distinguish between two different types: economic performance and Science, Technology and Innovation (STI) performance. Table 7.7 shows the provides an overview of the Swedish innovation system.

The main purpose of an innovation system is to pursue innovation processes; to develop and diffuse innovations, which includes introducing and diffusing them not only in the firms but also on the market. During the last years, and as a matter of increasing interests from policy-makers concerning public accountability a long stream of literature has emerged in relation to the measurement, management, or evaluation of innovation systems performance. Several related concepts have popped up regarding the propensity of territories to innovate, such as

’innovative capacity’, ’innovation potential‘, ’innovation capabilities‘, ‘innovation intensity’ or ’innovativeness‘. Despite all these different notions, all of them are oriented to capture the performance in innovation. According to Spronk and Vermeulen (2003: 482) “performance refers to the result(s) of an activity (or set of activities)”, that is to the results achieved once the activity has taken place, which translated to the innovation systems framework, drives us to talk about these two types of performance.

Indeed, it is not possible to say whether certain innovation intensities are high or low in a concrete system if there are no comparisons with those from other systems. This has to do with the fact that we cannot identify optimal or ideal innovation intensities (or optimal innovation systems). Hence, and in order to address the measurement of the performance, it is necessary to make comparisons among systems. Such comparisons can be made between the same systems over time, or between different existing systems. In this case, since the focus of the paper is the Swedish NIS, we have tried to provide both views. On the one hand, we aim at offering a dynamic view of its performance, by analyzing its major trends as illustrated by several indicators, while on the other we also aim to offer a comparative perspective with regard to the other two Scandinavian countries, Denmark and Norway.

First, and regarding the economic performance of the Swedish NIS, we have included three indicators that provide an overall view about this. Concerning the population between 25-64 years with tertiary education (as a percentage of total population) we can observe that the three countries have very similar values. However, despite Sweden is the country with the lowest values during the last 2004-2006 period, it seems that the growth in terms of Swedish tertiary educated people (8.7 percent) is much higher than those observed in the neighbor countries. Interestingly, when compared to the 2006-1996 period, one can observe that the growth on both Denmark and Norway (30 percent and 14.1 percent respectively) are much higher than those for Sweden. Accordingly, it is possible to conclude that both Denmark and Norway have had a more sudden growth during the last 10 years than Sweden, who clearly shows a much more stable pattern. As to the employment rates observed, the three countries seem to have very similar and high patterns during the last 10 years considered. Finally, and in relation to the GDP per capital and its relative growth, Sweden is the country with the lowest GDP per capita and the lowest growth rates.

Second, we aim to characterize the STI performance by means of five indicators: R&D expenditure growth, R&D personnel growth, innovation expenditures, patent applications to the EPO (per million inhabitants) and triadic patent families.[5] Concerning the first of these measures, we have calculated the growth of the R&D expenditures executed by the different sectors (business enterprise, government and higher education). From an overall perspective it seems that during the 2004 to 2006 period, Norway is the country who has in relative terms increased more its R&D expenditures. However, this is probably related to the fact that Norway does not invest as much as Sweden and Denmark on R&D activities. Concerning the Swedish case, interestingly enough, it can be observed a clear differentiation in the pattern of R&D expenses. From 1996 to 2006, the government sector was the main driver of the growth in R&D activities, in the latter 2004-2006 period; this sector shows decreasing growth rates. However, the business enterprise sector shows a more stable pattern. This outline is followed

[5] The data concerning STI performance need to be complemented with a set of new indicators we are still collecting and processing: publications per million inhabitants, % of turnover due to new to the firm products and % of turnover due to new to the market products.

in parallel by the growth observed in terms of R&D personnel and number of researchers employed in these sectors. Finally and as to the patents are concerned, Sweden shows the highest values both in terms of triadic patent families and EPO patent applications, with a clear relative advantage compared the its neighbor countries.

Finally, our last block of measures is intended to characterize the Global Innovation Networks by means of the following indicators: firms that cooperated in innovation, R&D executed by source of funds and job-to-job mobility of Human Resources in Science and Technology (HRST).[6] Concerning the cooperation in innovation activities, Swedish firms (both in the manufacturing and services sectors) seem to cooperate much more than those in Denmark and Norway respectively. As to those in the services sector, some mention is needed. Despite during the 1996-2006 period the services sector in Sweden did not cooperate to the extent observed in the neighbor countries, between 2004-2006, the firms in this sector caught up in this sense, not only taking over those values observed in the other countries but also approaching the ones in the Swedish manufacturing sector.

When analyzing thee cooperation patterns depending on the geographical level of the cooperation, the three countries show a clear tendency to cooperate with other organizations within their own countries or within the EU, rather than establishing cooperation agreements with organizations in the USA or Japan. However, we also consider that these dynamics will require further investigation, since as it has been illustrated along the paper, the impact of GINs, particularly in Sweden, has changed a lot during the last years. The second of our measures aims to capture the amount of R&D expenditures executed in-house but which are funded by foreign organizations. In this sense, the Swedish NIS seems to be the one that has a clearer tendency towards supporting open innovation activities, not only within the business enterprise sector but also among higher education organizations. Finally, and a propos the job-to-job mobility of HRST, the only data available for Sweden refer to the 1996-2006 period. In this sense, we can observe something already pointed out before. The efforts done within the services sector in order to increase its level of cooperation is also reflected in this particular indicator. Next, and quite logically, firms within the knowledge-intensive sectors are those that higher mobility rates show within the Swedish economy.

In this section we have tried to complement the information and evidence included in the previous sections as to the main characteristics of the Swedish NIS, not only in terms of its performance, but also in terms of the role played by the GINs as one of the main determinants of innovation activities. As it is well known from the literature, the Swedish NIS has traditionally had an structural characteristic by which the very high values of input indicators for innovation do not correspond with the low values achieved for output indicators. Several scholars have labeled this as the “Swedish Paradox” (Edquist and Hommen, 2008; Kander and Ejermo, 2009). In this chapter we have not addressed this issue directly. However, we think that the structural change that is being observed in the Swedish economy towards smaller and more service oriented firms, and the relevance that during the last years are taking the GINs may have a direct impact on this paradox. This is a matter of further research. Related to it, the entrepreneurial properties of the new firms should also be considered. In fact, new firms in Sweden tend to be smaller, more diversified, employing a considerable part of the creative workers in the country, and with a clear view of their GINs. We consider that

[6] The data concerning Global Innovation Networks need to be complemented with a set of new indicators we are still collecting and processing: co-authored patents (% of all patents) and Co-authored publications (% of all publications).

these aspects briefly addressed here should be analyzed more in-depth in order to get a more comprehensive understanding about the new dynamics observed within the Swedish NIS.

7.7 The Swedish NIS and GINs – final reflections

The Swedish innovation system is highly internationalized in terms of global research collaboration, global generation of innovation and global sourcing. Firms as well as universities are very active internationally in terms of their research and innovation activities. However, the geographical analysis of the flows of knowledge shows a high preponderance of USA and Europe as the origin and destination of those knowledge flows. That is, the innovation networks in which Swedish firms and universities are engaged are, as of today, more regional than global.

However, this is gradually changing. The percentage of students from the CIBS countries in Swedish Universities has increased dramatically over the last decade. The same can be said for innovation collaboration and for offshoring of R&D activities by Swedish multinational. In that respect, one could argue that the Swedish Innovation System is gradually engaging in innovation activities and networks with CIBS countries, more specifically, China and India. This is true for the large enterprises (that dominate the Swedish Innovation System) as well as for SMEs: about 20

Table 7.7. *Main features of Scandinavian NIS and its GINs.(Growth rates between time periods in brackets)*

	2006-2004			*2006-1996*		
	Denmark	Norway	Sweden	Denmark	Norway	Sweden
Economic performance						
Percentage of population between 25-64 with tertiary education	18.9 (4.5%)	17.7 (2.2%)	16.1 (8.7%)	14.5* (30%)	15.5* (14%)	14.9* (8.6%)
Employment rate	77.4 (2.2%)	73,1 (0.4%)	75,4 (1.4%)	73,8 (4.9%)	…	70.3 (4.0%)
GDP per capita in €	40,200 (10.14)	57,600 (26,87)	35,000 (8,02)	27,600 (45,65)	28,800 (100)	24,600 (42,28)
STI performance						
R&D expenditure growth (%)**						
All sectors	3.7	8.6	0.3	32.8	1.2	3.7
Business enterprises	5.9	7.3	1.5	50.8	-4.3	2.3
Government sector	-50.0	4.1	-5.6	-73.3	-7.4	41.7
Higher education sector	13.3	10.6	-2.5	58.1	20.9	2.7
R&D personnel growth (%)**						
All sectors	7.3	6.2	-3.6	32.0	…	7.4 (19.3)
	(7.2)	(8.8)	(-15.4)	(67.7)	…	17.2
Business enterprises	9.2	4.5	-2.5	50.7	…	(36.2)
	(8.2)	(11.1)	(-17.9)	(144.4)	…	-12.5
Government sector	-45.4	4.5	-12.5	-70	…	(-33.3)
	(-42.9)	(14.3)	(-33.3)	(-69.2)	…	-12.2
Higher education sector	17.5	12.8	-5.3	62.1	…	(3.3)
	(13.8)	(9.68)	(-3.1)	(50.0)	…	
Innovation expenditures (percent of GDP)	5,689,209	…	11,970,62	3,044	1,242	12,930
Patent applications to the EPO per million inhabitants	210.1 (10.0)	111.3 (30.3)	271.3 (10.5)	118.2 (77.8)	61.8 (80.0)	204.2 (32.9)
Triadic patents families	277.1 (8.1)	131.4 (19.3)	847.1 (13.4)	226.2 (22.5)	75.3 (74.6)	913.9 (-7.3)
Global Innovation Networks						

Firms that have cooperated in innovation ***	961/790 [37/31]	509/384 [33/26]	1586/1574 [42/35]	1243/963 [57/66]	553/540 [49/61]	1217/878 [59-48]
Location of partner:						
Same country	757/555	407/279	1494/1400	1036/834	513/503	1115/834
EU	416/452	216/143	962/…	829/461	294/188	684/262
US****	298/394	109/134	441/…	192/228	111/88	378/78
Japan	…	…	…	76/80	35/20	104/54
Elsewhere	…	…	…	290/179	47/48	148/59
R&D funded abroad**						
Business enterprise sector	5.3	11.1	16.7	100	42.9	211.1
Government sector	-50	0	-	0	0	-
Higher education sector	0	0	0	300	0	66.7
Job-to-job mobility of HRST, employed, 25-64 years old**						
All sectors	34.3	…	…	60.2	46.6	…
Manufacturing sectors	41.7	…	…	131.7	…	-3.8
Services sectors	34.6	…	…	52.2	…	50.7
Knowledge Intensive sectors	22.9	…	…	35.8	…	48.6

Notes:
* The last available data at Eurostat is 1999.
** Percent of job-to-job mobile HRST. **The period of reference is 2007 – 2005 and 2007-1997 respectively.
*** Square bracket is the percentage of innovative firms that cooperate. The data refer to the manufacturing and services sectors correspondingly.
**** For CIS 2006, the data regarding the cooperation in innovation only considers the cooperation within the same country, within Europe and "within US and other countries".

percent of Swedish SMEs have engaged in some form of collaboration in innovation with partners of China and India.

The data presented in this chapter also points out to some challenges for the future. If GINs are attracted by the accumulation of competences in certain regions and countries worldwide, Sweden may be in danger of losing its attractiveness, as the amount of students in tertiary education decreases over time. This could partly explain the gradual decrease in inward R&D in Sweden. As other regions in the world rapidly accumulate research and innovation capabilities while maintaining relatively lower costs, they become more attractive for the location of R&D activities, which may move from Sweden to other parts of the world. The challenge for the Swedish Innovation System and GINs is to continue investing in world-class research and innovation capabilities beyond large multinational companies (i.e. supporting SMEs), to continue the support of certain industries which attract a large proportion of knowledge intensive activities into the country (for example, the industries/clusters in which Sweden is specialized) and to facilitate the mobility of highly qualified workers into Sweden.

7.8 References

Archibugi, D., and J. Michie, 1995. The globalisation of technology: a new taxonomy. *Cambridge Journal of Economics* 19: 121-140.

Arnold, E., N. Brown, A. Eriksson, T. Jansson, A. Muscio, J. Nählinder, and R. Zaman, 2007. *The Role of Industrial Research Institutes in the National Innovation System*, Stockholm: VINNOVA.

Chaminade, C. 2009. On the concept of Global Innovation Networks and its use in INGINEUS, *CIRCLE electronic working paper, 2009/05.*

Edquist, C. and L. Hommen, L. 2008. Comparing National Systems of Innovation in Asia and Europe: Theory and Comparative Framework, In Edquist, C. and L. Hommen, *Small Country Innovation Systems: Globalisation, Change and Policy in Asia and Europe*. Cheltenham: Edward Elgar, pp. 1-28.

Edquist, C., P. Bitard, L. Hommen, A. Rickne. 2008. Reconsidering the paradox of high R&D input and low innovation: Sweden, In Edquist, C. and L. Hommen, *Small Country Innovation Systems: Globalisation, Change and Policy in Asia and Europe*. Cheltenham: Edward Elgar, pp. 237-280.

Ejermo, O., A. Kander, H.M. Svensson, H. M 2008 The Swedish Paradox arises in Fast-Growing Sectors” *CIRCLE electronic working paper, 2008/07.*

EUROSTAT 2007, Comunity Innovation Survey 2004-2006.

EUROSTAT 2009. “Pocketbooks, Science, technology and innovation in Europe 2009”,

Forskning.se 2009. Swedish Research. Main financing bodies. www.forsning.se.

ISA (Invest in Sweden Agency) Automotive: vehicle innovation the Swedish way.

ITPS (2007), Forskning och utveckling i internationella företag 2007 (Research and Development in International Enterprises 2007*)*, tillväxtanalys, Statistik 2009:03.

Jacobs, M. 2006. Utilization of Social Science knowledge in Science Policy: Systems of Innovation, Triple Helix and VINNOVA, *Social Science Information*, 45: 431–462

Kander, A. and Ejermo, O. 2009. The Swedish paradox revisited. In C. Karlsson, B. Johansson, and R. Stough, (eds), *Entrepreneurship and Innovation in Functional Regions*. Cheltenham: Edgar Elgar, pp 48-76

Lorenz, E. ; Lundvall, B-A. (forthcoming), Accounting for Creativity in the European Union A multi-level analysis of individual competence, labour market structure, and systems of life-long learning. Forthcoming in *Cambridge Journal of Economics*.

Marklund, G., R.R. Nilsson, P. Sandgren, J.G. Thorslund, and J. Ulström 2004. The Swedish National Innovation System 1970-2003. *Vinnova Analysis* VA 2004:1. www.vinnova.se

OECD 2008. *Activities of multinationals*, volume II, Paris: OECD

OECD 2010, *Main Science and Technology Indicators*, 2009:2. Paris: OECD.

Pavitt, K. 1984. Sectoral patterns of technical change: towards a taxonomy and a theory, *Research Policy*,13: 343–373

Plechero, M., and C. Chaminade, 2010. Different competences, different modes in the globalization of innovation? A comparative study of the Pune and Beijing regions, *CIRCLE electronic working paper, 2010/03*

Roos, G., L. Fernström, and O. Gupta 2005. *National innovation systems: Finland, Sweden & Australia compare*, Australian Business Foundation.

Spronk. J. and E.M. Vermeulen, 2003. Comparative performance evaluation under uncertainty. *European Journal of Operational Research*, 150: 482–495.

Swedish Higher Education Authority (Högskoleverket) 2009, *Statistics for 2008* (in Swedish)

Swedish National Agency for Higher Education (SNAHE) 2010, Swedish Universities and Universities Colleagues Annual Report 2009.

VINNOVA 2001. *Regional Growth through Dynamic Innovation Systems*, Vinnova. VINNOVA 2002. *Effective Innovation Systems and Problem-oriented Research for Sustainable Growth, Vinnova Strategic Plan 2003-2007*. Stockholm, VINNOVA.

VINNOVA 2006. Vinnova and its role in the Swedish Innovation System: Accomplishments since the start in 2001 and ambitions forward, Presentation by Per Ericsson.

Chapter 8: Estonia

Tarmo Kalvet and Marek Tiits, Institute of Baltic Studies (IBS)

8.1. Introduction

Estonia, with a population of 1.4 million, is a Baltic economy in Northeast Europe. In August 1991, Estonia re-established political and economic independence from the Soviet Union. Since then, Estonia has undergone strong liberalization of trade and capital markets. In order to allow technology transfer, the improvement of managerial skills and more effective market competition, large-scale privatization was undertaken, and by 1995, most companies were privatized. Estonia has often been considered by many as one of the successful, if not the most successful, Eastern European catching-up economy (e.g. European Bank for Reconstruction and Development 2000, Laar 2008). At the same time, others have expressed their concerns (e.g. Tiits et al. 2003, Drechsler et al. 2006, Tiits et al. 2008).

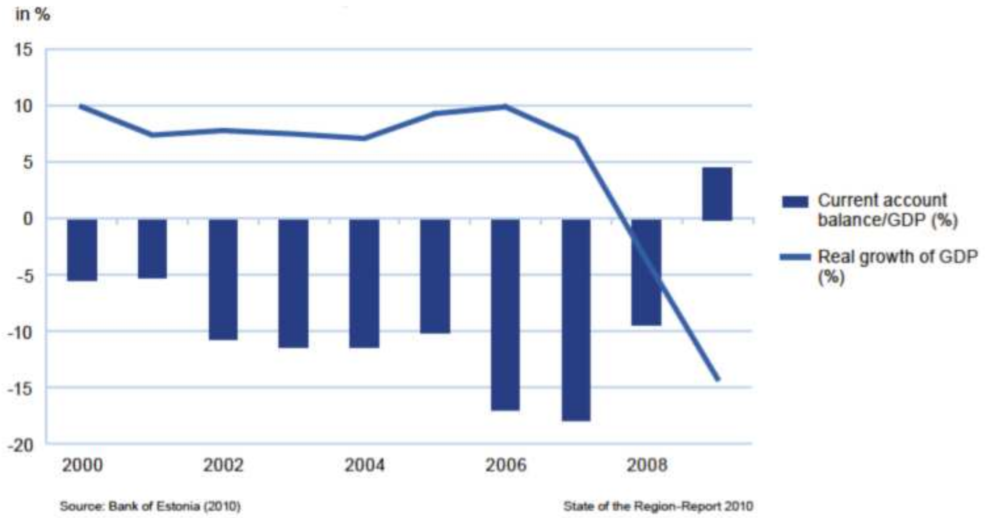
The main challenge Estonia continues to face, is how to turn the earlier domestically led growth into export led growth, and to increase the competitiveness of its enterprises at the global markets. The Nordic countries are the largest export markets for Estonia; although Estonia is itself, on an absolute scale, a relatively small supplier of imported goods to the Nordic countries (Ekholm and Hakkala 2008, 11-12). The Nordic countries are for Estonia also the greatest source of the foreign direct investment and other source of external financing. In other words, Estonia is an integral part of the cross border production networks, which operate in the Baltic Sea Region. This is how Estonia is integrated into the Global Production Networks (GPN).

The objective of the current chapter is to analyse to what extent and Estonia is influenced by the transformation of the GPNs into Global Innovation Networks (GIN). We aim to show that although the emergence of the GIN offers considerable possibilities, successful participation assumes the existence of strong National Innovation System (NIS). While, similar to other chapters, we are providing description of the Estonian innovation system and interactions with GIN, our analytical focus is on the benefits of and barriers to internationalisation of the Estonian innovation system.

8.2 Economic performance and the economic environment for innovation

Estonia has made considerable economic progress over the past decade. Figure 8.1 illustrates the rapid economic progress in the growth of real GDP. This remarkably rapid GDP growth started to slow down in 2007, and was followed in 2008, in the course of the global financial crisis, by one of the most severe contractions of an economy in the World.

Figure 8.1. *GDP growth and current account balance, Estonia, 2000-2009.*



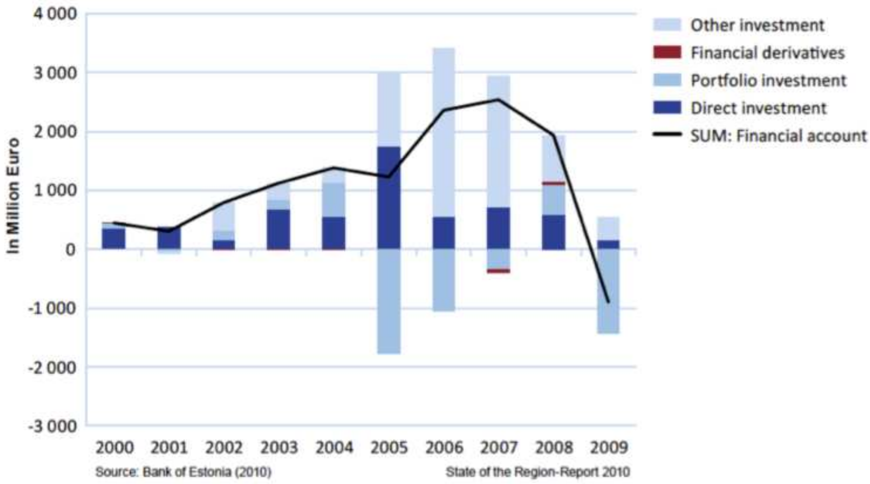
Source: SORR 2010.

The very rapid economic growth demonstrated by Estonia over the last years was based on the massive inflow of foreign capital. The record low interest rates in Western Europe and in the United States in combination with the EU enlargement led to a significant inflow of foreign direct investments to the Central and Eastern Europe. In per capita terms, Estonia was one of the particularly attractive locations for foreign direct investment. However, in Estonia the majority of the foreign capital came in form of the reinvested profits rather than new export oriented greenfield investments.

In addition to the inflow of foreign direct investments there was a remarkable inflow of debt financing (Figure 8.2). A significant share of the inflow of the debt financing was provided by the Scandinavian banks, which were fighting for their market shares in Estonia and the other two Baltic States.

Such inflow of capital, which came at record low interest rates, triggered major asset and consumption booms in Estonia. The later contributed, in turn, to the emergence of a large and widening current account deficit reaching 17.8 percent of GDP in Estonia (in 2007). The domestic consumption fuelled growth that triggered very rapid wage inflation. In 2008 consumer prices grew more than 10 percent and the average annual growth of gross wages and salaries was 12.6 percent during the period 2000-2008, reaching 20 percent in 2007 compared to 2006.

Figure 8.2. *Structure of foreign capital inflows into Estonia, 2000-2009*



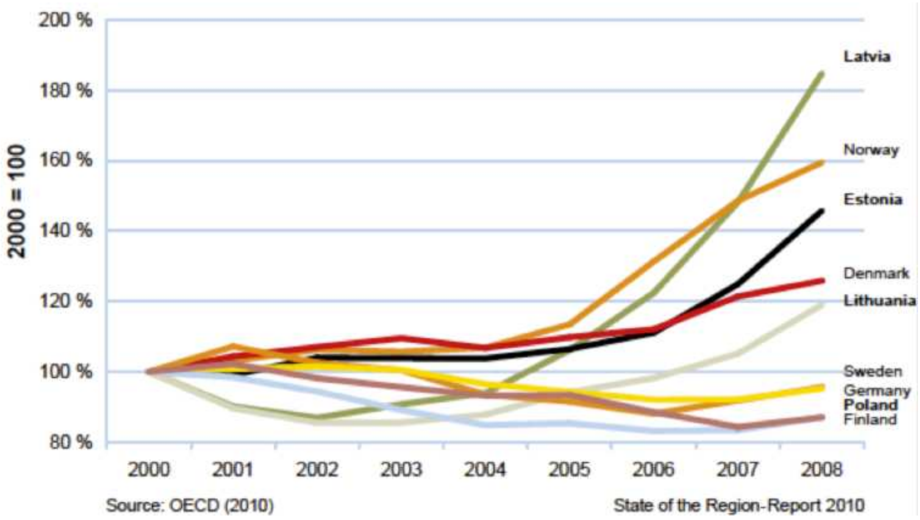
Source: SORR 2010.

Also, for a number of years wage growth had outpaced significantly the productivity growth in industry. According to OECD, the unit labour cost (ULC) increased by almost 40 percent from 2005 till 2008 in Estonia. The increase of the unit labour cost was in all three Baltic States remarkably more rapid than in Germany or Finland where the ULC has over the last decade in fact decreased (Figure 8.3 below). The rapid increase of the wages was clearly led by non-tradable sectors such as real estate, renting and business activities, wholesale and retail, transport and communications, financial services, and construction. We take the above for a clear indication of an overheating of the economy.

According to the World Economic Forum's Global Competitiveness Index (GCI), which represents the perceived competitiveness of individual economies among more than 130 surveyed economies, Estonia has throughout the decade retained a relatively stable position on the borderline of the 25 most competitive economies. Estonia's relative strongholds have been the low burden of government regulation, low level of corruption, ease of starting new businesses and the success of government in promotion of ICTs. Broad take-up of ICTs both in the public and private sector is an area where Estonia has really excelled. Yet, low sophistication of business strategies and low level of clustering remain major weaknesses. Also, the limited availability of qualified labour and low levels of business R&D investments remain to be major hindrances to further development (SORR, 2010).

Estonian enterprises have been according to recent Community Innovation Surveys more innovative than enterprises in the EU27 on average (see Figure 2.3). The nature of these innovations can be, however, characterised by "doing, using, and interacting" rather than "science, technology, and innovation" mode of innovation (Jensen et al., 2007). Acquisition of the machinery and technologies, education and training, relatively simple experimentation with new business models have been the most crucial inputs to innovation. At the same time, the role of formal R&D has remained in the most enterprises rather limited.

Figure 8.3. *Development of Unit Labour Costs in Baltic Sea Region countries, 2000-2008.*



Source: SORR 2010.

In summary, the innovative activities of enterprises and the actually experienced economic growth became in mid-2000s in Estonia increasingly decoupled from each other. It was the combination of the excessive inflows of finance and the assets boom in non-tradable sector that led first to the remarkably rapid economic growth and then to the crisis. In other words, both the growth experience and the crisis that followed have relatively little to do with the evolution of the innovative capabilities of enterprises or of the national innovation system in Estonia.

8.3 Governance of the Estonian innovation system

The preparation for the EU membership was clearly the most dominant theme of the Estonia's public policy in the 1st half of the 2000s. Prioritisation of the rapid adoption of the *acquis communautaire* was an important part of this process. Although the innovation policy and related objectives were not very high in the policy agenda, the harmonisation of laws and standards brought still about the need for new investments and upgrading the existing competitive advantages. Such an effect was particularly visible in relation to the food safety and environmental standards, which necessitated and continue to necessitate major investments into adoption of new technologies. One could even argue that the adoption of the EU regulations and standards formed an implicit, but very strong innovation policy element, although this was never part of the original intensions. At the same time, the impact of the official R&D and innovation policies in gearing economic development remained negligible (Tiits et al. 2005).

During the same period, in parallel to the introduction of the EU Lisbon Agenda, R&D and innovation, and economic development policies gained a lot in importance in Estonia. During 1990s Estonia had a relatively modest number of public support programmes for entrepreneurship, technological development, exports, etc. However, for the end of the century a full range of business development programmes had been put in place. Both the EU

Lisbon Strategy and the introduction of the EU Structural Funds were instrumental to bringing about a change in mentality and introducing relatively stable policy programmes that operate on the basis of the multi-annual budget allocation and directed enterprises towards the development of more knowledge-based products.

The main R&D and innovation policy document in Estonia is the Knowledge based Estonia Strategy 2007-2013 (KBE, 2007). The main headline target of this strategy is similarly to the Lisbon Strategy of the EU an increase of the Estonia's R&D intensity by 2014 to 3 percent of GDP. For the achievement of this and other more specific targets, the strategy sets out three main action lines:

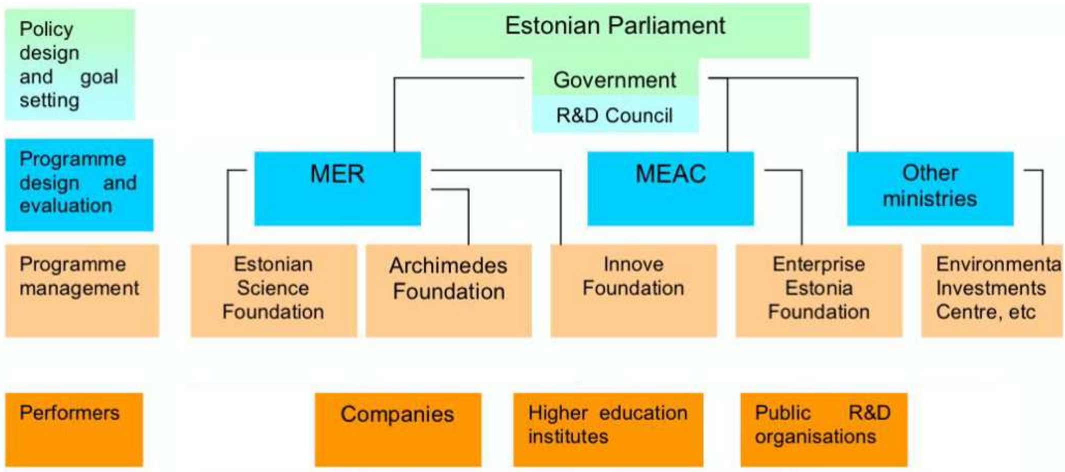
- An increase of the R&D intensity as well as its quality, including an increase of the supply of top-level specialists, advancement of research management, and major upgrading of the R&D infrastructure;
- Innovative enterprises creating new value in the global economy, including the internationalisation of indigenous businesses, support to inward technology transfer and attraction of innovation intensive foreign direct investments into Estonia.
- Innovation friendly society – in this part of the strategy a number of broader institutional and social issues are addressed, including the development of legislative and business environment as well as awareness raising on longer-term development challenges of Estonia.

The basic governance structure of the Estonian innovation system is similar to the one in various other countries. The cabinet of ministers is responsible for the overall policy co-ordination, and there is the R&D Council, which is to advise the cabinet in this role. The actual policy work takes place in two key ministries. The Ministry of Education and Research (MER) is responsible for R&D policy, while the Ministry of Economic Affairs and Communications (MEAC) is responsible for innovation policy. Both ministries have established a number of executive the agencies for the implementation of their policy programmes. Besides the above, other ministries are also expected to contribute in their respective policy fields to the R&D and innovation policies (Figure 8.4).

The two key ministries (MER & MEAC) have set up a number of different funding programmes to pursue such R&D and innovation policy objectives. This includes direct funding of R&D activities in universities, specialised research establishments and enterprises; but also myriad of other support measures that aim at the development of human resources, mobility, networking and clustering activities. The later are not strictly speaking all part of the Knowledge based Estonia strategy, but derive from various other strategies and action plans, which have been devised for the advancement of education and life-long learning, entrepreneurship, etc.[7]

[7] For detailed overviews of Estonian policy see the European Inventory of Research and Innovation Policy Measures (http://proinno.intrasoft.be/index.cfm?fuseaction=page.display&topicID=262&parentID=52) that been created by the European Commission with the aim of bringing together national information and documentation on research and innovation policies, measures and programmes.

Figure 8.4. *Governance structure of the Estonian innovation system*

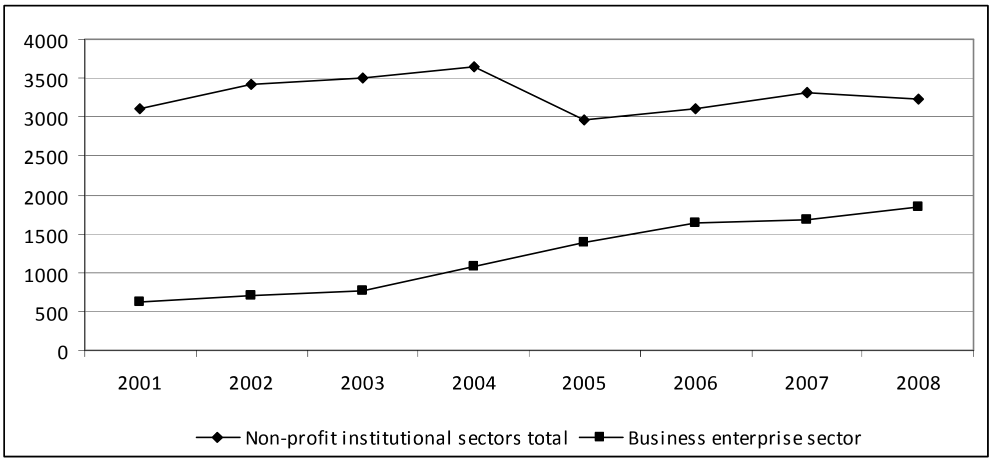


Source: Adopted from ERAWATCH 2009.

8.4. The main actors and their activities in the national innovation system

Although the number of R&D personnel in the private sector has increased in 2001-2008 rather rapidly, public universities continue to perform majority of the R&D activities in Estonia (Figure 8.5). The University of Tartu, Tallinn University of Technology, Tallinn University and Estonian University of Life Sciences are the most prominent providers of higher education in Estonia. Table 8.1 shows that the vast majority of the public research takes place in the University of Tartu, Tallinn University of Technology, while other organisations play a substantially smaller role. And table 8.2 shows that the natural sciences research dominates the public sector R&D scene, and the number of researchers continues to increase in this field.

Figure 8.5. R&D personnel in full time equivalent by institutional sector in Estonia in 2001-2008



Source: Statistics Estonia 2010.

Table 8.1. *The top 20 of the most productive research institutions contributing to papers authored by Estonian scientists (1997–2007)*

Rank	Institution	Number of Papers	Percent of Total
1	University of Tartu	4 523	59.2
2	Tallinn University of Technology	1 353	17.7
3	Estonian University of Life Sciences	535	7.0
4	University of Helsinki *	376	4.9
5	National Institute of Chemical Physics & Biophysics	302	4.0
6	Uppsala University *	265	3.5
7	Tartu Observatory	236	3.1
8	Estonian Academy of Sciences	181	2.4
9	Karolinska Institute *	163	2.1
10	Estonian Biocentre	148	1.9
11	Tartu University Clinic	142	1.9
12	Tallinn University	124	1.6
13	Russian Academy of Sciences *	123	1.6
14	National Institute for Health Development	122	1.6
15	Lund University *	90	1.2
16	University of Hamburg *	77	1.0
17	Helsinki University of Technology *	72	0.9
18	Swedish University of Agricultural Sciences *	72	0.9
19	University of Kuopio *	70	0.9
20	University of Turku *	70	0.9
	Total:	9 095	119.1 percent

Notes: Conference abstracts were excluded (N = 7636); *foreign institutions.
Source: Adopted from Allik 2008, 261.

Table 8.2. *Researchers in non-profit institutional sectors by fields of science, 2000-2008*

	Total	Natural sciences	Engineering	Medical sciences	Agricultural sciences	Social sciences	Humanities
2000	2392	859	431	214	193	345	350
2001	2270	824	395	176	189	306	380
2002	2595	859	568	176	170	392	430
2003	2615	895	533	184	159	387	457
2004	2707	973	517	188	152	437	440
2005	2448	870	502	170	141	336	430
2006	2637	935	535	163	149	365	490
2007	2729	1007	543	182	139	342	516
2008	2746	1047	547	186	138	376	452

Source: Statistics Estonia 2010.

In private sector, the R&D personnel employed in financial intermediation and computer-related activities accounted in 2008 for 46 percent of the total business-sector R&D personnel (Statistics Estonia 2010). At this, the ICT sector itself accounts in Estonia only for 3-4 percent of GDP. This is no different from international data, which demonstrates that the ICTs continue to be globally one of the most R&D intensive industries. This is due to the fact that the nature of innovative activities varies from industry to industry very substantially (Tiits et al., 2005).

Table 8.3 shows that the larger the companies tend to be in Estonia, similarly to other countries, relatively more innovative than their smaller peers. This may, however, have to do with the way, how innovation statistics is collected. Larger enterprises have usually broader product portfolios and are thereby also more likely to come up at any period of time with new or substantially modified products, services or processes.

Table 8.3. *Innovativeness of enterprises by size, 2006-2008*

	All enterprises	Technologically innovative enterprises (%)	Non-technologically innovative enterprises (%)
10-19	1833	36	30
20-49	1311	50	33
50-99	472	62	44
100-249	296	76	50
250 and more	111	89	75

Source: Statistics Estonia 2010.

The activities of large enterprises and especially branches of multinational corporations operating in Estonia are very important for us to consider even closer, when the Estonia’s participation in the Global Innovation Networks is to be considered. The total number of employees of the 30 largest companies was 79,300 in 2006. This corresponds to 18 percent of the total employment in the private sector. The manufacturing sector is even more concentrated. The 35,400 employees of the 30 largest manufacturing companies correspond to 28 percent of the total employment in the manufacturing sector, and 8 percent of the total employment in the private sector. Of the manufacturing-sector companies, the largest sub-sector is textiles with 6 companies employing 9,590 employees, followed by electronics, metal production and ship-building. Companies from these three sectors account for 60 percent of the employment of the largest manufacturing companies.

Table 8.4. *Foreign ownership and employment by ownership, all sectors, 2006*

Ownership	No of companies	Employment	Employment (%)
Local	15	41,322	52.1
Sweden	6	18,580	23.4
Finland	6	9,518	12.0
Denmark	1	7,421	9.4
Other	2	2,409	3.0
Total	30	79,250	

Source: Kalvet 2010.

Table 8.4 shows that of the 30 largest companies of all sectors, half are foreign owned, of which all but two have owners from the Nordic countries. Similarly, when we consider the 30 largest manufacturing companies, then foreign ownership (mostly 100 percent) is recorded for 20 companies. Out of these 20, 13 are owned by the Nordic multinationals, and their total employment – 15,309 – slightly exceeds the employment of the locally-owned companies.

The largest firms all sectors account for 21 percent of total business-sector R&D personnel (2006), although just in 2005, the figure was only 14 percent. Such a steep increase has to do largely with the increases in R&D personnel in financial intermediation and computer-related activities. The concentration of R&D activities in the largest enterprises can also be observed over time: when in 2001, they accounted for 12 percent of total business-sector R&D expenditures, this has increased to 32 percent as of 2006. The largest manufacturing enterprises accounted for 41 percent of total manufacturing R&D expenditures in 2001 increasing to 59 percent as of 2006.

The largest manufacturing companies account for 35 percent of total R&D personnel employed in the manufacturing sector. At the same time, according to Statistics Estonia (2008), about half of the largest manufacturing companies did not report any R&D expenditures or any R&D personnel at all. This reflects once again the gross difference of the nature of competitive advantages and innovative activities in different industries. We conclude also that both the public and private sector R&D activities are in Estonia not only concentrated, as a fairly small number of actors is responsible for majority of R&D activities.

8.5. National learning systems and technological capabilities

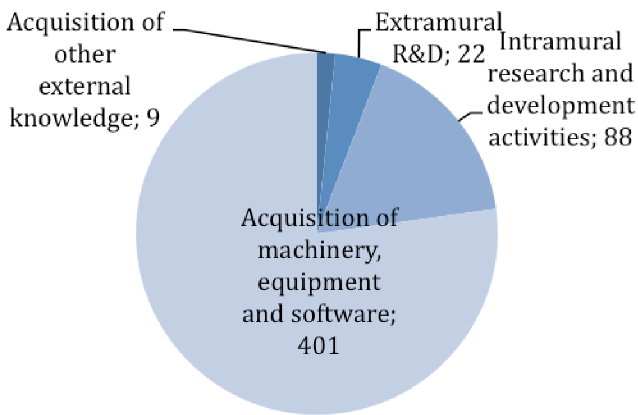
A study by Gabrielsson *et al* (2007) has concluded that Estonia has about 50 world-class or close to world-class research-intensive companies. Indeed, according to data from the Archimedes Foundation, from 2002 through 2006, forty-three companies have co-ordinated or participated in successful R&D projects funded by the European Union Framework Programme (2007). This number has doubled for the period 2005-2009 (Archimedes Foundation, 2010). So, while the number has considerably increased since the first estimate in 2006, the number of companies with competitive R&D activities remains still below 100. Also, based on the participation in the Framework Programme, these companies belong mostly to the following sectors: information and communication technology, electronics, biotechnology, energy, environment, nanotechnologies, and to the chemical industry in general.

The number of internationally competitive companies with limited research but strong development capacity is estimated to be some hundreds and they belong mostly to the following sectors: information and communications technology, financial intermediation, electronics, chemical industry, manufacture of transport equipment, dairy industry, manufacture of metal as well as non-metallic mineral products.

The number of competitive (growing firms) with limited development and no research capacity can be assumed to number about 1,500; e.g., according to CIS4, the number of exporting innovative companies with more than ten employees (2002–2004) was 1,342 (Statistics Estonia, 2006). Such innovative and exporting companies can be found in all economic sectors.

In sum, the number of enterprises that are in the very core the Estonian innovation is tiny – less than 2,000 enterprises. Their activities, including networking with each other and other companies, both locally and internationally, as well as with public and non-profit research institutions determines how the Estonian innovation system progresses and contributes to general economic development. For the rest of the innovative enterprises, the acquisition of equipment and machines remains the most important source of innovation. From the total of 519 Million EUR, which a group of companies covered by the Community Innovation Survey spent on innovation activities, 77 percent was spent on acquisition of machinery, equipment and software. Intramural R&D activities accounted for 88 Million EUR. Extramural R&D and acquisition of other external knowledge combined accounted for 6 percent of the total innovation expenditure (Statistics Estonia, 2010; Figure 8.6).

Figure 8.6. *Innovation expenditures of technologically innovative enterprises, Million EUR, 2006-2008*



Source: *Statistics Estonia 2010.*

Given the very nature of innovative activities of Estonian enterprises, higher education remains one of the most crucial inputs, when an increase of the R&D activities is sought. Estonia is well known for having a high share of students participating in tertiary education (Eurostat 2008). The Estonian higher education system is, still, criticized by many for producing a relatively small proportion of graduates who could become future innovation staff. Estonia is witnessing both quantitative and qualitative gap between demand and supply caused by a low output of science. The number of mathematics, computing, engineering, and manufacturing graduates has remained for many years below optimal levels, and although the output has grown recently, the increase is not still big enough to close the gap (e.g., Huisman et al. 2007, Kattel and Kalvet 2006).

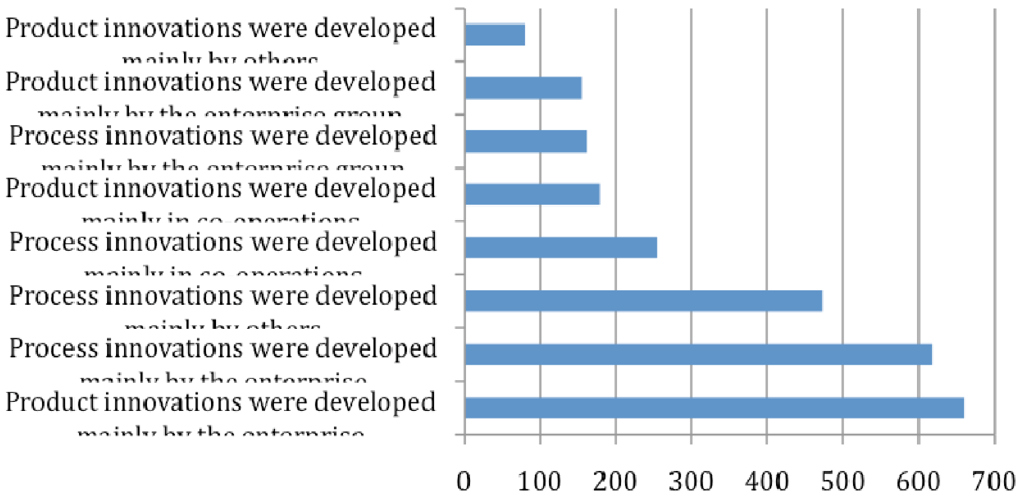
8.6. Knowledge flows and networks in the national innovation systems

Although the availability of human resources remains a major constraint, majority of the technological innovations introduced by the enterprises are still developed by the respective enterprises themselves (Figure 8.7). This applies both to product as well as process innovations, although in the case of process innovations the importance of other sources is relevant as well. This is so, because many process innovations originate largely from supplying industries and such technology transfer is important for the Estonian companies.

However, if we look at the technologically innovative enterprises and their high importance information sources for innovation activities during 2006-2008, it follows that not only are the intramural innovation activities most widely practiced, but they are considered the most important next to suppliers and clients (Figure 8.8). Universities or other higher education institutes were considered to be important by relatively small number of technologically innovative enterprises. In other words, higher education institutions have a very important role to play in providing high quality labour, but their direct involvement in innovative activities of enterprises is far less significant.

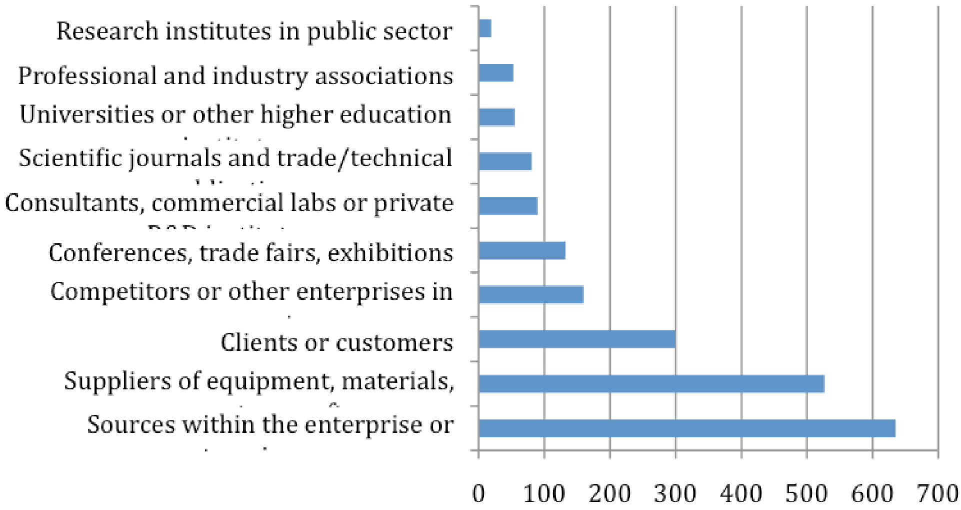
A similar conclusion follows when we look at the technologically innovative enterprises involved in co-operation in 2006-2008. The clients and suppliers continue to be the main partners of enterprises in as they introduce technological innovations. It is the ‘value chain’ or production network, where specific enterprises participate on daily basis, where also innovation co-operation takes place (Figure 8.9).

Figure 8.7. *Developers of technological innovations, 2006-2008*



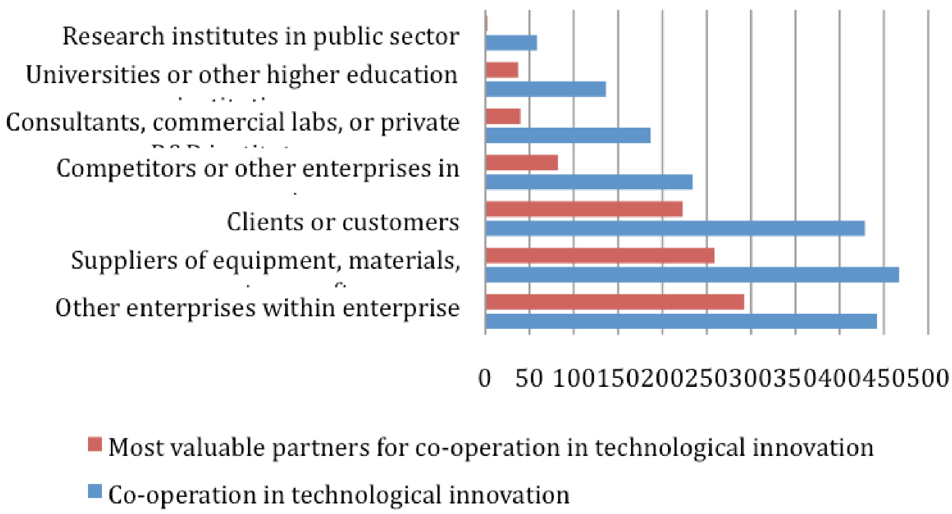
Source: *Statistics Estonia 2010*

Figure 8.8. *Technologically innovative enterprises indicating high importance of information source for innovation activities during 2006-2008*



Source: Statistics Estonia 2010

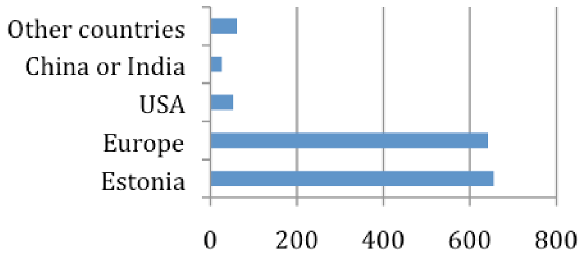
Figure 8.9. *Co-operation in technological innovation, 2006-2008*



Source: Statistics Estonia 2010

Partners from Estonia dominate for co-operation in technological innovations, but partners from other European countries are on the same par (Figure 8.10). Namely, Estonian innovative companies are exporting to the (neighbouring) European countries and co-operation with clients is important in co-operation in technological innovation. Suppliers of technologies or materials are also often from the (neighbouring) European countries and co-operation with them is important as well. In addition, due to high presence of the FDI in the Estonian economy, those foreign-owned companies are co-operating with other enterprises within enterprise group. Co-operation with the USA is taking place mostly in the field of ICT, both in the manufacturing of ICT as well as in the software-related activities. Of the 26 companies co-operating with Indian and Chinese companies in technological innovation, dominated by co-operation in the wholesale trade and manufacturing of machinery and electrical equipment (Statistics Estonia 2010).

Figure 8.10. Technologically innovative enterprises having during 2006-2008 partners in co-operation on innovation activities[8]



Source: Statistics Estonia 2010

Co-operation with the academic partners from the Nordic region is also recorded for the Estonian academic sector. Table 8.4 lists 20 most productive research institutions with regard to the number of papers authored by Estonian scientists in the period between 1997 and 2007 based on Thomson Reuters Web of Science. Of these top 20 institutions, 11 are not located in Estonia but in some other countries (five in Sweden, four in Finland, and one both in Germany and Russia). The University of Helsinki is the fourth most productive research institution contributing to Estonian science. These 20 institutions produced virtually all Estonian papers because the total score is above 100 percent (a considerable number of papers have authors from several listed institutions). The largest number of papers has been written in collaboration with colleagues from Sweden, Finland, Germany, USA, and England (almost 50 percent of all papers). The proportion of papers written in collaboration with Russian scientists has decreased and is now only 4 percent (Allik, 2008).

8.7 Conclusions

Estonia is frequently considered as one of the successful, if not the most successful Eastern European catching-up economy. Estonia experienced for the most of the 2000s very rapid economic growth. The high ratios of exports and inward FDI to GDP seem to indicate that it has well integrated through its Nordic neighbours into the global production networks. Estonia has retained according to the World Economic Forum’s annual Global Competitiveness Reports throughout the recent decade a relatively stable position on the borderline of the 25 most competitive World economies. The ratio of technologically innovative companies is, according to European Community Innovation Surveys, in Estonia also higher than in the EU27 on average.

[8] Europe is considered as member and candidate countries of European Union (excl. Estonia) and EFTA countries.

However, the above is only a part of the story. The very rapid economic growth experienced by Estonia and led by foreign finance has not been sustainable. In fact, Estonia was in terms of the contraction of the GDP in 2009 among the worst hit economies in the World. With this a number of weaknesses of the national innovation system, and especially in relation to the participation in the GINs, have been revealed.

First, it is important to realise that the Estonian economy is better described by the "doing, using, and interacting" mode of innovation than the "science, technology, and innovation" mode of innovation (see Jensen et al. 2007). Namely, (1) the Estonian industry is dominated by low and medium-tech industries, which are, by the very nature of these industries, not very R&D intensive. This is why formal R&D statistics is not a very good indicator of the innovative activities of Estonian enterprises. Instead, (2) Estonian companies' innovative activities are largely related to the inward technology transfer (acquisition of equipment and machines). For the technologically innovative enterprises and their high importance information sources for innovation activities during 2006-2008, not only are the intramural innovation activities most widely practiced, but they are considered the most important next to suppliers and clients. Direct R&D and innovation co-operation with universities or other higher education institutes is considered to be important only by a relatively small number of respondents.

Theory suggests that successful entrance into the global production networks does lead necessarily to the automatic upgrading of the local nodes (subsidiaries, affiliates, but also independent suppliers and sub-contractors) into the nodes of global innovation system. Estonian attempts and achievements to internationalise its economic system have been since the early 1990s mostly related to the attraction of foreign capital and foreign direct investments, resulting with entrance into the GPN. This is vividly illustrated by the foreign ownership amongst the Estonian largest companies: of the 30 largest companies of all sectors, 15 companies with foreign ownership can be identified; in most cases, the foreign ownership is 100 percent. Of the 30 largest manufacturing companies, the foreign ownership (mostly 100 percent) is recorded for 20 companies. In many economies the largest corporations are also the biggest spenders on R&D. In the case of Estonia the linkages of the largest companies with the local innovation system remain limited, e.g. about half of the largest manufacturing companies did not report any R&D expenditures and any R&D personnel, and for those undertaking R&D more than 90 percent expenditures were intramural.

The emergence of GIN on top of the GPN is, thereby, foremost about greater specialisation and gradual upgrading of the value chain relationships. As individual enterprises might acquire new capabilities and enter new markets, their basic production and maintenance activities might be complemented with more knowledge intensive activities, such as applied research and product development, management of multi-site production and supporting facilities, global brand development and marketing, etc. The transformation of the GPN into the GIN is, thus, primarily about the increase of the quality of innovative activities of the involved enterprises. The mode and quality of innovative activities is, however, in catching up economies rather different from that in advanced industrialised nations, as well as the barriers.

Although the emergence of global innovation networks can be observed generally, there are barriers for weaker small economies to participate in them (Kattel et al. 2010). Although there are cases of successful internationalisation of the local companies (such as Skype), most of the companies lack capacities and capabilities stemming partially from their small size.

Also, when international co-operation is considered, regional collaboration in the Baltic Sea Region is in most cases preferred by Estonian companies. Namely, Estonian innovative companies are exporting to the neighbouring European countries and co-operation with clients is important in co-operation in technological innovation. Suppliers of technologies or materials are again also largely from the neighbouring European countries and co-operation with them is important as well. In addition, due to high presence of the FDI in the Estonian economy, those foreign-owned companies are co-operating with other enterprises within enterprise group. So, we are seeing emergence of the cross-border supranational innovation network in the Baltic Sea Region rather than entrance into the truly global innovation networks.

Estonian true and large-scale entrance into the global innovation network (or rather to the Nordic innovation network) from the current Nordic production network remains still to be seen and, as we would argue, is largely dependant upon public policies. While continued investment into R&D system remains crucial for further capacity building, it is of utmost importance to maintain and increase the quality of higher education and achieve its contribution to the development of absorptive capacities of the local companies. It is already clear that the research-intensive companies need senior (top-level) researchers and marketing specialists who must have excellent technical knowledge about research-intensive products, services, and processes. Internationally competitive companies with limited research but strong development capacity need internationally experienced managers, people with product- and technology-management competence. Those with limited development and no research capacity need internationally experienced managers, engineers, designers, innovation managers, international sales, and other specialists.

It is also important to admit that while research on innovation systems has focused on activities related to the production and use of codified scientific and technical knowledge, it is flawed and much wider perspective has to be taken when catching-up and developing countries are under focus.

8.8 References

Allik, Jüri (2008). Quality of Estonian science estimated through bibliometric indicators (1997–2007), Proceedings of the Estonian Academy of Sciences, 57 (4): 255–264.

Archimedes Foundation (2010). Database of FP6 and FP7 projects.

Archimedes Foundation (2007). Database of FP5 and FP6 projects.

Drechsler, Wolfgang, Jürgen G. Backhaus, Leonardo Burlamaqui, Ha-Joon Chang,Tarmo Kalvet, Rainer Kattel, Jan Kregel, Erik S. Reinert (2006). Creative destruction management in Central and Eastern Europe: meeting the challenges of the techno-economic paradigm shift, in T. Kalvet and R. Kattel (Eds.): *Creative Destruction Management: Meeting the Challenges of the Techno-Economic Paradigm Shift*, Tallinn: PRAXIS Centre for Policy Studies.

Ekholm, Karolona and Katarina Hakkala (2008). International Production Networks in the Nordic/Baltic Region, *OECD Trade Policy Working Papers*, No. 61, Paris: OECD Publishing.

ERAWATCH (2010). Country Profile – Estonia, ERAWATCH, http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.content&topicID=35&parentID=34&countryCode=EE.

Eurostat (2008). *Science, Technology, and Innovation in Europe, 2008 edition*, Luxembourg: Office for Official Publications of the European Communities.

Gabrielsson, Nils, Tarmo Kalvet and Kimmo Halme (2007). Innovation Staff Recruitment: Program Feasibility Study. *Innovation Studies, no. 9.* Tallinn: Enterprise Estonia.

European Bank for Reconstruction and Development (2000). *Transition Report 2000,* London: Hyway Printing Group.

Huisman, Jeroen, Paulo Santiago, Per Högselius, Maria José Lemaitre and William Thorn (2007). *OECD Reviews of Tertiary Education, Estonia*, Paris: OECD.

Jensen, Morten Berg, Björn Johnson, Edward Lorentz, Bengta Ake Lundvall (2007). Forms of knowledge and modes of innovation, *Research Policy* 36: 680-693.

Kalvet, Tarmo (2010). Business Models of the Largest Enterprises in a Small Country Context: The Case of Estonia, *Halduskultuur*, 11(1): 128 - 151.

Kattel, Rainer and Tarmo Kalvet (2006) *Knowledge-Based Economy and ICT-Related Education in Estonia : Overview of the Current Situation and Challenges for the Educational System,* Tallinn: Praxis Centre for Policy Studies.

Kattel Rainer, Tarmo Kalvet and Tiina Randma-Liiv (2010). Small states and innovation, in R. Steinmetz and A. Wivel (Eds.): *Small States European: Challenges and Opportunities,* Ashgate: Aldershot, pp. 65-85.

KBE (2007). *Knowledge Based Estonia - Estonian R&D and Innovation Strategy 2007-2013,* Ministry of Education and Research, Tartu.

Laar, Mart (2008). Leading a successful transition: the Estonian miracle, *European View*, 7 (1): 67–74.

SORR (2010). State of the Region Report 2010, Baltic Development Forum.

Statistics Estonia (2010). Community Innovation Survey (2006-2008), www.stat.ee.

Statistics Estonia (2006). Community Innovation Survey (2002-2004), www.stat.ee.

Tiits, Marek, Rainer Kattel, Tarmo Kalvet and Dorel Tamm (2008). Catching up, forging ahead or falling behind? Central and eastern European development in 1990–2005, *Innovation: The European Journal of Social Science Research*, 21 (1): 65–85.

Tiits, Marek, Rainer Kattel, Tarmo Kalvet (2005). *Made in Estonia*, Institute of Baltic Studies, Tartu, http://www.ibs.ee/MiE.

Tiits, Marek, Rainer Kattel, Tarmo Kalvet and Rein Kaarli (2003). *Competitiveness and Future Outlooks of the Estonian Economy*, Tallinn: Research and Development Council.

Chapter 9: China

Xielin Liu and Peng Cheng, Graduate University of the Chinese Academy of Sciences (GUCAS)

9.1 Introduction

China is one of the fast growing economies in the world. After thirty years of open and reform, China has already established a unique economic and enterprises system. This system proves to be very effective for mobilizing resources for economic performance. Associated with the rapid economic growth and the ongoing structural reforms as well as the increased importance of S&T capacity for the Chinese economy, NIS has become an increasingly useful tool when analyzing innovative capacity and providing inputs for policy making in China. In 2006, the government released “National Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020) of China” (MOST, 2006), S&T is considered the key driving force for sustainable economic growth and for the transformation of China into an innovation-oriented nation through the construction of an enterprise-centered NIS with strong indigenous innovation capacity. Accompanied by the strong policy messages, some specific targets were also set up such that the research and development (R&D) expenditure needs to increase rapidly so that the R&D to GDP ratio will rise from the current level of 1.3 percent in 2005 to 2.0 percent by 2010 and to 2.5 percent by 2020.

There are many papers and reports on Chinese innovation system (Liu and White, 2000; Motohashi, 2007; OECD, 2008). For example, OECD just had published a review on Chinese innovation policy. It suggests that China needs more bottom-up decision-making, give private sector a more important role and more coordination among agencies to promote innovation (OECD, 2008). Due to the reason of history and culture, Chinese innovation is more up-down decision making. The innovation shows the resolve of China, such as the moon-landing project. But, China's economy is still more cost driven and limit profit margin, trapped by IPR and high royalty for licensing technology. Especially, China is heavily reliant on the foreign technology supply in key industry, such as chips, software, machine tool, engine etc. In order to be more effective to introduce innovation in China and enter a road of development based on more innovation, there is still a long way to go. So, how to evaluate the national innovation system in China, is more important step for the world.

The second part of this chapter will give a framework of national innovation system (NIS) in China. The third part of the paper will look at the national learning systems and technological capabilities. The fourth part will describe the knowledge flows and networks in the National innovation systems. The fifth part will discuss the institutional arrangements of the national innovation system. The last part will be conclusions on the performance of innovation system of China.

9.2 The main actors and their activities in the national innovation system

Framework of national innovation system in China. The innovation system of innovation is widely known invented by Freeman to explain the emerging of Japan. He defined it as "the network of institution in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" (Freeman, 1987:1). But later on, researchers realized that there is wide difference between NIS in developed and developing countries (Lundvall et al, 2006). In this paper, we emphasize that the big difference between NIS in developed countries and developing countries lies in the difference of institutions and their function. The institutions include laws, rules and norms, which stimulate the actors to innovate in some conditions (Edquist, 2000).

There are two main approaches to understand the function of NIS in a country. One is activity-based approach developed by Liu and White (2000). They take idea creation, R&D, implementation, education, and consumption as the five key activities. This approach is enhanced by Edquist, and he lists such as R&D, competence building, formation of new product markets, networking, financing and so on as the fundamental activity that defines the efficiency of a country's innovation system (Edquist, 2005). The second approach takes the government, university, enterprises, and public research institutes (PRIs) as the key systematic actors to analyze the innovation in one country. This is a very common approach to mark national difference of innovation (Nelson, 1993). Since the beginning of economic reforms, the Chinese innovation system has undergone significant changes, in terms of the relative importance of key actors and the mechanisms that drive the development of the innovation system.

Before 1980, the PRIs were the main players in the S&T system. From the 1950s to the 1980s, China established different layers of PRIs with various missions. At national level, the most important PRI was the Chinese Academy of Sciences (CAS), focusing mainly on basic research. There were also hundreds of industrial research institutes under a wide range of industrial ministries, mainly focusing on applied science and experimental development. Regional PRIs would carry out research and development work according to the needs determined at regional level (Commission of S&T, 1986). At that time, enterprises were no more than manufacturing plants. Most of them did not perform any R&D. Only some large state-owned enterprises had their own R&D labs, but their work mainly focused on experimental issues (Liu & White, 2002). Most of the universities were not involved in research either, except a few research universities such as Tsinghua University and Peking University. Many were specialized universities (such as the university of light industry, of metallurgy, of printing, etc.) focusing on industry-specific technology.

Following the dramatic reform of the S&T system, most PRIs have been transformed into enterprises. Universities have been given a much more important role in science. In 2003, the share of universities in the big three foundations, that is, the National Science Foundation of China, the National Basic Research Programme ("973" Programme) and the National Laboratories for basic research, was respectively about 67 percent, 47 percent and 56.79 percent. In 2005, the share of basic research performed by PRIs, universities and industry was 44.7 percent, 43.7 percent and 11.6 percent respectively. This confirms that universities are nowadays a very important actor in terms of basic research.

As shown in Table 9.1, the share of R&D expenditure by research institutes in the total R&D expenditure nationwide has gradually decreased from 50 percent in 1990 to 17.6 percent in 2008, while the corresponding share for enterprises has increased from 27 percent to 73.3 percent in the same period. This change is driven by a combination of the restructuring of research institutes, the expansion of the higher education sector and the strengthening of innovation capacity of enterprises. In particular, the privatization and the opening up of the manufacturing sector for foreign firms have largely contributed to this transformation.

Besides enterprise, university and PRIs, China is strong in role of government compared to other market economy countries. So, administration rather than law is the key to understand the economic process and innovation in China. In this paper, we will analyze the role of government, research institute and university, enterprise in the innovation system. There will be also one section on linkage between research institute, university and industry.

Table 9.1. *The relative importance of key actors in R&D expenditure (percentage)*

Performers	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008
Research institutes	50.0	28.8	27.7	27.3	25.9	22.0	17.6	18.9	18.5	17.6
Enterprises	27.0	60.0	60.4	61.2	62.4	66.8	71.2	71.1	72.3	73.3
Universities	12.0	8.6	9.8	10.1	10.5	10.2	10.3	9.2	8.5	8.5
Others	11.0	2.7	2.1	1.4	1.2	1.0	0.9	0.8	0.7	0.7

Source: China Statistical Yearbook on Science and Technology, 2009.

Role of the Chinese Government. The role of government in innovation system is not a new topic (Freeman, 1987). The rising of Japan, Korea and four tigers of Asia all, more or less, were closely related to the interference of government (Okimoto, 1989). Nation or state played a very important role in the early literature such as List in a country's competitiveness (List, 1928). But in late days, most scholars take a stand that market can do better than government. Some international organizations such as World Bank usually concluded that the role of government is limited in Asian rising (World Bank, 1993).

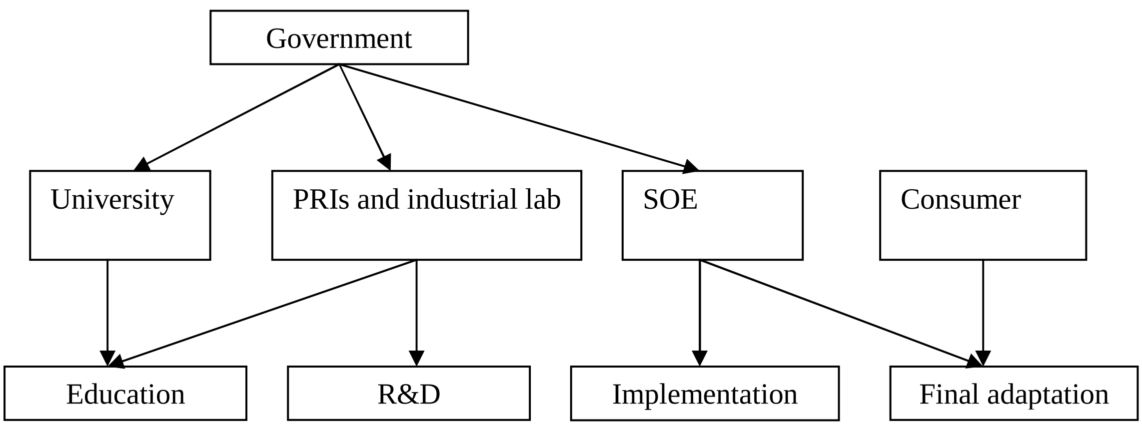
China is a unique country in the world. The government plays a very important role in innovation system than other countries. There are several key fundamental factors requiring for a powerful government in China. Firstly, this is a legend of thousands years of Chinese history for a powerful government. One can see that in Japan and later Korea's catch up, government also played a very important role. Secondly, China used to be a socialist country with a powerful system to control the economy. Though with market-oriented reform, the regulation system changed but basic power structure not changed much. Thirdly, China is a big country with more than 1.3 billion population. It needs a powerful government to regulate and coordinate the regions. Lastly, China is a developing country. During the early stage of catch-up, business system is relatively weak. The government had to mobilize the limited resources on some key industries. So, system of public research institutes and SOE had been established.

In order to better understand the role of government in the innovation system, one needs to understand the governance of science and technology and innovation in China. The State Council Steering Group for Science, Technology and Education is a top-level co-ordination mechanism, which meets two to four times a year to deal with strategic issues. A number of ministerial level agencies – the National Development and Reform Commission (NDRC), Ministry of Science and Technology, the Chinese Academy of Sciences (CAS), the Chinese Academy of Engineering (CAE), industrial line ministries such as the Ministry of Information Industry (MII) and the Ministry of Agriculture (MOA), and the National Natural Science Foundation of China (NSFC) – play a direct role in designing and implementing S&T and innovation policies. A number of other ministerial agencies, notably the Ministry of Finance (MOF), and the Ministry of Commerce (MOC) have significant influence on S&T and innovation policies and implementation, while others, such as Ministry of Personnel (MOP) and the State IP Office (SIPO), also exert an important, albeit somewhat indirect, influence. The current governance structure has resulted from the institutional changes and innovations implemented.

According to the government structure, there is a division of laboUr among those ministries. For example, MOST is responsible for R&D activity, and NDRC is responsible for the implementation of R&D results. MOST can also make national S&T and innovation policy and strategy. The plan-based innovation system can be seen in Figure 9.1. Science and technology programming and plans are the strong way for government to intervene the S&T and innovation activity. This kind of intervention copied from former Soviet Union and be kept effective till today. Science and technology programs are also the important ways for catch up and promote technological and innovative capability.

In 1956 the government launched its 1956–1967 National Science and Technology Long-Term Programming, which focused on developing Chinese research and production capabilities in atomic energy, electronics, semiconductors, automation, computer technology and rocket technology. This objective of this program was for China to catch up with developed countries both in defense and advanced civil technologies. At the same time, several specific mission projects were initiated and ultimately successful; namely, developing atomic and hydrogen bombs (by 1964 and 1967, respectively) and launching satellites (by 1970).

Figure 9.1 *Chinese innovation system in planned economy*



Source: Edited based on Liu, Xielin & Steven White (2001), Comparing innovation systems: a framework and application to China’s transitional context, Research Policy 30 (2001) p.1094.

The most important policy tool to realize the national strategy is specific national S&T programs controlled by MOST. Table 9.2 gives a brief overview of the main programs controlled by Ministry of Science and Technology (MOST). Among those S&T programs, national high-tech program (863 program) was launched in 1986 with specific goal of catch up and has been most important one. From 1995-2005, about US$4.6 billion were spend on civil technology development of 863 program. It mainly focuses high-technology. Most of local high technology industries owned to its support. It spread the seeds of high-tech industry in China and is deeply related with the development of high-tech zones in China.

Table 9.2. *National S&T programs (100 Million US$)*

	2001	2002	2003	2004	2005	2006	2007	2008
973 Basic Research	71.2	82.8	96.6	108.3	121.8	173.6	225.5	275.4
Key Technologies R&D program	127.2	161.6	162.5	195.0	201.3	384.6	745.4	734.8
National Key Experimental Lab Program	15.7	15.7	15.7	15.7	16.6	27.7	21.9	23.3
Innovation fund for SME	94.6	65.2	80.2	99.9	122.5	108.1	172.1	211.6

Source: MOST, China Science and Technology Development Report, 2009.China S&T Literature Press.

The power of S&T programs can be seen in varies ways. Firstly, those national S&T programs and increasing R&D inputs are relevant for the growing number of SCI papers and patent application in China, especially in the university and public research institutes. China now has been increasing its share of world publication (Table 9.3) (Zhou and Leydesdorff, 2006). Secondly, those programs are the overwhelming ways to train the scientists and engineers. Lastly, those programs also serve as the important way to continuously catch up the technological progress in the world. But it is hard to say that those programs are directly related to the innovation capability in the business community.

Table 9.3. *Percentage of world share of scientific publications (percent)*

	China	France	Germany	Japan	Korea	UK	US	EU-15
1995	2.05	6.09	7.62	8.65	0.79	8.88	33.54	34.36
1998	2.90	6.48	8.82	9.42	1.41	9.08	31.63	36.85
2001	4.30	6.33	8.68	9.52	2.01	8.90	31.01	36.55
2004	6.52	5.84	8.14	8.84	2.70	8.33	30.48	35.18

Source: Adapted from P Zhou and L Leydesdorff, ‘The emergence of China as a leading nation in science’, Research Policy 35, no 1 (Feb 2006).

The “National Programming 2006-2020 for the Development of Science and Technology in the medium and long term” is the current long-term S&T policy framework of China. The goal of the new national programming is to make China an innovative country by implementing indigenous innovation strategy. The specific goals are: to increase R&D expenditure per GDP to a level of 2 percent in 2010, and 2.5 percent by 2020; making S&T and innovation the most important factor for GDP growth to contribute about 60 percent of GDP growth; to decrease the dependence on foreign technology less than 30 percent (in the ratio of expenditure on technology import to R&D expenditure, estimated at 56 percent in 2004); and finally, to be among the top-5 worldwide in terms of the number of domestic invention patents granted, and the number of international citations of scientific papers(State Council, 2006).

The most interesting element of the new programming is the declared intention to strengthen “indigenous” innovation. The reasons for this strategy are followings: Firstly, the economic growth of China has been strongly dependent on foreign technology and foreign invested firms. Since 2000, foreign-invested enterprises accounted for more than 85 percent of all high-tech exports (China Statistics Yearbook on high-tech technology industry, 2004- 2006). In recent years, there has been an increasing frustration among domestic actors, caused by the fact that “market for technology” policy has not resulted in the immediate and automatic knowledge and technology spillovers from foreign to Chinese enterprises that policymakers had hoped for. Secondly, a culture of imitation and copying is common not only in product development and design, but also in the field of scientific research. Hence innovations from domestic knowledge bases and intellectual property rights are acutely needed in China. Thirdly, the high growth rate of the Chinese economy during the last twenty years will not be sustainable without a change in the development strategy. China needs, for example, more energy-efficient and environment-friendly technology, new management skills and new organizational practices to ensure sustainable growth in the near future.

There are three main policies selected to fulfill the indigenous innovation strategy. Firstly, the government plans to increase R&D by 2020 to 2.5 percent of GDP (from the current level of 1.3 percent). Since GDP growth is projected to increase at a similar pace, increasing R&D expenditure as a share of GDP implies a huge increase in absolute terms. Secondly, fiscal policy to activate innovation capability in the company level is assumed most important one. The new tax policy will make R&D expenditure 150 percent tax deductible, thus effectively constituting a net subsidy, as well as accelerated depreciation for R&D equipment worth up to 300 000 RMB. Thirdly but also new policy is public procurement of technology. This policy is the result of learning from USA and Korea’s best practices. Public procurement in China today is significant, but the policy tool itself is relatively new to China. The purpose of current public procurement practice is to cut the costs rather than promote indigenous innovation. Under the new policy, government agencies have to prioritize innovative Chinese companies by procuring their goods or services even if these are not as good or cheap as those of other companies (both Chinese and foreign). In this new policy, government set priority for indigenous innovative products in public procurement. It required that more than 30 percent of technology and equipments purchasing should go to domestic equipment if using public money. It would give indigenous innovative products some price advantage when procurement (State Council, 2006).

But before the real policy to be effective, people are worried that this kind of policy will not help domestic company much. Firstly, public organizations usually like to buy high-end products, so it often buys the foreign products rather than domestic company products. For example, in automobile industry, the main buyer of Audi in China is public organization. Secondly, it is not easy to distinguish the foreign from domestic products. For example, the products of Lenovo seem fitted in the category of domestic products, but the core components of Lenovo computer are from Microsoft and Intel.

Role of Enterprises. In the period of plan economy, SOE was the exclusive form of enterprises and was very weak in terms of innovation. Usually they did not have the function of R&D. The government would told firms when, where and how to introduce the new technology. The main economic tool for government to do that is five-year and annual economic and S&T plans. The main institution was government research institutions. Even at the government level, there is an elaborated division of labor. For example, the State Planning Committee (now State Development and Reform Commission) was central in allocating production targets for the enterprises and also had the powers and obligation to introduce new technologies to the economic system. The Ministry of Science and Technology would make five year and annual plans in the area of science and technology.

But overall, the whole system was less than efficient. The enterprises were output-based, with few if any incentives for efficiency and profit, and paid no attention to IPR. The research institutions and universities were funded by government and typically produced project reports with limited industrial use. Hence the performance of innovation in that time was poor, although reverse engineering made a great impact in some sectors. Many new industries started around the same year as Korea initiated her new growth path, such as the automobile industry, ICT industry, and steel industry, but lagged behind Korea decades later. "Import, lag behind, import again, lag behind once more" was the rule of that period.

For a long time, enterprises have typically operated as manufacturing units with few if any R&D activities or formal R&D centers. Their production capability was maintained and upgraded mainly through technology imports and enterprises spent more money on technology imports than on their own R&D during the period before 1998. Since the 1980s, SOEs were given more autonomy to invest and innovate based on their own strategic decisions. Also, enterprises with different ownerships, such as private and foreign enterprises have also to a larger extent, engaged in innovation activities. This wave of privatization and competition made enterprises have stronger incentives to invest in product development and innovation on top of exploiting cost advantages or diversification. Tables 9.4 and 9.5 show that, large and medium-sized enterprises gradually increased their R&D inputs and R&D intensity. Nevertheless the R&D intensity is still quite low, comparing to that of developed countries.

Overall, the power of enterprise is still relatively weak in China. PRI and university are the main actors to implement the national goals. The weakness of enterprise can be seen from Table 9.6, which shows that enterprises only got invention patents as many as that of PRI and university. Large foreign firms dominate patenting activity in China, accounting for roughly two-thirds of all invention patents granted in China in 2004 (Miller, 2006).

Table 9.4. R*&D expenditure and technology importation of LME (100 Million US$)*

Year	Expenditure on R&D	Expenditure on technology import
1995	16.75	42.65
1998	23.86	26.00
1999	30.25	25.12
2000	42.81	29.71
2001	53.55	34.61
2002	67.68	45.00
2003	87.08	48.98
2004	115.31	44.45
2005	152.63	36.23
2006	208.77	41.03

2007	286.73	61.42
2008	392.46	64.46

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

Table 9.5. *Ratio of R&D/sales in large and medium sized companies (percent)*

Year	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008
R&D/sales	0.46	0.71	0.76	0.83	0.75	0.71	0.76	0.77	0.81	0.84

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

Table 9.6. *Patents granted in China, 1987-2008 (Number and percentage)*

Year	Number	University	Research institute	Enterprises
1987	250	48	43	9
1990	863	38	38	24
1993	1,514	33	38	29
1996	654	34	38	29
1999	1,430	30	38	32
2002	3,065	23	30	48
2003	6,789	25	25	50
2004	12,018	29	20	51
2005	14,588	31	17	53
2006	18,184	34	14	52
2007	24.238	34	13	53
2008	36.703	28	11	61

Source: Yearbook of China S&T Statistics (1988-2005), China Press of Statistics.

The Role of Public research institute and University. For a quite long time, from the 1950s through the 1960s to the 1980s, public research institutes (PRI) were the main agencies to realize the national S&T strategy and goal. For a long time, they got more than half of total R&D expenditure in China (Table 9.7). There are five layers of public research institutes: central level, ministry level, provincial level city and county level. In central level, such as Chinese Academy of Science, PRI focused mostly on basic and applied research. In ministry level, PRI were more specialized on industry areas. For many industrial PRIs, from 1949 to the 1980s, their main tasks were the assimilation of imported technology from the former Soviet Union, Germany, Japan and other countries. In order to replace the imported technology and to save foreign currency, incremental innovations based on imported technology were implemented according to the principles of a planned economy.

Table 9.7. *Key actors in R&D expenditure (100 Million US$)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Research institutes	31.2	34.9	42.4	48.2	52.2	50.4	72.6	93.4	118.7
Enterprises	65.0	76.3	95.2	116.0	158.7	204.3	273.3	364.0	495.0
Universities	9.3	12.4	15.8	19.6	24.3	29.6	35.4	42.7	57.1

Others	2.9	2.6	2.2	2.2	2.4	2.5	3.1	3.5	4.8

Source: China Statistical Yearbook on Science and Technology, 2009.

In the previous plan-based innovation system, there was little space for curiosity- driven research. The share for basic research has been low and remained at a level around 5 percent of the total R&D expenditure during the period 1995-2005 (China Statistical Yearbook on Science and Technology, 2006). Since the economic reform was initiated in 1978, the S&T system of China was soon exposed to market competition. The objectives of the reform were twofold: to introduce competition-based funding system and to establish a new governance system of S&T institutions in order to more efficiently commercialize R&D results.

One of the key initial changes was to reform the funding system and make the governance of the S&T institutions more flexible. It meant that government reduced the direct funding for PRIs, and makes the source of the funding of PRIs increasingly diversified than ever. While this change aimed to enhance incentives for innovation and to accelerate commercialization, it imposed also increased pressure on scientists and led to short-term research projects for pursuing more immediate economic returns.

In order to speed up the process from research to commercial products, the government also encouraged PRIs and universities to set up their own spin-offs and encouraged scientists to leave their research position and engage in commercial activities. Furthermore, a new institution called technical market was introduced. This new specialized market was supposed to facilitate technology transactions between suppliers and users of technology. Moreover, special economic zones were established across China to support the development of high-tech enterprises. In the 1990s, after more than ten years of reform, there was still a great gap between the research activities of PRIs and the needs of industrial sectors. In the meanwhile, the government system underwent a significant change as most of the industry-specific ministries were abolished. The new structural challenge was how to deal with the industrial research institutes, which were previously affiliated to those ministries. Toward the end of 1998, the State Council decided to transform 242 PRIs at the national level into technology-based enterprises or technology service agencies. This important structural change implied that the dominance of PRIs in the Chinese innovation system was over and instead, the industrial enterprises were on the way to become the core of the innovation system. Thus whereas in 1991, there were close to 6000 government research institutes with around 1000000 employees, in 2004 the numbers had shrunk to less than 4000 research institutes with approx. 560 000 employees (NBS 2006).

Since 2000, the enterprises performed more than 60 percent of total R&D in China (See Table 9.8). However, PRIs and universities are still the key players in frontier science and technological research. They still attract a larger number of talented scientists than enterprises do. After the transformation of applied PRI, some of them have been operated quite well such as, but some of them are not. It is not easy to make scientists to be good managers. Some of the transformed PRI cannot find their market position. They lost their technology capability and became a common company. It is a fact that most of public money goes to public research institutes and universities. As table 9.10 shows, from 2003-2005, public research institutes got about of 65.96 percent of all government money, university is about 20.62 percent, business only 11.85 percent. This kind of R&D expenditure structure shows that government in most of time will rely on PRI and university to realize their S&T ambitions.

Table 9.8. The allocation of government R&D (2003-2005) (100 Million US$ and percentage share)

Year	2003	Share	2004	Share	2005	Share	2005	Share
Total government R&D	55.6	100.0	63.3	100.0	78.8	100.0	159.4	100.0
PRI	38.7	69.54	41.6	65.76	52.0	65.96	102.4	64.27
Enterprises	5.7	10.27	7.6	11.96	9.3	11.85	21.3	13.36
University	10.6	19.04	13.1	20.78	16.2	20.62	33.0	20.71
Others	0.6	1.13	0.9	1.49	1.2	1.58	2.7	1.67

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

9.3 National learning systems and technological capabilities

Education. Education system is a complex system providing human resources, knowledge and skills for the NIS. China’s education system could roughly be classified into 4 levels, namely preschool education, primary/elementary education, secondary education and higher education (Table 9.9), which are comparable with the International Standard Classification of Education – ISCED (UNESCO, 2006). The first one, preschool education (equivalent of ISCED 0 – Pre-primary education) commonly consists of a stage of 3 years’ nursery education and a stage of 1-year preparatory education, but its successful completion does not mean that any level of education has been attained, and it is not compulsory. Primary/elementary education (equivalent of ISCED 1 – Primary education) is the first full-sense stage of compulsory education in China, both 5-year and 6-year system have existed for a long time, but now, almost all primary school is 6 years’ education. A successful completion of this level is sufficient to acknowledge that the primary/elementary education has been attained. The next stage - secondary education is somewhat more complex than that of most western countries, which has two stages: junior middle-school education (equivalent of ISCED 2 – Lower secondary education) and senior middle-school education (equivalent of ISCED 3 – Upper secondary education). The 3 years’ junior middle-school education is the second part of compulsory education, while the 3 years’ high middle-school education is not. For the high middle- school education, both general high middle-school and vocational school education (equivalent of ISCED 5B – Tertiary-type B education) exist. A successful completion of this level is sufficient to acknowledge that the secondary education has been attained. After this grade citizens can continue their learning of higher education (equivalent of ISCED 5A – Tertiary-type A education), which provides possibility of obtaining postgraduate education (ISCED 6 – Advanced research programs). Besides these levels of education, there are also students enrolled in other formal programs, such as employed people enrolled in doctoral and master's degree programs, etc.

Table 9.9. *China’s Education System*

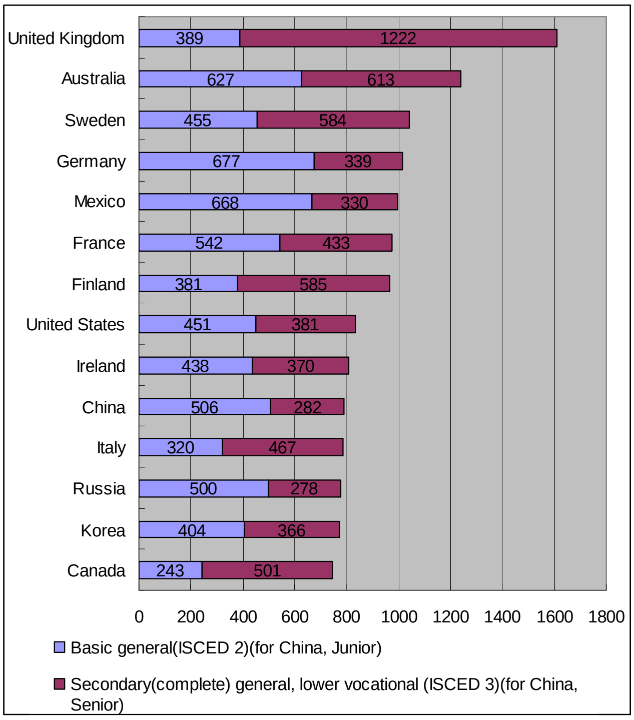
Higher education	1. Postgraduates (master's program 3 year, doctor's program 3 year) 2. Undergraduates in Regular HEIs (bachelor's course 4 years, short-cycle course 3 years) 3. Undergraduates in Adult HEIs (bachelor's course, short-cycle course)

	4. Employed People Enrolled in Doctoral and Master's Degree Programs
Secondary education	1. General middle school Junior middle-school: 3 years, equivalent of ISCED2 ,compulsory education Senior middle-school: 3 years, equivalent of ISCED3 2. Vocational school (3 years) 3. Specialized secondary schools (senior 3 year, equivalent of ISCED 3 – Upper secondary education) 4. Skilled worker school (senior 3 year, equivalent of ISCED 3 – Upper secondary education)
Primary/elementary education	5-year elementary school; 6-year elementary school equivalent of ISCED 1 – Primary education compulsory education
Preschool education	1. Nursery school (3 years) 2. Preparatory education (1year) Equivalent of ISCED 0 – Pre-primary education

China’s enrolment in junior (equivalent of ISCED 2 – basic general education, lower secondary) and senior (equivalent of ISCED 3 – Upper secondary education) education is not high (this certainly have relation to do with the demographic structure of China). In 2004, it accounted for 788 students per 10,000 populations (Figure 9.2). The difference between junior and senior enrollment in China shows a certain demographic decline. The similar trends can be also seen in many other countries such as Russia, Mexico, Germany, etc. At the same time some countries perform a reverse proportion (e.g. Canada or Finland). As shown in table 9.10, Performance of the basic education in China can be illustrated by PISA survey. In 2006 China occupied 16th position of 56 by reading, 1st - by mathematics and 4th - by natural science (OECD, 2007). These are at very high positions, which mean China’s basic education system is one of the world’s best. Therefore PISA results are an exciting signal for the Chinese government and people.

In China, a higher education institution (refers to as HEIs hereinafter) is defined as an organization providing higher professional education in accordance with the state accreditation. There exist three types of HEIs: universities (multidisciplinary HEIs performing education programs and research in multiple domains of knowledge), academies (focused on particular areas, such as natural sciences, social sciences, agriculture etc), and “institutes” (providing education services in certain

Figure 9.2 *Enrolment in China and Some OECD Countries: Basic General and Secondary (complete), per 10,000 Population: 2004*



Source: Indicators of Education in China, 2004.

Table 9.10. *PISA 2006 Results Comparison: China and Other Countries*

	Natural Science		Reading		Mathematics	
	Average score	Position	Average score	Position	Average score	Position
Finland	563	1	547	2	548	2
China	532	4	496	16	549	1
Germany	516	13	495	18	504	20
France	495	25	488	23	496	23
US	489	29	-	-	474	35
Italy	475	36	469	33	462	36
Russia	479	35	440	39	476	34
Mexico	410	49	410	43	406	48
Brazil	390	52	393	49	370	54

Source: OECD, 2007

narrow areas, such as Chinese traditional medicine, music etc) (Table 9.11). Some key universities and institutes are directly under Ministry of Education or other state ministries, while the others usually under local government. In May 1998, China's former president, Jiang-Zemin, put forward the famous "985 Program" at the 100th anniversary celebration of Peking University, which means China will develop a number of world-class universities in order to achieve modernization. By now, there are 34 universities including Tsinghua University and Peking University on the "985 Program" list.

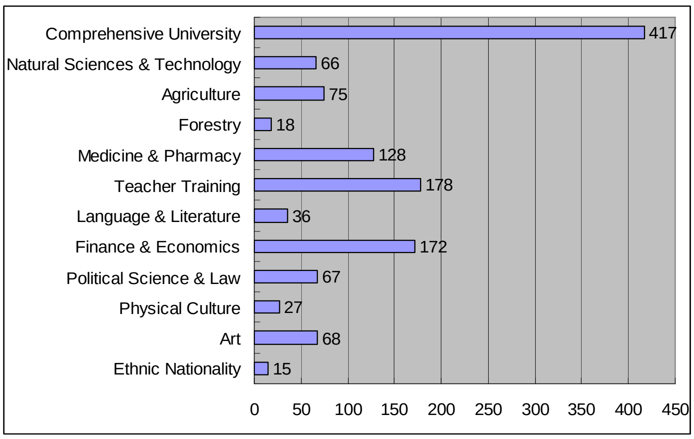
Table 9.11. *Number of Regular Higher Educational Institutions (Institution)*

	Total	Universities & colleges	Short-cycle colleges	Tertiary vocational technical colleges
Total	1867	720	1147	981
Comprehensive university	417	150	267	261
Natural sciences & technology	666	193	473	444
Agriculture	75	33	42	40
Forestry	18	6	12	11
Medicine & pharmacy	128	77	51	11
Teacher training	178	122	56	5
Language & literature	36	14	22	21
Finance & economics	172	50	122	103
Political science & law	67	20	47	31
Physical culture	27	14	13	12
Art	68	29	39	39
Ethnic nationality	15	12	3	3
Of which: non-state/private colleges	276	29	247	241

Source: Indicators of Education in China, 2006. Online data: http://www.moe.gov.cn/

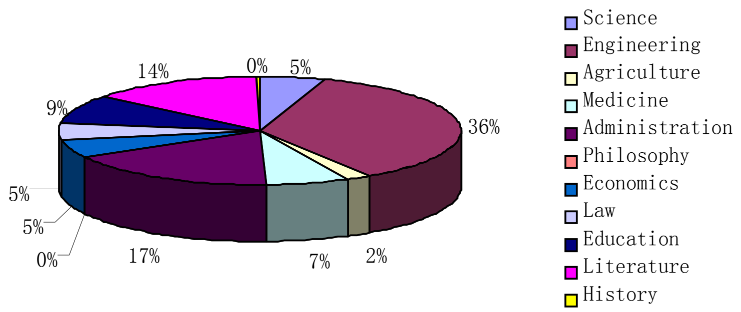
Today, the country has 1867 HEIs (Table 9.11), of which 1591 are state-owned and 276 are private (Indicators of Education in China, 2007). From the discipline distribution of all HEIs (Figure 9.3), we can see that the HEIs in natural sciences & technology accounted for more than 40 percent of all, while the HEIs in social sciences (art, political science and law, finance & economics, language & literature) accounted for less than 20 percent. This implies that China put much emphasis on science & technology education in the last several decade years. From the pie chart of Figure 9.4, we can also see this trend of China. In 2007, the total number of HEI students was 25.29 million (23.66 million and 1.63 million in governmental and private HEIs respectively). The scale of higher education in China is now among the biggest in the world.

Figure 9.3. *Discipline Distribution of HEIs in China*



Source: Indicators of Education in China, 2006. Online data: http://www.moe.gov.cn/

Figure 9.4. *Graduates from Regular Higher Education Institutions by Major, 2006*



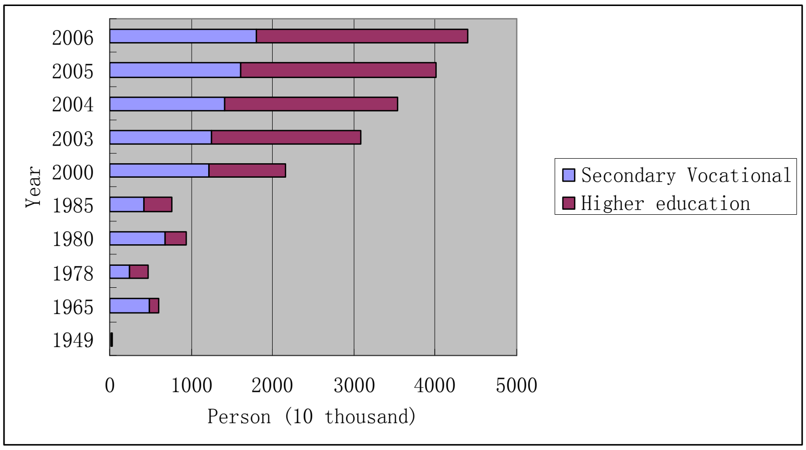
Source: China S&T Statistics Data Book on line www.most.gov.cn

After obtaining a Certificate of Complete Secondary Education a student can take higher education entrance exam to enter a University or an Institute (College). There are three different degrees that are conferred by Chinese universities: The first degree is the Bachelor's degree. Bachelor's programs regularly last for 4 years of full-time university-level study except medical students (who need 5 years). The programs include professional and special courses in Science, the Humanities and Social-economic disciplines, professional training, completion of a research paper/project. The Bachelor's degree is awarded in all fields. Some students who don't pass the higher education entrance exam can choose to attend adult HEIs (need only 3 years) and pass the final exam for another 2 years' study to apply for bachelor's degree.

Holders of the Bachelor's degree are admitted to enter the Master's degree programs after passing the entrance exam, and only very small number of bachelor students who have got excellent performance during their undergraduate studies can be admitted to master's degree program without examination. The Master's degree is awarded after successful completion of two or three years' full-time study (some of HEIs' master program is still 3 year's while some have transformed into 2 year's education, depending on different HEIs and different disciplines). Students must carry out 1-year's research including practice and prepare and defend a thesis which constitutes an original contribution. Often students have to release at least one academic paper before they can get master's degree.

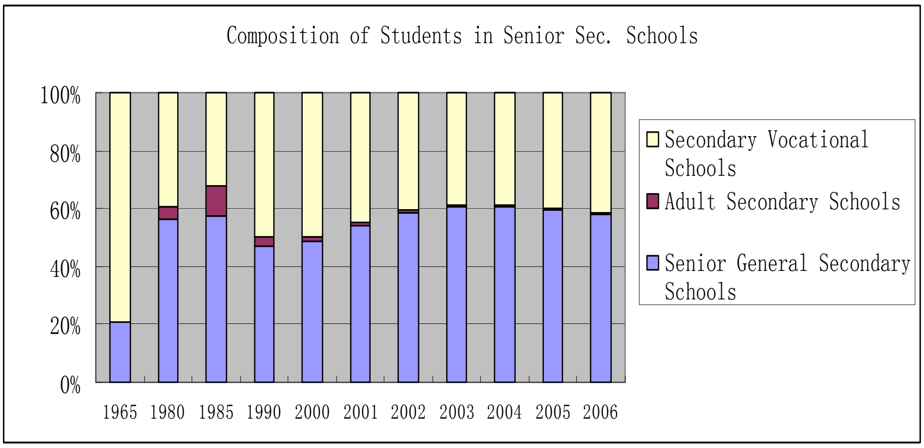
Besides higher education, secondary vocational education (in China, this term consists of Regular Specialized Secondary Schools, Adult Schools, Vocational High Schools and Skilled Workers Schools) is also enough to obtain profession (for most of blue-collar jobs including technical). However, now in China, enrolment rate on this level is much lower than that of higher education. In the 1980s and 1990s, the social and economic development in China was very rapid; labour force was well in need. At that time, secondary vocational education was glorious in China. Many students would rather go to these schools than senior general schools because it is easy for them to find a job after secondary vocational education, and it is a quick way for them to obtain profession compared to higher education; the enrolment rate of secondary vocational education is high compared with senior general education and higher education. However, in the new century, the competition in labour market is more and more fierce. College students are no longer the "unusual favourite person" in the society, and some of them in turn become blue-collar job hunter who was formerly the role of vocational graduates. And it becomes harder for vocational graduates to find jobs; students are no longer eager to enter secondary vocational schools. So, the enrollment rate of vocational schools decreases relative to higher education (Figure 9.5 and Figure 9.6).

Figure 9.5. *Enrollment Number of Secondary Vocational and Higher Education in China*



Source: Indicators of Education in China, various years. Online data: http://www.moe.gov.cn/

Figure 9.6. *Composition of Students in Senior Secondary Schools*



Source: Indicators of Education in China, various years. Online data: http://www.moe.gov.cn/

In recent years, the higher vocational education had emerged in China and has developed very quickly in the last five years. The higher vocational education is part of 3-year short-cycle higher education. The aim of this level education is to cultivate higher technical workers. Higher vocational education colleges are now partly replacing the role of secondary vocational schools. From recent year's statistic data, we found that the employment rate of higher vocational education colleges (especially in some hot specialty) is growing year by year and had nearly exceeded the employment rate of general college's 4-year bachelor students. This implies that the education system has developed with social and economic development.

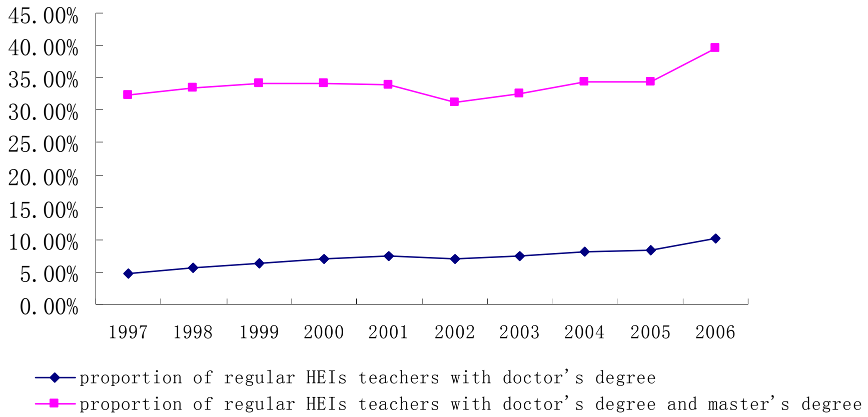
In a long period time before liberation, China's education system had a strong feudal color, only the upper class has the right to be educated. Since PRC was founded in 1949, all Chinese people gradually got the equal chance to be educated; the reform of China's education system has also made tremendous achievements, during which the structure of China's education system continues were improved. For example, in the year 1949, the number of enrolled elementary school students, junior middle school students, senior middle school students and college students are only 24,000,000, 952,000, 315,000 and 117,000 respectively (National Research Center of Education Development, 2005). The enrollment ratio of school-age children is only about 20 percent, and 80 percent of Chinese population is illiterate at that time. However, in the year 1977, the number of enrolled elementary school students and junior middle school students had attained historically high of 151,000,000 and 49,900,000, which is respectively 6.2 times and 52.5 times of those in 1949. The number of enrolled senior middle school students also reached about 19,000,000, which is 60 times of that in 1949 (National Research Center of Education Development, 2005). Looking back to today, the achievements is obvious (the below-mentioned data sources in this paragraph are from online "Annual Education Statistic Reports of China, 2007"; www.moe.gov.cn): the 9-year compulsory education has basically become universal; the net enrollment ratio of school-age children in primary schools has reached 99.49 percent; the gross enrollment ratio of junior middle school students has reached 98 percent; the promotion rate of senior school graduates has reached 75.1 percent; the facilities conditions of primary and secondary schools are further improved, for example, their building area has reached 1,353,200,000 square meters, which are also full equipped with physical, musical, art and natural science educational instruments. By the end of 2007, there are more than 2,300 HEIs in China (including general HEIs and adult HEIs) and about 27,000,000 students have attended China's different kinds of higher education, and the gross enrollment rate of higher education has reached 23 percent. The postgraduate students enrolled have reached 1,200,000.

Besides the government-owned educational system, there are also many private schools in China. In 2007, there are 95,200 private schools in China ranging from preschool education to higher education as well as vocational school. The development of China's education system had been influenced to some extent by former Soviet Union. For example, for a long time, China's charging system had followed the "free education" system of Soviet Union. However, during the 1980s, China was in transition from planned economy to market economy, the notion of "free education" as the basic feature of socialistic education was subject to many queries. The reform of the charging system gradually implemented. The scope of education charge had gradually extended and amount of education charge had continually increased. Higher education made her farewells to free education and elementary education also transformed from gratuitous education to paid education. At present, the charging of post-graduate education had also actualized in some HEIs where different kinds of scholarships and subsidies are to compensate for tuition fees.

With the development of higher education, the quality of college teachers in China has also increased. From the line chart of Figure 9.7, we can see that the proportion of regular HEIs teachers with doctor's degree and master's degree is continually increasing in the past decade. In 2006, teachers with doctor's degree in general HEIs had accounted for 10 percent of all general HEIs teachers, which indicate a rise in qualification of Chinese HEI teachers. Especially in recent years, the competition between HEIs has been more and more fierce, so does the competition of talent HEI teachers. HEI teacher candidates are required with better quality. PhD degree is a necessity but no longer insurable for a college teacher title. Besides teaching, research ability has more and more brought into consideration. More and more HEI teachers perform R&D besides teaching affairs especially the teachers in HEIs with post-graduate education (Table 9.12). In these post-education HEIs, graduate students and young teachers are the main R&D labor force.

On the other hand, with the development of higher education, the age structure of college teachers is growing equitable (Figure 9.8). In 2006, all the HEI teaching staff younger than 30 years accounted for 30 percent. Professors and Associate professors older than 60 years only accounted for 14 percent and the age of most Professors and Associate professors have centralized around 30-50 years especially around 41-45. This implies the young energy of Chinese higher education compared with Russia where the young teachers (younger than 30 years) accounted only for 16 percent and more than half of professors were older than 60 years.

Figure 9.7. *Academic Qualifications of Full-time Teachers in General HEIs in China*



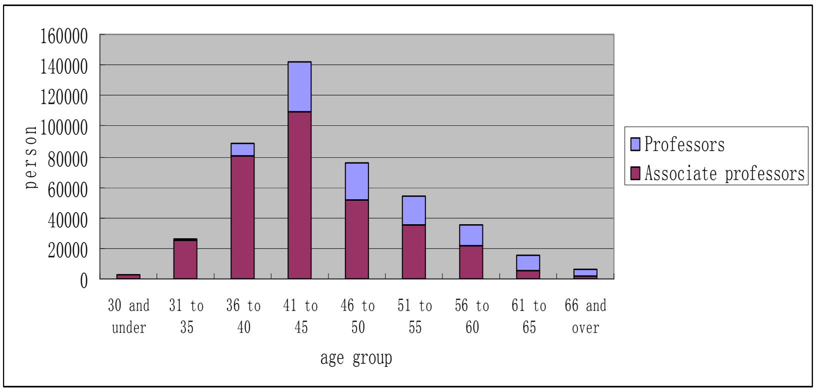
Source: Indicators of Education in China, various years. Online data: http://www.moe.gov.cn/

Table 9.12. *Chinese College Teachers Performing R&D in Recent Years.*

Indicators	2002	2003	2004	2005	2006
Staff Performing R&D (in 10 thousand)	38.3	41.1	43.68071	47.09	50.8711
R&D Expenditure (100 million US$)	15.77	19.61	24.28	29.58	35.45
Number of Released Papers	541390	612738	668520	728082	830948
Number of Patent Applications	6778	10770	14888	20094	24490
Number of Authorized Patents	2251	3954	6399	8843	12043

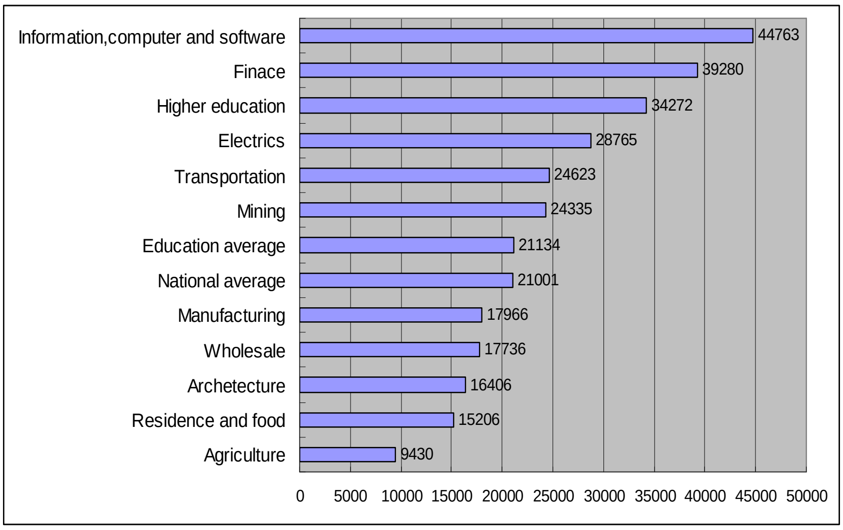
Source: China Statistic Year Book Online, 2007. http://www.stats.gov.cn/

Figure 9.8. *Breakdown of Full-time Professors and Associate Professors by Age*



Source: Indicators of Education in China, 2006.

Figure 9.9. *Average Annual Salary by Sector in China, 2006 (Unit: RMB)*



Source: China Statistic Year Book Online, 2007. http://www.stats.gov.cn/

In China, the average annual salary in the higher education sector is 63 percent higher than the national economy average level in 2006. This implies that higher education sector is relatively a high paid sector in China. From Figure 9.9, we can see that only information; computer and software sector and finance sector are beyond the sector of higher education in their salary level in 2006. However, the salary level of primary education and secondary education is lower than the national average level, which is the reason why State Council of China had recently promulgated some measures to increase the salary level of primary and secondary education to promote social equity.

High salary level of higher education sector is partly the result of high expenditure on higher education. In 2005, the total education expenditure is 255 billion RMB, however, the expenditure on higher education per student in China is only 559 RMB (calculate according to indicators of education in China), which is much lower than developed countries such as United States, United Kingdom, France, Canada, and also is much lower than Russia which is about 3.6 thousand $ PPP in 2005. (If calculate with only general HEIs students, the expenditure on higher education per student in China is 15,364 RMB, which is still much lower than developed countries and lower than Russia). Chinese college teachers also earn money form R&D projects. The total R&D fund raised by HEIs had attained 619.67 billion RMB in 2006 and the growth rate of R&D fund maintained 20 percent in the last five years (Table 9.13). However, there is an obvious inequity among college teachers in earnings from performing R&D. "Big professors" have both social resources and academic ability raising R&D fund and undertake national R&D projects thus could earn a lot from R&D project while young teachers/lectures often lead a "simple" life.

R&D. In recent years, China's R&D expenditure has expanded rapidly (Table 9.14). In 2007, the R&D expenditure amounted to 48.79 billion US$, which is 11.12 billion US$ more than that of 2006. Moreover, this number has surpassed that of Britain and France for the first time, and made China rank 4th in the world in 2007 in terms of R&D expenditure. However, concerning with the R&D expenditure, the gap between China and the top three countries has remained very large, as that number in 2007 of USA, Japan and Germany respectively accounted to 343.7, 148.5, 73.8 billion US$.

Table 9.13. *R&D Fund in Chinese General HEIs, 2002-2006 (100 million US$)*

Indicators	2002	2003	2004	2005	2006
R&D fund raised (100 million US$)	354.96	417.92	522.93	640.99	793.56
Of which:	0.00	0.00	0.00	0.00	0.00
Government fund	93.78	101.40	119.07	148.08	175.16
Enterprise fund	202.57	248.10	334.81	419.97	525.94
Loans from financial institutions	24.39	31.33	32.02	33.80	47.93

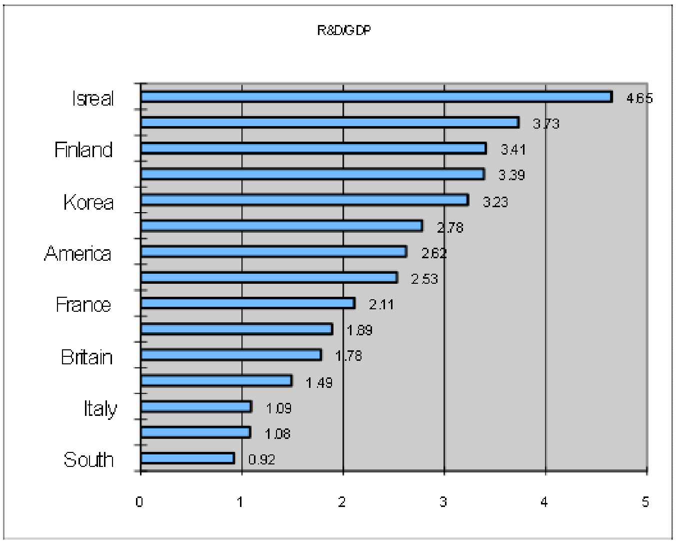
Source: China Statistic Year Book Online, 2007. http://www.stats.gov.cn/

Table 9.14. *R&D Expenditure in China, 2002-2007*

	2002	2003	2004	2005	2006	2007	2008
R&D expenditure (Billion USD)	15.56	18.60	23.76	29.91	38.46	50.36	67.56
R&D/GDP (percent)	1.07	1.13	1.23	1.33	1.42	1.44	1.54

Source: MOST, Main S&T Indicators Database, 2008.

Figure 9.10. *The Ratio of R&D/GDP in Selected Countries in 2007 (percent)*



Source: MOST, Main S&T Indicators Database, 2008.

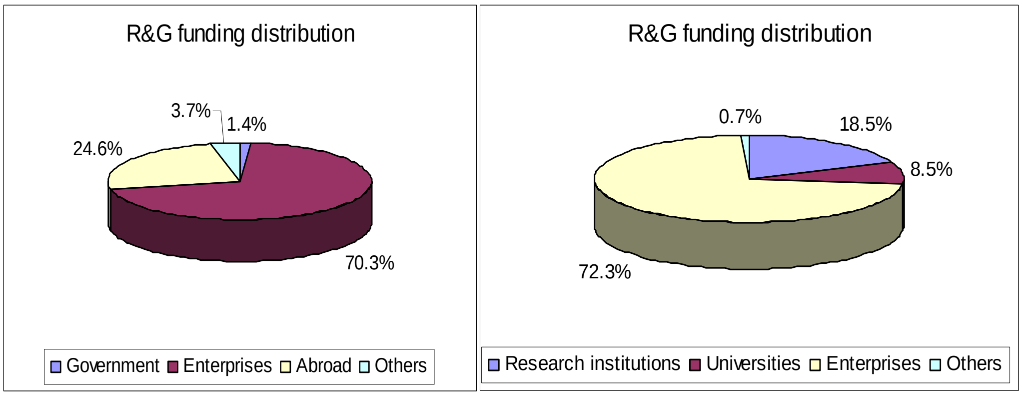
It is usually considered that high level of R&D intensity is an important guarantee of innovation capability. According to the intensity of R&D input, which is usually measured by the rate of R&D/GDP, this ratio began to improve rapidly after 1999. It accounted to 1.49 percent in 2007, and took the first place among developing countries. But there still exists a wide gap between the R&D intensity level of China and that of developed countries, since the ratio in most developed countries were more than 2 percent in 2007 (Figure 9.10).

R&D funding resources in China are enterprises, government and other institutions. From Figure 9.11, we can see that enterprises are the main funding resources, whose R&D funding accounted for 70.4 percent of the total R&D expenditure of China in 2007. The ratio of R&D funding of enterprises in most developed countries were more than 60 percent in 2007, and China's R&D funding distribution is similar (Figure 9.12).

In addition, enterprises are also the main R&D performer in terms of R&D activities. In 2007, R&D activities performed in enterprises spent 72.3 percent of the total R&D expenditure of the country (Figures 11). In 2007, the basic research funding in China was 2.29 billion US$, which increased by 0.34 US billion dollars than 2006, but the basic research funding proportion of the total R&D expenditure was only 4.70 percent, which only accounted to less than half of developed countries (Figure 9.13). During the past years, this proportion has been remained stably at about 5 percent.

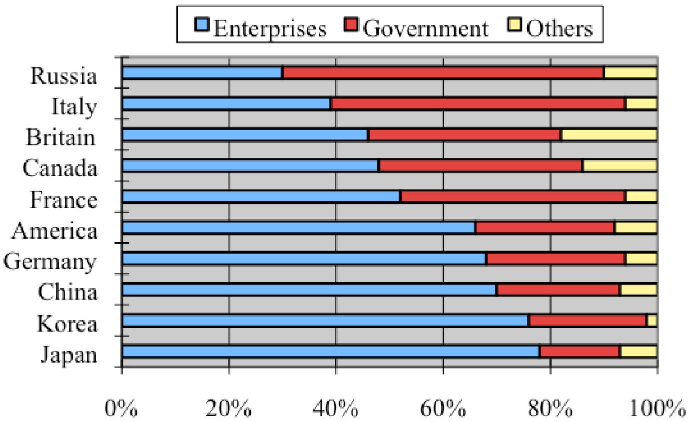
The number of Chinese R&D personnel has increased rapidly in recent years (Table 9.15). It achieved 1.50 million in 2006. Moreover, the number of scientists and engineers reached 3.13 million, which increased at a rate of 11.8 percent than that in 2006. In addition, the amount of scientists and engineers during 10 thousand working people has increased to 39.8 in 2007.

Figure 9.11. *R&D Funding and Performing Distribution in China in 2007*



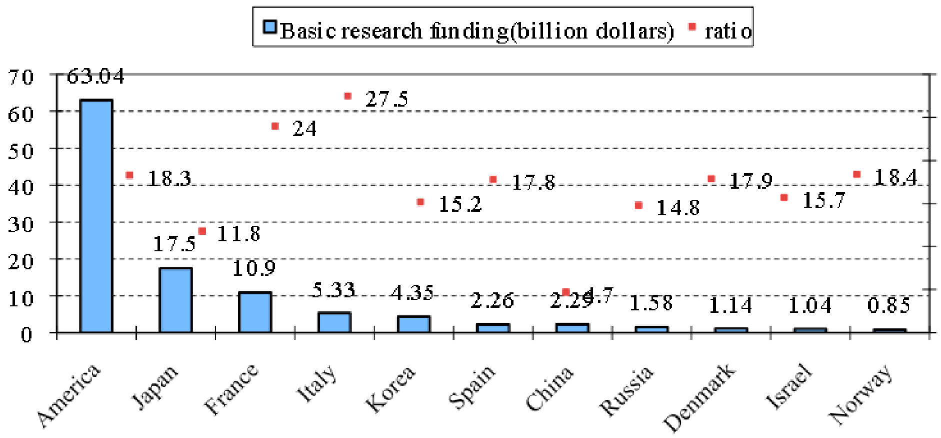
Source: MOST, Main S&T Indicators Database, 2008.

Figure 9.12. *R&D Funding Distribution in Selected Countries in 2007*



Source: MOST, Main S&T Indicators Database, 2008.

Figure 9.13. *Basic Research Funding Proportion of Total R&D Expenditure in Selected Countries in 2007*



Source: MOST, Main S&T Indicators Database, 2008.

Table 9.15. *R&D Personnel in China, 2000-2007*

	2000	2001	2002	2003	2004	2005	2006	2007
Number of R&D personnel (thousand)	922	957	1035	1095	1153	1365	1503	1736
Number of scientists and engineers (thousand)	2046	2072	2172	2255	2252	2561	2798	3129
Number of scientists and engineers in 10 thousand working people	27.7	27.8	28.8	29.6	29.3	32.9	35.8	39.8

Source: MOST, Main S&T Indicators Database, 2001-2008.

Enterprises, research institutions, and universities are the main R&D performer in China. In 2007, the distribution of R&D personnel in the three sectors was: the ratio of R&D personnel in enterprises was more than 2/3 and such ratio in research institutions and universities was totally less than 1/3.

The increase of the amount of R&D personnel mainly owns to the enterprises. In 2007, the number of R&D personnel in China increased by 234 thousand, among which 162 thousand came from enterprises. In the same time, the increasing rate of the number of R&D personnel in the country was 15.6 percent, while that in enterprises was 23.3 percent (Table 9.16). In terms of the R&D personnel input, enterprises had become to play the main part in China's R&D activities. In recent years, China's imports and exports of high-tech products have been increasing rapidly and the exports have gradually exceeded the imports (Table 9.17). This may indicates that Chinese S&T capability has been improved.

Furthermore, the high-tech industrial output has increased greatly, and the economic profits have also been improved (Table 9.18). Thus we can see that the R&D inputs, including funds and personnel, have made the technology enhanced and brought forth great profits. But the high-tech enterprises in China are much weaker than that in advanced countries, as China's technology still needs to be improved by learning from advanced countries and developing innovation capabilities.

Table 9.16. *Distributions of R&D Personnel in China, 2001-2007*

	Total		Research institutions		Universities		Enterprises and others	
	thousand	(%)	thousand	(%)	thousand	(%)	thousand	(%)
2000	922	100	227	24.6	163	17.7	536	58.1
2001	957	100	205	21.4	171	17.9	581	60.7
2002	1035	100	206	19.9	181	17.5	648	62.6
2003	1095	100	204	18.6	189	17.3	702	64.1
2004	1153	100	203	17.6	212	18.4	738	64
2005	1365	100	215	15.8	227	16.6	922	67.6
2006	1502	100	232	15.4	242	16.1	1028	68.4
2007	1736	100	255	14.7	254	14.6	1227	70.7

Source: MOST, Main S&T Indicators Database, 2001-2008.

Table 9.17. *National Imports and Exports of High-tech Products*

	2002	2003	2004	2005	2006	2007
Exports of high-tech products (One billion US$)	67.86	110.32	165.36	218.25	281.45	347.82
Share in total exports (percent)	20.8	25.2	27.9	28.6	29.0	28.6
Imports of high-tech products (One billion US$)	82.84	119.30	161.34	197.71	247.3	286.98
Share in total imports (percent)	28.1	28.9	28.7	30.0	31.2	30.0

Source: MOST, Main S&T Indicators Database, 2008.

Table 9.18. *Main Economic Indicators of High-tech Industry (One Billion US$)*

	2002	2003	2004	2005	2006	2007
Gross industrial output	182.42	248.35	335.50	419.53	537.81	684.90
Value added	45.54	60.82	76.61	99.22	128.78	157.73
Revenue from principle business	176.56	246.61	336.43	414.10	532.55	674.77
Profits	8.95	11.73	15.04	17.37	22.76	32.52
Exports	72.73	109.92	179.18	215.29	300.64	385.78

Source: MOST, Main S&T Indicators Database, 2008.

One of the serious challenges Chinese companies are facing is that they are still pursuing a cost advantage strategy; spend relatively little on R&D. From Table 9.3, it is clear that large and medium sized companies have continuously increased their R&D, but still remains at a low level. In 2005, R&D spending relative to sales was only about 0.76 percent. Secondly, a surprising fact is that many large and medium sized companies have reduced their R&D labs in those years; the reasons for these phenomena may be out of merging, joint venture and ownership transformation which made them to cut off their previous R&D labs (see Table 9.19).

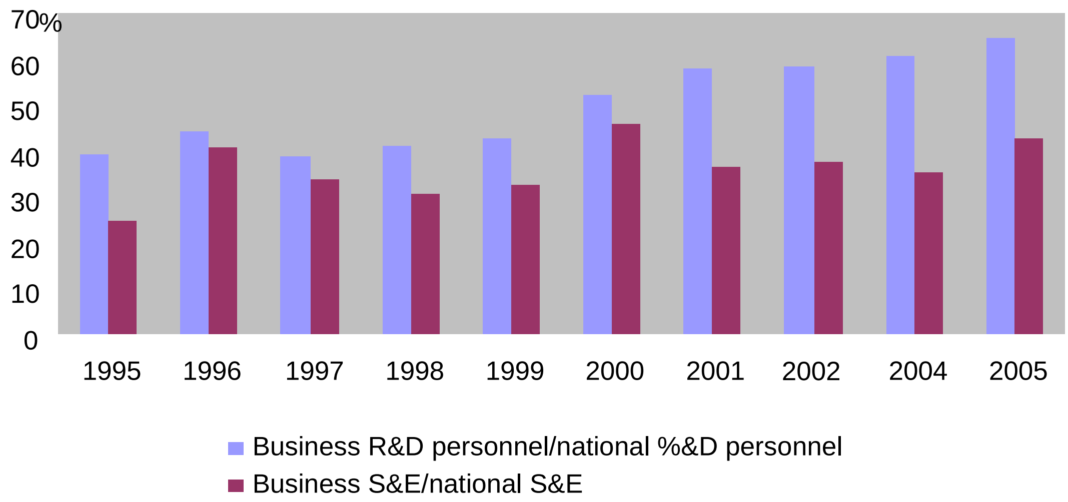
Table 9.19. *R&D Expenditure and R&D Labs in Large and Medium Sized Companies (1995-2005)*

Year	Number of companies	Share of companies with R&D labs (percent)	R&D/sales (percent)
1995	23,026	56.9	0.46
2000	21,776	34.9	0.71
2001	22,904	32.3	0.76
2002	23,096	31.1	0.83
2003	22,276	30.7	0.75
2004	27,692	32.8	0.71
2005	28,567	32.75	0.76
2006	32,647	23.22	0.77
2007	36,252	24.33	0.81
2008	40,314	24.66	0.84

Source: MOST, Main S&T Indicators Database, 2006.

Thirdly, the total number of business R&D personnel has increased from 294,000 in 1995 to 883,100 in 2005, with an annual growth rate of 12.4. Its share in total R&D personnel is about 64.7 percent. But since 2001, the share of key scientists in business R&D personnel has been flattening at about 37.25 percent, with no obvious increase. It means that even now, the R&D activities of businesses are still not an attractive place for leading scientists compared to universities and GRIs (Government Research Institutions) (Figure 9.14).

Figure 9.14. *Business R&D Human Resources/ National R&D Human Resources (1995-2005)*



Note. No data of 2003.
Sources: MOST, Main S&T indicator databank, 2006.

9.4 Knowledge flows and networks in the national innovation systems

The intensity and efficiency of ***industry-science linkages*** are important indicators of innovation capability at the system level in a country. As there was a functional division of labor in knowledge creation and diffusion for a long time in China, strong barriers existed between the knowledge creation by PRIs and universities and the utilization of knowledge by enterprises. But since the introduction of economic reforms in China, under the strong competition pressures and supported by various institutional changes, the industry-science linkages have been improving greatly in the past 20 years. In this section, we illustrate industry-science linkages in the Chinese innovation system in the following three aspects: university spin-off, R&D outsourcing, and co-publication.

PRIs and University Spin-off. PRIs and universities were allowed and encouraged to set up their own spin-offs so that they could commercialize their technology and research results directly. In this way, PRIs and universities could be more integrated in the economic activities. Spin-off companies could also provide PRIs and universities with some financial resources, which could compensate for budget cuts from the government. Up to 2004, there were around 2400 spin-off enterprises established and generated around US$ 9.7 billion revenue (Ministry of Education, 2005).[9] Although the number of spin-off firms in China is small compared to that of the Chinese industrial sector, it is very important for high-tech

[9] Total revenue of 2355 spin-offs amounted RMB 80,7 billion and converted into USD using the annual average exchange rate at the value of 8,28.

industries in China. Spin-off companies provided many scientists from PRIs and universities with opportunities to access new market opportunities. The policy to encourage spin-offs also gave birth to many successful domestic high-tech companies, such as Lenovo (from the CAS) and Beida Founder (from Peking University), which are now leading companies in the Chinese ICT industry. Most of the Chinese biotechnology companies are also spin-offs. For example, Shenyang Sunshine Pharmaceutical Co. Ltd., Beijing Shuanglu Pharmaceutical Co. Ltd., and Anhui Anke Biotechnology Co. Ltd. were all founded by former researchers from research institutes (Liu and Lundin, 2006a). However, since 2000, as the government has continuously strengthened its support for research and higher education, many PRIs and universities no longer consider development of spin-off companies as one of their primary functions.

S&T Outsourcing by Industrial Enterprises. As an integral part of the establishment of science-industry linkage, PRIs and universities began to conduct contract research for the industrial sector. This type of activities has been beneficial for the industrial sector, as most of Chinese enterprises, especially small and medium-sized Enterprises (SMEs), have limited innovation capabilities. Outsourcing of S&T research to PRIs and/or universities has become important development strategy of industrial enterprises. For instance, the share of universities' S&T funds from industrial enterprises was about 38 percent of their total research funds in 2004. However, the share of government research institutes' S&T funds from industrial enterprises remains relatively low and was at a level around 6 percent of their total S&T funds in 2004. It is because PRIs are still heavily relying on direct funding from the government (China Statistical Yearbook on Science and Technology, 2005).

Joint Publications. Individual researchers from either the higher education sector or from research institutes submit the majority of published scientific papers in China. As another indicator of industry-science linkage, the number of joint scientific publications by researchers from universities and the industrial sector is still relatively small. For IPR and other reasons, the S&T staff from industrial enterprises is typically reluctant to publish papers. But recently, researchers from universities and to an increasing extent engineers and researchers from industrial enterprises have become co-authors of science and technology publications. For instance, the number of co-authored papers, by researchers from universities as the first author, together with engineers/researchers from the industrial sector has rapidly increased from 867 articles (1.7 percent of total number of scientific papers published) in 2000, to 7421 pieces (7.4 percent of the total) in 2003 (Chinese Institute of Information, 2005). This intensified interaction and co-operation may promote innovation capacity in both sectors as well as enhance the mutual understanding of their different, but closely related innovation activities.

Venture Capital. The venture capital system also has a very important role in promoting links between universities, PRIs and industries. It was introduced in the end of 1990s. The first wave of the VC was driven by the government; later on, private and international VC firms have recently started to emerge in China. Recently, China's venture capital market has been developing rapidly. In the year 2001, the overall amount of venture capital in China is only 518 million dollars; however, just by the end of the second season of 2008, this figure has risen to 3845.04 million dollars, nearly eight times that in the year 2001. Especially in the last two years, the number and amount of venture capitals both maintained a high growth rate, reaching an average rate of more than 50 percent.

With regard to VC by sector, we see that the IT industry, traditional industry, bio-tech/health industry and service industry, which together make up 84 percent of the VC number and 85 percent of overall amount, are the sectors attracting most VC. As White said, China’s venture capital system is still immature in terms of the resources and capabilities of most of the constituent organizational actors, as well as the institutional environment in which they operate. Currently, venture capital firms do not have the expertise or operational mechanisms to adequately select and manage new technology ventures, nor have they been able to add much value beyond financing. Because their incentive structure creates a bias towards late-stage investment projects, these venture capital firms are not acting as a channel of funds to true start-ups, despite the government’s intentions for the promotion of venture capital (White, et al., 2005).

Since the open-door policy was implemented in China, firms with ***foreign direct investment (FDI)*** have become increasingly important in production as well as in R&D in China. During 1998-2004, the number of large- and medium-sized FDI firms has been steadily increasing. While the shares of value-added and exports of FDI firms in the Chinese industrial sector have reached a relatively high level (40 percent and 76 percent, respectively in 2004), the shares of R&D expenditure and employment are still relative low (29 percent and 34 percent respectively in 2004). Apart from the large number of new FDI establishments of capital-intensity processing manufacturing units, R&D-related activities in these new FDI firms are still relatively limited. It implies that, FDI firms’ production in the Chinese industrial sector has been relatively capital-intensive, but not really R&D-intensive manufacturing.

Beyond the manufacturing, internationalization of the high-tech industries is of significant importance to China’s upward mobility in global innovation. But such a move also has some controversial characteristics. On the one hand, the increased trade volume shows the international competitiveness of the high-tech industries of China. But on the other hand, the dominance of FDI firms and the large share of processing of imported materials as well as the reliance on foreign technology raise the following questions: Are China’s high-tech industries really high-tech? And are the high-tech industries in China really Chinese? Nevertheless, there are also substantial cross-industrial variations in the high-tech industries. As a well-known fact, the ICT sectors are the most internationalized high-tech industries, in which value-added, FDI firms dominate technology imports and exports. As table 9.20 shows, the share of FDI firms in the computer and office equipment industry has the largest increase and FDI firms in the medical equipment and instruments industry have also noticeably increased their contribution to R&D investment at the industry level.

Table 9.20. *Importance of FDI firms across high-tech industries, 1998 & 2004*
(Share in the high-tech industries, percent)

	Number of firms	Share of LMEs	R&D expenditure	Tech import	Export	Employ ment
		1998				
Pharmaceutical products	83	16	20	4	19	11
Electronics & telecommunication	349	52	41	77	86	42
Computer & office equipment	70	59	37	94	94	51
Medical equipment & instrument	28	20	11	41	40	14
		2004				
Pharmaceutical products	158	21	22	20	21	16

Electronics & telecommunication	1145	72	42	93	93	73
Computer & office equipment	336	86	82	98	98	91
Medical equipment & instrument	105	38	27	33	88	36

Source: Lundin et .al, 2006b.

In addition to the relative importance of FDI firms at the industry level, another important and controversial question is, are FDI firms more R&D-intensive than domestic firms? While the R&D intensities across different ownerships have increased during 1998-2004, so far domestic firms, both stated-owned and private, have higher R&D intensity than FDI firms. The implications of these observations are: Domestic firms in China are strengthening their innovation capacity through increased R&D investments. This is achieved not only by the increased R&D investments in the SOEs, but also is driven by an increased number of entrepreneurial and S&T-based private firms.

Two types of FDI activities in China may explain the lower R&D intensities in FDI firms. For the first, some of FDI firms’ activities are still capital or labour intensive manufacturing in the high-tech industries. For the second, while some foreign firms are increasing their R&D effort in China, the R&D activities are still based in the OECD home countries where the firms originate. Even though the R&D intensities in the high-tech industries have increased over time, they are still at a much lower level compared to the high-tech industries in the OECD countries. As shown in Table 9.21, the R&D intensities in most of the high-tech industries, except in the aerospace industry, were not substantially higher than in the manufacturing sector on average. In an international comparison to the U.S. and Japan, the difference is remarkable. From a long-term perspective, the R&D intensities need to, and will be further boosted, driven by continued indigenous R&D efforts and intensified competition between domestic and FDI firms when the technology gaps between them are being narrowed. Furthermore, the narrowed technology gap can also facilitate strategic alliances among firms with various ownerships and thereby boost R&D investments in both domestic and FDI firms.

Table 9.21. *R&D intensity in the high-tech industries (percent)*

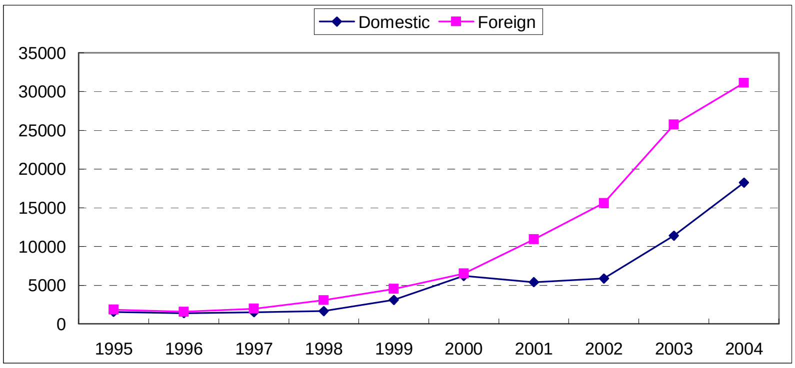
	R&D/value-added 2001	R&D/ value-added 2003	R&D/value-added U.S. (2001)	R&D/value-added Japan (2001)
Manufacturing average	3.4	2.0	8.7	9.9
High-tech average	5.0	4.4	27.2	26.3
Aerospace	15.0	15.8	14.4	22.3
Pharmacy	2.6	2.7	14.8	22.9
Computers and Office machines	4.1	2.5	36.7	30.7
Electronic ,Telecommunications	5.8	5.4	37.2	18.6
Medical Equipments and Meters	2.5	3.0	36.8	30.2

Source: China Statistics Yearbook on high technology industries, 2004, 2005.

In terms of innovation output, one of the largest differences between domestic and foreign applications is the structure of applications. For domestic firms, the majority of their patent applications are utility model or design, although the number of invention applications has been increasing as well. For foreign patent applications, the invention application is the main category. The number of invention applications by domestic firms exceeded for the first time their foreign counterparts in 2003. Figure 9.15 shows that the foreign firms still outperformed their Chinese counterparts significantly in terms of the number of granted invention patents in the past years. There is no straightforward explanation why the number of domestic patents granted lags behind foreign patents granted. The awareness of protection of intellectual property right has indeed increased among domestic firms and innovation activities have become an important strategic reaction for both domestic and foreign firms to enhance their competitiveness. As figure 9.15 shows, the gap may suggest that despite the increased awareness, the technology gaps, in terms of degree of novelty and technological sophistication between domestic and foreign firms, make the catch-up process of domestic firm somehow difficult. Table 9.22 shows that among foreign patent applicants, the multinational enterprises from Japan and the U.S. are the most active, while German, Korean and French companies are also applying for a large number of patents in China. The distribution by field of technology reflects to a large extent the competitive strengths of these multinationals in the Chinese market.

Globalization of R&D and China. In recent years the number of R&D centers of multinational enterprises in large cities such as Beijing and Shanghai has increased rapidly. The purpose of these establishments is mainly twofold: to take advantage of abundant and relatively cheap R&D human resources in China and to locate R&D units near their (exiting) manufacturing units in China. According to von Zedtwitz (2006), there were 199 foreign R&D facilities in China in the beginning of 2004. Figure 9.16 shows the number has increased rapidly since then, and possibly has amounted to 250-300 currently.

Figure 9.15. *Domestic and foreign invention patents granted*



Source: China Statistical Yearbook on Science and Technology, 2005.

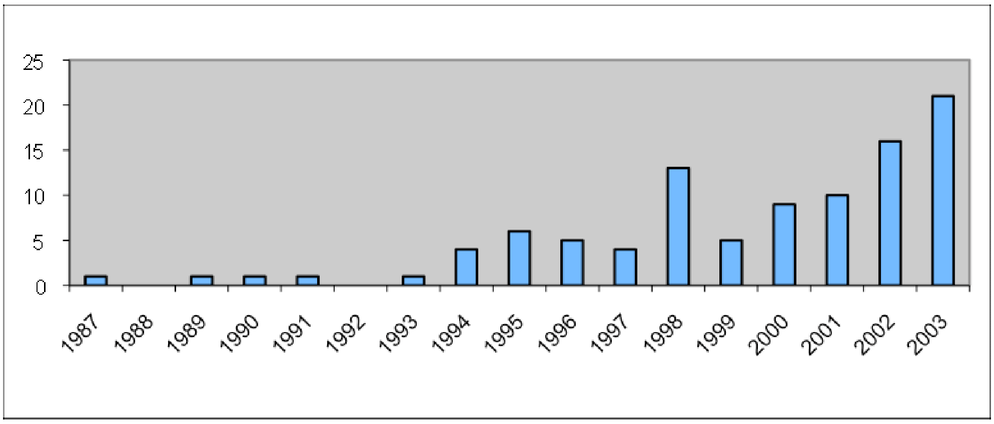
Table 9.22. *Top ten foreign enterprises in applications for invention patents in China (2003)*

Ranking	Country	Enterprise	Number of applications
1	Japan	Matsushita Electric Industrial Co., Ltd.	1817
2	South Korea	Samsung Electronics Co., Ltd.	1560
3	Japan	Canon Co., Ltd.	820
4	Japan	Seiko Epson Corp.	781
5	South Korea	LG Electronics Corp.	624
6	Japan	Toshiba, Inc.	583
7	United States	IBM Corporation	581

8	Japan	Sony Corp.	560
9	Japan	Mitsubishi Electric Co., Ltd.	556
10	Japan	Sanyo Electrical Motors Co., Ltd.	541

Source: Ministry of Science and Technology Indicators, 2005.

Figure 9.16. *Number of new establishments of foreign R&D labs in China, (1987-2003)*



Source: von Zedtwitz (2006)

The globalization of R&D in China can also be observed from the co-operation between foreign enterprises and Chinese universities and research institutes. This new type of co-operation is in an initial and immature stage and it is still very difficult for foreign enterprise to find original ideas and sufficiently innovative projects through this kind of co-operation. At the current stage, foreign enterprises do not buy ready-made projects or research, rather they utilize the existing R&D research capacity and facilities (which were often purchased by the support of governmental funding and of very high standard) to carry out research projects, which are defined by the foreign enterprises themselves and modified during the working process to adapt to local conditions.

Nevertheless, the mutual benefits generated through such co-operative efforts should not be underestimated. It will provide local universities and research institutes with additional funding and more advanced equipment. More importantly, it will also generate positive demonstration- and spill-over effects to the universities and allow them to get more informed about the international research frontier. Finally, it can be an efficient way for foreign firms to identify research units and personnel with high research capacity.

Compared to the level of inward foreign direct investment (which reached USD 72 billion in 2005, UN World Investment Report, 2006[10]), China's outward direct investment (ODI) and cross-border Mergers and Acquisitions (M&A) are still very limited. By the end of 2005, China's aggregated ODI reached USD 57.2 billion, accounting for only 0.59 percent of global ODI and ranked 17th in the world among outward investors in 2005 (MOC, 2006). However, this low level of ODI may change, associated with both the increased openness of the Chinese economy, new government policies and the relaxing of financial controls as well as the efforts

[10] This large increase is also due to the fact that, in 2005 for the first time data on Chinese inward FDI included inflows to financial industries. In 2005, non-financial FDI alone was USD 60 billion. The FDI into financial service surged to USD 12 billion, which was driven by large-scaled investment in Chinese largest stated-owned banks.

to diversify China’s huge foreign exchange reserves.11 In 1999, the Chinese government launched the “Go Out” policy and China’s Ministry of Commerce predicts that ODI will maintain an average annual growth rate of over 22 percent in the years to come and will exceed USD 60 billion by 2010.

Even though at the current stage, Asia and Latin America account for 90 percent of China's ODI I order to target the acquisition of energy and natural resources, the new “Go Out “ strategy is also a measure to promote and facilitate the internationalization of Chinese firms in S&T-intensive sectors. It aims at encouraging successful Chinese firms to strengthen their technological capacity and build brand recognition as well as to counter intensified competition in the Chinese market by investing abroad.

Recently, some Chinese enterprises, in particular in the electronics and ICT sectors, have initiated their international R&D activities, by either acquisition of foreign enterprise/units or through setting up R&D organizations in OECD countries. The high profile M&A deals involving Chinese enterprises in the high-tech sectors have caused huge attention worldwide. In these M&A deals, the access to R&D centres of western sellers is one of the key elements. For example, in the TCL- and Thomson deal, it included Thomson’s R&D centres in Germany, Singapore and the U.S. Similarly, in the Lenovo-IBM deal, Lenovo took over IBM’s R&D centres in Japan and the U.S. (see Table 9.23). In a recent report from Boston Consulting Group (BCG, 2006), among the top 100 emerging global companies from developing economies, 44 are Chinese firms and 18 of which are in the ICT sector and a few from the automobile sector. Even though the number of such Chinese firms is very few and the scale of their international R&D activities is still small, a new generation of Chinese firms seem to emerge as important players in S&T-intensive (instead of labour-intensive) segments of the global market. The innovation capacities of these Chinese firms and their ability to tap into the global network have therefore generated large interests, from both research- and policy-making perspectives. In other words, will these emerging Chinese multinationals become global players in the near future?

Table 9.23. *Selected M&A deals by Chinese firms (2001-2005)*

Chinese bidder	Target foreign firm / Unit	Industry	Bid value
Holly group	Philips Semiconductors, CDM hand-set reference design (US), 2001	Telecom	USD 180 million
TCL International	Schneider Electronics AG (Germany), 2002	Electronics	USD 8.5 million
TCL international	Thomson SA, Television manufacturing unit (France), 2003	Electronics	N.A.
BOE Technology Group	Hyundai display technology,(South Korea), 2003	Electronics	USD 1,305 million
Shanghai Auto Industry Corporation (SAIC)	Ssangyong Motor (South Korea), 2004	Automotive	USD 474 million
Lenovo group	IBM, PC Division (US), 2004	IT	USD 1620 million
Nanjing Automotive	MG Rover Group (UK), 2005	Automotive	USD 87 million

Source: Wu (2005), The Boston Consulting Group (2005) and various press reports.

[11] In 2005, China’s foreign currency reserves increased by USD 209 billion and reached USD 819 billion. It exceeded those of Japan and has become the world’s largest in 2006.

9.5 Institutional arrangements of the national innovation system

In China, there is little scope for curiosity-driven research. S&T has generally been viewed as a practical economic activity (Hu, 2005). Most Chinese cannot distinguish between sciences and technology. Although the share of the R&D budget and human resources for basic research is increasing gradually, it is still quite low compared to developed countries. Even now, the proportion of basic research has been kept to a relatively low level of 5-6 percent of total R&D expenditure. In addition, most of the government funds for basic research are targeted at limited areas such as biology and nanotechnology with a strong practical purpose (Hu, 2005).

Before the 1980s, the major actors in basic research were the government research institutes. Since the 1980s, universities became increasingly more important. Two important organizations support science research in China: the National Science Foundation and the Department of Basic Research within the MOST. Most regions have their own regional science foundation system, but their functions are more practical and geared to local economic and social needs.

The National Science Foundation of China. The National Science Foundation of China (NSFC) plays a unique role in the Chinese science system. For a long time, there was no special fund for basic science. After 1978, a fund similar to the US National Science Foundation was set up. It was established in 1986, firstly under the MOST and subsequently becoming an independent body in 2000. This system works mainly based on peer review rather than on government plan. The Foundation gives curiosity-based research a place in the whole R&D set-up in China. The NSFC is mainly funded by government budget. From 2001 to 2005, about ten billion RMB was spent on basic research. The channels of support were greatly diversified, from teams to talented scientists, from general to key projects. Table 9.24 shows that in 2006, the overall budget for the NSFC was 2.68 billion RMB. As the Foundation mainly operates on a peer review basis, it is widely regarded as the backbone of the Chinese science system.

Table 9.24. *Budget of the NSFC (100 million US$)*

	1996	1997	2005	2006
Total	0.78	0.94	2.76	3.43
For general projects			2.12	2.60
Projects for young scientists			0.55	0.72
Region-based projects			0.09	0.12

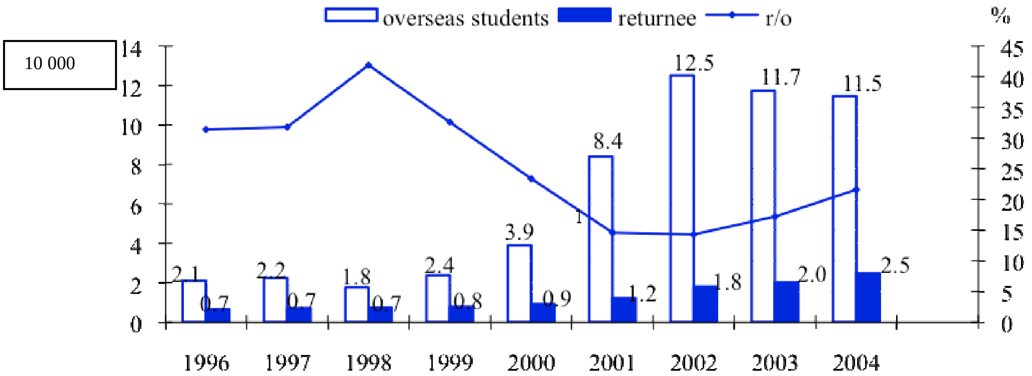
Source: www.nsfc.gov.cn.

The National Basic Research Programme (or "973" Programme). The "973" is a national mission-oriented science programme for big science and transnational cooperation, launched in 1997 with the aim of strengthening the role of government in science. The target areas are the so-called strategic areas, such as energy, information, health and materials. From 1998 to 2005, more than 5 billion RMB was allocated to this Programme. More than 143 key projects are being supported. In 2005, the main fields sponsored by the 973 Programme were: population and health care (17.4 percent), IT (12.1 percent), materials (14.3 percent), agriculture (17 percent), energy (10.5 percent), resources and the environment (17.4 percent) interdisciplinary study (14.7 percent) and others (2.8 percent) (MOST, 2007). The Knowledge Innovation Programme was launched in 1998, mainly to allow the CAS to survive in the context of rising university research. With this meta-project, the CAS has been reorganizing itself to upgrade its core competence in the face of the universities. The budget is about one billion RMB a year. The main goal is to make the CAS the leading international basic research centre. In reality, this project helps the CAS greatly in facilitating the work of and attracting key scientists, making the CAS the largest basic science centre in China and in the world.

Talent people policy. China has a large pool of human resources spread around the world. How to use this pool is a critical problem for Chinese science policy. In order to attract talented scientists back to China, special grants for returnees have been prepared by the government. The result is positive. More and more have returned (Figure 9.17). For example, from 2001 to 2005 under the Knowledge Innovation Programme, the CAS attracted 422 scientists with special money for their research and labs via the One Hundred Talents Programme.

Science policy in China has been implemented through a supply-side as well as a demand-side approach. But as a developing country, the national strategy has downplayed the demand side. Sometimes, scientists are not happy with that. Neither are they glad to see that the government cannot give as much support as developed countries do, since the funding for basic research in China remains about 5-6 percent of national R&D funding.

Figure 9.17. *The comparison of oversees student and returnee of China*



Note: Unit for number of overseas students and returnees: 10 000.
Sources: MOST, 2006a, China Science and Technology Development Report, 2006. China S&T Literature Press. Beijing.

Technology policy on importing technology. For a long time, from the establishment of the People's Republic of China in 1949 until the 1970s, the main aim of technology policy was to cover shortages of technology and enhance China's military strength. In the 1950s, the Soviet Union was the main source of foreign technology; 156 key projects with that country were the most famous. They became the incubators for later industrialization in various industries. But after the break-up of the alliance with the Soviet Union, China began to emphasize independent technology development, although imported technology still played a very important role. The success of the nuclear bomb and artificial insulin projects was the result of the technology policy in this period. China nevertheless imported technologies on a grand scale from the Soviet Union, Germany, Japan and other countries. Those technologies laid the foundations for many Chinese industries, including chemicals, automobiles, steel, textiles (Wang, 2000). But the absorption capacity of Chinese firms is rather poor. So "Import, lag behind, import again, lag behind once more" seems to be the pattern of technology importing. Many new industries started in China at around the same time as Korea, such as the automobile industry, the ICT industry and the steel industry, but now, decades later, China lags behind Korea.

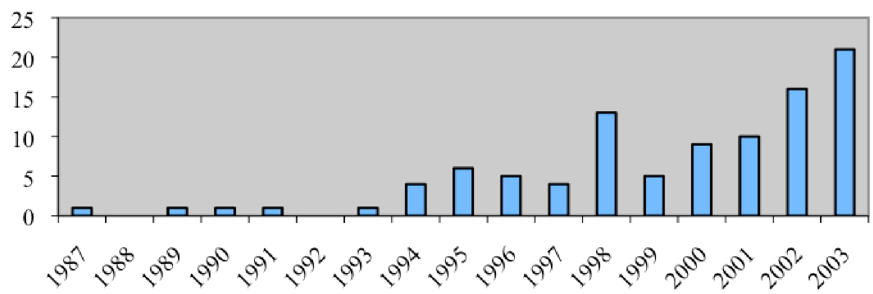
Market for technology. Foreign direct investment came to China in the 1980s. In the first stage, the government hesitated as to how to deal with FDI. China was in great need of foreign technology and capital. But for a long time, under traditional ideology, foreign investment was not regarded as a good thing for Chinese society. So "market for technology" became a practical technology policy, although the government never formally used the term. First, government used the big Chinese market to press foreign companies to transfer technology to local companies and to protect local companies from international competition. In IT and the automobile industry, the specific policy tool was to require multinationals to license technology to Chinese companies as a precondition for their investment. For example, "Industrial policy for the automobile industry (1994)" stated, "the preconditions for a joint venture are that the companies have to set up institutes for technology development and the products introduced have to be at the level of the 1990s in developed countries". Second, multinationals were required to sell most of their products internationally. The purpose of that requirement was to protect domestic companies. As only local companies could sell their products to customers in China, the result of these policies was to make joint ventures the main route for foreign companies to invest in China.

This policy has been very effective for international technology transfer. Here the large market provides effective leverage for technology transfer. A very interesting case concerns power plant equipment. For the construction of the Three Gorges Dam, in June 1996 the government explicitly required bids for the project to include foreign companies. For the left bank of the Three Gorges Dam, the winner of the first 12 out of 14 equipment contracts could be foreign companies, but Chinese companies had to be involved in the bidding and the building. A Chinese company had to be the main player in the last two equipment contracts. At the same time, foreign companies had to co-design and co-manufacture the equipment jointly with Chinese partners. If foreign companies did not agree to these terms, they would lose their chance to bid. This kind of special arrangement helped Chinese companies a lot. Through this way of learning, Harbin Electricity Power Station Equipment has now become the largest player in this business (Yu, 2007). The "market for technology" policy was stopped by China's entry into the WTO. After that, the foreign wholly owned firm became the main channel for multinationals to invest in China.

The issue of FDI spillovers through the establishment of joint ventures is very controversial in China. For example, in the automobile industry, the first mover was Volkswagen in the 1980s. Later on, Citroën, General Motors, Mazda, Nissan, Honda, Ford, Hyundai, Toyota and Suzuki all became key players in the Chinese market. Most of them engaged in joint ventures. In 2004, in the passenger car industry, local brand manufacturers produced about 2 million passenger cars in China, but only one tenth of them. These are quasi-private companies: Chery and Jeely. The rest are joint ventures with large TNCs throughout the world. The passenger car industry is therefore dominated by TNCs. Some observers have argued that there is little spillover from them to domestic firms. On the contrary, domestic companies have in their view been losing their innovation capability after entering into joint ventures with foreign companies (Lu & Feng, 2005). Firstly, as the foreign partner in the joint venture cannot have an equity share of more than 50 percent to control the new company, it would normally not open up much to the domestic partner in terms of technology transfer. Secondly, TNCs would care more about the contract than the market, so they would lack incentives to innovate in China. Those multinationals have usually used Chinese partners as their production base and no real technology has been transferred to the Chinese partner. The result is that local companies have made little progress in product innovation (Lu & Feng, 2005). Thirdly, the TNCs see importing core parts from their parent structure as a more cost-effective route to profit than Chinese production. Lastly, at the same time, market protection has sometimes given the local companies less incentive to innovate as they can enjoy high profits with no innovation.

Encouraging multinationals to set up R&D centres in China. With the new trend towards globalisation of R&D driven by multinationals seeking to localize their products and R&D, and to take advantage of the cheap R&D human resources available in China, the Chinese government, with the intention of getting the latest technology from foreign R&D facilities, adopted some special policies to attract multinationals to set up R&D centres in China. Up to now, there are no precise data about the number of R&D centres established by multinationals in China. According to von Zedtwitz (2006), there were 199 foreign R&D facilities in China at the beginning of 2004 (Figure 9.18). The number has increased rapidly since then and possibly amounts to 250-300 at present. Most of these R&D centres are located in large cities, such as Beijing and Shanghai.

Figure 9.18. *Number of new establishments of foreign R&D labs in China, 1987-2003*



Source: von Zedtwitz (2006).

But technology spillovers cannot easily be seen. More time is needed to observe the positive results. A recent study by the Office for Technology Transactions operating under the Commission for Science and Technology of Beijing shows that the spillover effect is very low. According to the study, from 2001 to 2006, about 94 percent of the technology sold by 52 multinationals having R&D centres in Beijing is bought by their headquarters and other subsidiaries or joint ventures of multinationals located in China. This means that the R&D system of multinationals in China is mainly a closed one, with little linkage with Chinese actors in the national and local innovation system (OTTB, 2007).

However, this result should be taken with caution. There may be other important ways in which spillover takes place that have not been discerned. Liu & Lundin (2006) have observed a great deal of cooperation between FDI companies and Chinese universities and PRIs, and have suggested some benefits of such cooperation (Table 9.25). They think that it will not only provide local universities and research institutes with additional funding and more advanced equipment, but, more importantly, it will also generate positive demonstration effects and spill-over to the universities and allow them to become better informed about the international research frontier.

Table 9.25. *Select list of research cooperation projects between domestic research institutes and multinationals in the biomedical industry*

Foreign company	Chinese partner	Details
GlaxoSmithKline	Shanghai Institutes of Materia Medica (SIMM)	Chemical compound database
Roche	Chinese National Human Genome Centre	Diabetes and schizophrenia
Novartis	Shanghai Institutes of Materia Medica (SIMM)	Herbal compounds, Chinese traditional medicine
AstraZeneca	Shanghai JiaoTong University	Gene linked to schizophrenia
DSM	Joint lab with Fudan University in Shanghai. JV with Chinese vitamin makers	Nutritional products activities
Novo Nordisk	Collaboration with Tsinghua University in Beijing	Diabetes

Source: Liu & Lundin (2006a).

Technology importing and “market for technology” policies, the most important technology policy is ***Chinese high-tech policy***. The main policy tool for high-tech industry is the National High-Tech R&D Programme (863 Programme), which is the largest national programme in China. It was launched in 1986 with the aim of tracking and catching up with the development of high technology in developed countries. The 863 Programme is divided into two parts: defence technology and civil technology. From 2001 to 2005, about 15 billion RMB was spent on civil technology (Table 9.26). From Table 9.27, it appears that this high-tech programme has performed well in terms of the output of patents and papers.

High-tech zones are another policy instrument for promoting high-tech industry in China. They are a mixed result of policy, institutional reform and government action. Zhongguancun was the first high-tech zone to be created and there are now 53 national high-tech zones in China. Their purpose is to establish efficiently functioning infrastructure to serve as a platform for innovation activities and interactions among universities, research institutes and firms. More specifically, high-tech zones have the following functions: to provide preferential treatment for high-tech firms in the form of a broad range of tax incentives; to create a new governance model, described by the watchword “small government, but big service”; to reduce transaction costs and to establish a cluster structure in order to promote active interactions and close cooperation among the firms.

In the past two decades, these high-tech zones have expanded rapidly in terms of their size and scope of activities and have therefore played an important role in promoting the development of the high-tech industry in China. In 2004, there are 53 National Science &Technology Industrial Parks (STIPs).In 2004, the total value added of all high-tech zones was 634 billion RMB, about 3.97 percent of GDP; high-tech companies in STIP accounted about 86.6 percent of high-tech industry value added(see table 9.28). Most of them are spin-offs from universities and PRIs, new private firms and FDI firms (MOST, 2006).

Table 9.26. *National S&T plans (100 Million US$)*

	2004	2001-2005
973 Basic Research	1.1	4.9
863 National High-Tech R&D Programme (from 1986)	4.6	18.3
Key Technologies R&D Programme (from 1983)	1.9	8.4
SME Innovation Fund	1.0	4.6
Torch Programme (1988, for high technology)	0.1	0.1
Spark Programme (1988, for rural SMEs)	0.1	0.1

Source: MOST, 2006b, Annual report on the state programmes of science and technology development, 2005.

Table 9.27. *Some indicators of achievement of the 863 Programme*

	1999	2000	2002	2003	2004	2005
Patents granted	108	286	245	1249	2173	3106
Patented inventions	67	180	141	745	1422	2252
Number of papers published in Chinese	6828	12329	9533	26832	29467	34462
Number of papers published in English	1629	3005	2056	6699	7590	9830
Number of new products or production processes	357	868	1105		3455	9328
Items of technology transferred	107	779	264		2009	3359

Sources: MOST, 2006c, Chinese science and technology statistics, 2006. http://www.sts.org.cn/.

Table 9.28. *The share of high-tech industry in GDP and manufacturing industry*

	1998	2001	2002	2003	2004	2005
Share of high-tech industry value added in GDP (percent)	2.12	2.82	3.13	3.71	3.97	4.44
Share of high-tech industry value added in all manufacturing value added (percent)	8.1	9.5	9.9	10.5	10.9	-
Share of high-tech industry value added in STIPs (percent)	59.4	70.1	71.7	84.7	87.2	86.6

Sources: MOST, 2006c, Chinese science and technology statistics, 2006. http://www.sts.org.cn/.

Special industrial policy. To foster strategic industries and Chinese local companies, some policies have been implemented, including subsidies to R&D labs in big companies. Under this policy, about 512 large companies were selected to enjoy special support. Among them, more than two hundred companies were chosen as leading innovative companies to be given direct support under the National Programme 2006-2020 for the Development of Science and Technology in the medium and long term implemented in 2007.

In 2000, a special policy was adopted for the integrated circuit and software industry in China, because integrated circuits and software are assumed to be the key sectors of the information industry and deserve a special policy to promote them. The main policy tool is tax abatement for businesses. The result of this policy is very interesting. While most foreign companies criticise the policy for giving too strong support to local companies as against foreign companies, many local companies also criticize the policy on the ground that they derive less benefit from it than foreign companies.

Innovation policy in China was born to break down the barrier between R&D outputs and their commercial application. The planned economy gave PRIs and universities the freedom to do their research without caring much about its application. The traditional system is closer to the linear model of innovation. The market-oriented policy pressed the S&T system to operate around economic needs. A variety of innovation policies have since then been brought forward.

Spin-off policy. In order to speed up the process from research to commercial products, in the 1980s the government encouraged PRIs and universities to set up their own spin-offs and scientists to leave their research position to engage in commercial activities. Although the size of the spin-off business in China was small compared to that of Chinese industry (Table 9.29), it was valuable for the high-tech industry in China. Spin-off companies gave many scientists in universities or PRIs good opportunities to access market knowledge.

Table 9.29. *Spin-offs from universities*

	Number of spin-offs	Revenue (One billion US$)	Profit One billion US$)
1999	2137	3.23	0.27
2000	2097	4.46	0.42
2001	1993	5.42	0.38
2002	2216	6.51	0.30
2003	2447	8.07	0.34
2004	2355	9.75	0.50

Sources: Statistics on university-based industry in 2004 in China,
Centre for S&T for Development, Ministry of Education, 2005.

The result of the spin-offs policy is that it gave birth to many dynamic domestic high-tech companies, such as Lenovo, spun off from the Chinese Academy of Sciences, or Beida Founder, from Peking University. Most biotech companies are also the result of spin-offs. But the policy gradually faced many challenges. For example, spin-off companies are not well regulated for producing further innovation. In addition, the conflict between profit-seeking and the public goal of universities put the universities and PRIs in a more risky position. To cope with this awkward situation, a new policy was implemented that separates the business from the university, leaving universities only as shareholders. At the same time, from the end of the last century, as the government has continuously stepped up its support for research and education, the universities stopped thinking of setting up and developing spin-off companies as their primary function. The same applies to the PRIs.

Industry-science linkages policy. As there was a functional division of labour in knowledge creation and diffusion for many years in China, a strong barrier existed between knowledge creation in PRIs and universities and the use of knowledge in enterprises. But since the introduction of market mechanisms in China and the stronger pressures from competition, industry-academic linkages have improved greatly in the last 20 years. Firstly, universities and PRIs were allowed to set up their own spin-offs so that they could commercialize their technology directly. In this way, universities and PRIs would be more integrated in China's process of economic growth. Secondly, spin-off companies served also as a way for PRIs and universities to compensate for the operating budget cuts that the government had been making since the 1980s.

At the same time, universities and PRIs began to do more contract research for industry. This benefits industry, as most companies, especially SMEs, have limited R&D capabilities and outsourcing of research to universities is thus a strategic component of their development. As a result of this, from 2000 to 2004 the share of universities' budgets coming from industry increased; it was about 38 percent of their total research funds in 2004 (Table 9.30). In 2004, about 26 percent of industry's total R&D expenditure went to the universities (Table 9.31).

Joint publishing of scientific papers between university and industry is an alternative indicator of industry-academic linkage. For IPR and other reasons, industry is reluctant to publish papers. But from Table 9.32, it is clear that universities are increasingly willing to have industry engineers as their co-authors for joint publishing.

Table 9.30. *Share of universities' research funding from industry*

		1999	2000	2001	2002	2003	2004
Total S&T funds (One billion US$)		1.25	2.02	2.42	3.00	3.72	4.74
From firms		0.67	0.87	1.09	1.37	1.80	14.9
	Share (percent)	52.2	33.3	36.2	36.2	36.7	38.0
From government		0.59	1.17	1.33	1.66	1.99	2.55
	Share (percent)	47.8	58.4	54.9	55.4	53.6	53.8

Source: MOE, 2006, Statistics on Science and Technology in Higher Education, 2000-2005, Department of S&T, Ministry of Education.

Table 9.31. *R&D outsourcing to universities and R&D institutes from large and medium-sized industrial enterprises*

	2000	2001	2002	2003	2004
Total R&D expenditure (One billion US$)	4.29	5.35	6.77	8.71	11.53
Funds for universities (One billion US$)	0.67	0.87	1.09	1.35	3.01
Share of total businesses' R&D (percent)	15.5	16.2	16.1	15.5	26.1
Funds for R&D institutes (One billion US$)	3.8	2.5	3.6	4.7	5.0
Share of total businesses' R&D (percent)	10.7	5.6	6.4	6.5	5.2
Total outsourcing to domestic university and R&D institute (percent)	0.46	0.30	0.43	0.57	0.60

Source: MOST, 2006c, China Science and Technology Statistical Yearbook, 2005. Beijing: Chinese Statistical Press.

Table 9.32. *Papers co-authored by industry and universities, 2000-2003, (number and percentage share)*

First/second author	2000		2001		2002		2003	
	Papers	*Share*	*Papers*	*Share*	*Papers*	*Share*	*Papers*	*Share*
Total	51,079	100	53,246	100	87,688	100	100,310	100
Industry/university	4,499	8.81	1,123	2.11	1,381	1.57	1,567	1.56
University/industry	867	1.7	5,301	9.96	6,448	7.35	7,421	7.39

Source: Chinese Institute of Information, China Science Paper and Citation Analysis, 2005.

Indigenous innovation. The National Programme 2006-2020 for the Development of Science and Technology in the medium and long term is China's current long-term innovation policy framework. The most interesting element of the new plan is the declared intention to strengthen "independent" or "indigenous" innovation. The essence of the policy is to strengthen the innovation capability in domestic companies. The main routes to indigenous innovation are: original innovation based on basic research, integrative innovation and second innovation.

There are three different factors behind this decision to push for indigenous innovation. First, China's economic growth has been strongly dependent on foreign technology and FDI. Since 2000, foreign-invested enterprises have accounted for more than 85 percent of all high-tech exports (NBS, 2006). But it is commonly believed that the "market for technology" policy has not resulted in the immediate and automatic knowledge and technology spillovers from FDI that policymakers had hoped for. Second, a culture of imitation and copying is common not only in product development and design, but also in the field of scientific research. Hence, innovations based on domestic knowledge and intellectual property rights are strongly needed in China. Third, the Chinese economy's high growth rate path of the last twenty years will not be sustainable without a dramatic change over the next twenty years. The government has adopted a new nationwide strategy called "Scientific development". In future, China will use more energy-efficient and environment-friendly technologies, new management skills and new organizational practices to ensure sustainable growth.

There are three main policies selected to implement the indigenous innovation strategy. Firstly, the government plans to increase R&D by 2020 to 2.5 percent of GDP (from the current level of 1.3 percent in 2005). Since GDP growth is projected to increase at a similar pace, boosting R&D expenditure as a share of GDP requires a faster increase in absolute terms. Already today, China has the third largest expenditure on R&D in terms of purchasing power parity, trailing only the US and Japan (Serger & Breidne, 2006). Secondly, fiscal policy to activate innovation capability at the company level is assumed to be the most important tool. The new tax policy will make company R&D expenditure 150 percent tax deductible, thus effectively constituting a net subsidy, as well as allowing accelerated depreciation for R&D equipment worth up to 300 000 RMB. Thirdly, public procurement of technology will be widely used. This policy is the result of learning from the United States' and Korea's best practices.

The aim of current public procurement practice is to cut costs rather than promote indigenous innovation. Under the new policy, government agencies have to prioritize innovative Chinese companies by procuring their goods or services even if these are not as good or as cheap as those of other companies (both Chinese and foreign). The main points of the new public procurement policy are: Giving priority to indigenous innovative products in public procurement, China will establish a system of procurement of innovative products on the current finance base, including a certification of what is an innovative product, and will give priority to innovative products in the procurement list;

In the purchasing process, domestic products have priority over foreign products. Only those products that are not available in China can be purchased from abroad. More than 30 percent of technology and equipment purchasing should go to domestic equipment if using public money. As for key national projects using government money, domestic equipment purchase should be not less than 60 percent of total value. For purchasing products of foreign companies, those companies that are willing to transfer technology to local companies and let them assimilate it will be given priority listing over other candidates;

Establishing a system of procurement of innovation means that the government should purchase the first vintage of innovation products created by domestic enterprises or research institutions if the innovative products have proven to have big potential markets. This gives government the scope to purchase R&D projects for commercial purposes; Giving indigenous innovative products have some price advantage when it comes to procurement. In price-based bidding, even if the price of indigenous innovative products is higher than that of other products, their price can be reduced in the real bidding. If the price of the indigenous products is not higher than other products, they will be selected — assuming that the quality is appropriate and comparable to the foreign products.

In its innovation policy, the Chinese government is trying to balance the supply side with the demand side. Recent policy such as public procurement of technology is a strong demand-side policy. But overall, demand-side policy is weak compared to supply-side policy. In China, the government controls large amounts of resources and so prefers to use supply-side rather than demand-side policies.

9.6 Conclusions on performance of innovation system of China

Similar to the Chinese economy, great changes have also taken place in the Chinese innovation system during the past twenty years. The innovation system has become dynamic with great potentials. The structural adjustments in various forms have made enterprises the core of the national innovation system. In the industrial sector, SOEs have undergone reforms of governance. Many large non-state-owned enterprises have emerged, such as Huawei, Lenovo and Haier, who are not only the driving force for innovation capacity building in the Chinese market, but are also on the way to entering the global market. SMEs have also become more important players in the Chinese economy as well as in the innovation domain, driven by competition and entrepreneurial spirit. The increased openness of the innovation system, spurred by FDI in both high-tech manufacturing and purely R&D-oriented activities has also created significant incentives for structural changes and generated mutual learning opportunities among domestic and foreign enterprises.

Innovation capability of enterprise is increasing. We use the number of patent granted in USA as indicators of innovation performance. Table 9.33 shows how quickly China narrowed the gap with Korea and Japan after 2005. This shows that innovation capability of Chinese company is increasing after the implementation of the indigenous policy (as show table 9.33). But in most of industry, Chinese enterprises are still in the low vale chain and play as world plant. Lot of key technology are imported or licensed from companies in developed countries. In the same time, the production in China also met serious problem of high consumption of resources and high pollution. So, it takes long time for Chinese enterprises to be as international industry leaders.

Research capabilities of university and government research institutes are increasing. Publications and citations are one way of measuring a nation's scientific output. Since the 1990s, the number of papers published by Chinese researchers both in English and in Chinese has been rapidly increasing. In terms of the SCI, China is already the fifth country in the world (Table 9.34). There are several reasons for this rapid growth: First, since 1978, the government has been promoting science and technology in various ways. The size of Chinese R&D is increasing in terms of both grants and human resources. Universities are expanding. China now employs the largest number of human resources in R&D in the world with more than 35 million people in the S&T system. Second, many universities and research institutions have introduced new incentives to promote publishing. Third, the open door policy is also contributing to progress in science. The most important means is international collaboration. From Table 9.35, it can be seen that Chinese researchers published four times more joint papers in 2003 than in 1996. Among the countries concerned, the US is the largest partner country engaged in joint research with China. Although the overall quality of publications is not high, it has been increasing, as measured through citations, especially in some emerging fields such as nanotechnology.

Challenges of NIS of China. Although China has some progress in the innovation system and innovation capacity building, the Chinese innovation system is still weak in terms of innovation capacity and innovation activities are mostly focused on incremental innovations. In addition, because of low indigenous innovation capacity and technological gaps, the cross-sector and cross-ownership spillovers are still limited. Hence PRIs and universities are still very important in R&D activities as well as in terms of R&D human resources. Furthermore, the specific Chinese characteristics such as the need for continuing structural reforms, the changing role played by the government, as well as the tension between indigenous capacity building and increased openness of the Chinese economy are serious challenges for future development of NIS.

There are at least, three important aspects that need to be taken into serious considerations. For the first, from the planned- to the market-driven system, the government will still have strong influence on the emerging innovation system through various policies, strategies and investments. However, the role played by the government in this process will be more like a conduit than a planner. In other words, the role played by the government is not only to provide financial incentives, but also to create an innovation-friendly environment. Secondly, while the importance of enterprises is increasing, there is still a strong need for strengthening the higher education sector and human resources. The balance between the short-run leapfrogging and the long-run strategic capacity building is crucial for the future development of the NIS in China. Finally, knowledge and technology diffusion through commercialization and industrialization of S&T/R&D results remain a key challenge as the barriers in such processes are associated with both inadequate innovation capacity and insufficient market opening mechanisms.

In such contexts, there are two major forces that will jointly shape the future development of the Chinese innovation system: One is the national strategy of indigenous innovation, which focuses on how to promote domestic innovation capability building. The second is an open innovation approach, which is based on knowledge creation and technology acquisition through global linkages and partnership.

Table 9.33. *Patents granted in USA of China, Japan Korea and Taiwan (Piece)*

Year	China	Japan	Korea	Taiwan
1995	91	23139	1265	2142
1996	78	24355	1603	2477
1997	103	24498	2027	2678
1998	133	32543	3427	3911
1999	172	32928	3741	4664
2000	274	33387	3560	5976
2001	472	35417	3849	6685
2002	626	36860	4100	6883
2003	724	37744	4246	6846
2004	951	37568	4769	7435
2005	963	32243	4696	6172
2006	1621	39954	6634	8241
2007	1827	36452	7465	7759
2008	2653	37250	8924	8126

Source: Online database of United States patent and trademark office.www.patft.uspto.gov

Table 9.34. *Percentage of world share of scientific publications*

	China	France	Germany	Japan	Korea	UK	US	EU-15
1995	2.05	6.09	7.62	8.65	0.79	8.88	33.54	34.36
1998	2.90	6.48	8.82	9.42	1.41	9.08	31.63	36.85
2001	4.30	6.33	8.68	9.52	2.01	8.90	31.01	36.55
2004	6.52	5.84	8.14	8.84	2.70	8.33	30.48	35.18

Source: Adapted from P. Zhou and L. Leydesdorff, The emergence of China as a leading nation in science, Research Policy 35, No 1 (Feb 2006).

Table 9.35. *International joint papers by Chinese researchers*

	1996	1999	2002	2003
Number of total papers	15 218	23 174	33 867	59 543
Number of joint papers	4 489	7 413	10 840	17 751
With US	1 364	2 104	3 267	5 791
EU	1 320	2 068	2 881	4 568
UK	430	646	895	1 561
Germany	429	615	949	1 381
France	213	294	441	827
Canada	294	402	566	1 109
Australia	180	353	593	974
Japan	530	945	1 461	2 222
Singapore	75	204	359	726
Korea	108	177	342	646

Source: Evidence Ltd, Patterns of International Collaboration:
China’s growing research collaboration (Leeds: Evidence Ltd, Dec 2006).

9.7 References

Archibugi. D. and B.Å. Lundvall. eds. 2001. *The Globalizing Learning Economy: Major Socio-Economic Trends and European Innovation Policy*. Oxford: Oxford University Press.

Bernal. D.J. 1939. *The Social Function of Science*. London: George Routledge.

Bush. V. 1945. *Science: The endless frontier*. Washington: United States Government Printing Office.

Chinese Institute of Information 2005. *China Science Paper and Citation Analysis*

COMMISSION of SandT 1986. Guideline of Chinese SandT policy. Beijing: SandT Literature Publishing House.

Edquist. C. 2005. *System of Innovation. Perspectives and Challenges*. in Fagerberg. J.. Mowery. D.. Nelson. R. edits. Oxford Handbook of Innovation. Oxford. Oxford University Press.

EVIDENCE LTD 2006. Patterns of International Collaboration: China's growing research collaboration. Leeds: Evidence Ltd. Dec 2006.

FIAS 2005 South multinationals: A growing phenomenon. FIAS. Washington. <rru.worldbank.org/PapersLinks/Open.aspx?id=6686>

Freeman. C. 1987. Technology policy and economic performance: lessons from Japan. London: Pinter.

HU ZHIJIAN 2005. Research of the Chinese Concept of basic research: creating a free space for it? PhD Thesis. Graduate University of Chinese Academy of Sciences.

IBM Global Bussiness Service 2006. Going global: prospects and challenges for Chinese companies on the world stage. IBM Institutes for Business value. New York.

Jefferson. Gary H.2004 . RandD and Innovation in China: Has China Begun Its SandT Takeoff? Prepared for the Harvard China Review.

Kazuyuki Motohashi; Xiao Yun. 2007. China's Innovation System Reform and Growing Industry and Science Linkages. Research Policy. 36:1251-1260.

Kostoff. R.N.. Stump. J.A. et. al. 2006. The structure and infrastructure of the global nanotechnology. In: Journal of Nanoparticle Research 2006 8: 301–321.

Lazonick. W. 2006. The innovative firm. in Fagerberg J.. Mowery. D. and R. Nelson eds. The Oxford Handbook of Innovation. Oxford: Oxford University Press.

List. F. The National System of Political Economy□Translated by Sampson S.Lloyd□London: Longmans Green Press .1928.

Liu. X. and Lundin. N. 2006. Globalisation of biomedical industry and the system of innovation in China. Stockholm: SNS report.

LIU. X. and WHITE. S. 2001. Comparing innovation systems: a framework and application to China's transitional context. J. Research Policy 30.

LIU. X. 2008. Globalization. Catch-up and Innovation. Beijing: Chinese Science Press.

LIU. X. et al. 2006. Chinese Report on Regional Innovation Capability in Chinese. Beijing: Chinese Science Press.

Liu. X. L. and Lundin. N. 2006. China's development model: an alternative strategy for technological catch-up. mimeo.

Liu. X.L. and Zhang. H.S.2002. Knowledge intensity and SOE's performance in China. in B.Grewal and Lan Xue et al edits. China's Future in the Knowledge Economy. Centre for Strategic Economic Studies. Victoria University and Tsinghua University Press. Melbourne and Beijing. pp.164-177.

LU. F. and FENG. K. 2005. The Policy Choice of Developing Indigenous IPR Chinese Automobile Industry. Beijing: Peking University Press.

Lu. F. and Feng. K. D. 2005. The Policy Choice of Developing Indigenous IPR Chinese Automobile Industry. Beijing. Peking University Press.

Lundin. N. Sjöholm. F.. Qian. J.C. and He. P. 2006a.The Role of Small Enterprises in China's Technological Development. Working Paper No. 695. at Research Institute of Industrial Economics RIIE.

Lundvall. B. A. ed.1992. National Systems of innovation: towards a theory of innovation and interactive learning. London: Pinter.

Lundvall. B.-Å.. Johnson. B. The Learning Economy. Journal of Industry Studies. 1994. 1 2: 23-42.

Lundvall. B.-Å.; Borras. S. The Globalising Learning Economy: Implications for Innovation Policy. Brussels. DG XII. 1999.

Lundvall.B-A. Intarakumnerd. P. Vang. Jan.2006. Asia's Innovation System in Transition. Edward.Elgar. Cheltenham. UK.

Mani.Sunil2002.Government. Innovation and Technology Policy. Cheltenham: Edward Elgar.

Miller. Tom 2006. Still more 'D' than 'R'. in China Economic Quarterly. Vol.10 nr.3. p.30.

Ministry of Commerce of the People's Republic of China MOC. 2006. China's overseas investment in 2005 hits new high.

Ministry of Education MOC. Statistics of Science and Technology in High Education. 2000-2005.

Ministry of Education. MOC.2005. Statistics of University's Industry in 2004 in China.

Ministry of Education. Center for SandT for Development. Statistics of University's Industry in 2004 in China. 2005.

Ministry of Education□Statistics of Science and Technology in High Education. 2000-2005.

Ministry of Science and Technology MOST 2005. The Yellow Book on Science and Technology Vol.7: China Science and Technology Indicators 2004. Beijing: Scientific and Technical Documents Publishing House.

Ministry of Science and Technology MOST 2006. China Science and Technology Development Report. Beijing: Chinese S&T Literature Press.

MOE Ministry of Education 2005. Statistics on Science and Technology in Higher Education. Department of S&T.

MOST 2005. Annual Report on the State Programmes of Science and Technology Development.

MOST 2006. China Science and Technology Development Report: 2006. Chinese S&T Literature Press.

MOST 2007. Chinese science and technology statistics. http://www.sts.org.cn/.MOST Ministry of Science and Technology 2005. The Yellow Book on Science and Technology. Vol. 7: China Science and Technology Indicators 2004. Beijing: Scientific and Technical Documents Publishing House.

MOST and NBS 2006. China Statistical Yearbook on high-tech technology industry: 2006. Chinese Statistical Press.

MOST. Main S&T Indicators Database. 2008.

MOST. China Science and Technology Indicator. 2007. Beijing: Press of S&T Literature 2008

Motohashi. K.. and Yun. Xiao2007 China’s innovation system reform and growing industry and science linkages. Research Policy. 361251-1260.

Mowery. D. C. and Sampat. B. N. 2006. Universities in national innovation systems. in Fagerberg J..

Mowery. D. and R. Nelson eds. The Oxford Handbook of Innovation. Oxford: Oxford University Press.

Mu. Q. and Lee. K. 2005. Knowledge diffusion. market segmentation and technological catch-up: the case of the telecommunication industry in China. Research Policy. No.34. pp.759-783.

National Bureau of Statistics NBS 2004. China Statistical Yearbook on high technology industry. 2004. China Statistical Press. Beijing.

National Bureau of Statistics NBS 2005. China Statistical Yearbook on Science and technology. 2005. China Statistical Press. Beijing.

National Bureau of Statistics NBS 2006. China Statistical Yearbook on Science and technology 2006. China Statistical Press. Beijing.

National Bureau of Statistics and MOST. China Statistical Tearbook of Science and Technology. 2007. Beijing: China Statistic Press 2007.

National Bureau of Statistics China Statistical Yearbook. 2007. Beijing: China Statistic Press 2008.

National Research Center of Education Development. 2005. Research report of China's education system .2005; http://www.china.com.cn/zhuanti2005/node_5158231.htm

NDRC 1994. Industrial Policy of Automobile Industry. www.sdpc.gov.cn.

Nelson. R.R. ed.1993. National Systems of Innovation: A Comparative Study. Oxford: oxford University Press.

OECD 1982. Innovation Policy. Paris: OECD.

OECD 1999. Managing National Innovation Systems. Paris: OECD.

OECD 2005. OECD Science. Technology and Industry Scoreboard 2005. OECD. Paris.

OECD 2006. OECD Science. Technology and Industry Outlook 2006. OECD. Paris.

OECD2008. OECD Reviews Innovation Policy: China. OECD. Paris. Forthcoming.

OECD. Science.Technology and Industry's Scoreboard. 2007. Paris.

Okimoto. D.I.. Between MITI and the Market. Stanford: Stanford University Press. 1989.

OTTB Office for Technology Transactions of Beijing 2007. The status quo impact and policy implication of technology transfer of RandD centers of multinationals in Beijing working report. 2007. 6.

RIP. A. and MEULEN van der 1997. The post-modern research system. In: Barre. Gibbons. Maddox. Martin. Papon eds. Science in Tomorrow's Europe. Editions Economica. Paris. pp. 51-69.

ROTHWELL. R. and ZEGVELD. W. 1982. Innovation in the small and medium-sized firm. London: Frances Pinter.

Schaaper. M. 2005 An Emerging knowledge-based economy in China? Indicators from OECD databases. STI working paper 2004/4. OECD. Paris.

SERGER. S. and MAGNUS. B. 2006. China's 15-year plan for science and technology — a critical assessment. Conference paper for New Asian Dynamics in Science. Technology and Innovation. Gilleleje. Denmark 27-29 September. 2006.

Sigurdson. Jon. Jiang. Jiang. Kong. Xinxin 2005. Technological Superpower China. Edward.Elgar. Cheltenham. UK.

State Council 2006. Some Complementary Policy for National Long and Middle –Range SandT Programming for 2006-2020. Feb.27. 2006.

The Boston Consulting Group 2006 China's global challengers: the strategic implications of Chinese outbound MandA.. BCG report. May 2006.

UNCTAD 2006. World Investment Report 2006 – FDI from Developing and Transitional Economies: Implication for Development. United Nations Conference on Trade and Development.

von Zedtwitz. M. 2006. Chinese multinationals: new contenders in global RandD. Conference presentation. http://goingglobal2006.vtt.fi/programme.htm.

WANG. Z. et al. 2000. A historical retrospect of technology import of Chinese machinery industry. In: Journal of Dialectics of Nature 1.

World Bank 1993 The East Asian Miracle: Economic Growth and Public Policy. New York: Oxford University Press.

World Intellectual Property OrganizationWIPO. WIPO Patent Report. 2007.2008.

Wu. F. 2005 The globalization of Corporate China. NBR analysis. Vol. 16. No.2.

YU. B. et al. 2007. Pattern of Indigenous Innovation: the Case of HPEC[R]. NSFC.

Z. Xiwei; Y. Xiangdong. Science and Technology Policy Reform and Its Impact on China's National Innovation System. Technology in Society. 2007. 29:317-325 .

ZHOU. P. and LEYDESDORFF. L. 2006. The emergence of China as a leading nation in science. In: Research Policy. 35. No 1 Feb 2006.

Zhu Zuoyan; Gong Xu. Basic Research: Its Impact on China's Future. Technology in Society. 2008. 30: 293-298.

Chapter 10: India

Balaji Parthasarathy and V. Ranganathan, International Institute of Information Technology (IIT-B)

10.1 Introduction

India offers a contrasting picture to the world. As the second most populous country, with the fourth largest economy in PPP terms in 2008, that is growing rapidly, it is a potentially vast market (see Table 10.1 for more data on the size of the Indian economy). Similarly, with a large number of engineers, the country offers opportunities as a site for production and innovation.[12] Thus, for instance, in a survey of 500 executives worldwide, about the attractiveness of various countries for foreign direct investment (FDI) India was the leading choice for access to highly skilled labour, new outsourcing opportunities, and research and development (R&D) activities. As table 10.2 shows, more than 29 percent of respondents to a survey by the World Investment Report (WIR) 2005 also identified India as the third most attractive R&D location, after China and the US (UNCTAD, 2005). In another global survey of 300 senior executives in November 2006, India was again the leading choice (26 percent) when respondents were asked to name the country they would choose as the best overall overseas location for R&D (EIU, 2007b).

Yet, such perceptions have not always translated into reality, reflecting another side to India. Despite the size of the economy, in 2008 the GDP per capita was 2,721 in constant 2005 PPP$. This, according to the World Development Indicators (WDI), placed India 120th out of the 170 countries, 72 percent below the global mean of $9,602. In addition in 2004-05, three fourth of the population lived on less than $2 a day, while 37 percent of the adult population was illiterate in 2006. Nor does India score highly on innovation indicators. The WIR 2005 ranked India 66 out of 117 on its Technological Activity Index (computed on the basis of R&D manpower, patents in the US, and articles in scientific journals). India's position was expected to only improve to 56 in the period 2007-12. India's relative position is not very different in the Global Competitive Index computed by the World Economic Forum. Even as India moved up two spots, from 46 to 44, between 2005-06 and 2009-10, among 114 countries, its rank slipped from 26 to 30 in the component that evaluates the potential to generate endogenous innovation (Geiger and Rao, 2009:9).

Table 10.1. *National income (in billions of constant 2000 US$ and per capita)*

	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008
GDP	157.6	270.5	460.2	484.2	502.4	544.5	589.6	644.7	707.0	771.1	817.9
Value-added[a]	145.1	244.9	421.4	445.9	463.0	502.4	539.8	591.3	648.9	707.4	754.8
GDP per capita	229	318	453	469	479	512	546	589	637	686	718

[12] The annual output of graduates with a Bachelor's degree in engineering grew from 247 at the time of independence in 1947 to 237,000 in 2006 (Banerjee and Muley 2008:9). The figure for the US in 2006 was 104,200 (*ibid.*:31). According to Altbach (2005), India's higher education system is the third largest in the world, when measured by number of students, only behind China and the US.

GDP per worker[b]	2,638	3,531	5,061	5,226	5,295	5,607	5,879	6,276	6,714	7,124	7,445

Note: (a) gross value added at factor cost; (b) in Purchasing Power Parities
Source: World Development Indicators

Table 10.2. *Most attractive target areas for FDI (responses of 500 senior executives, (percent)*

Criteria	China	Euro area	Japan	Russia	USA	UK	India	New EU entrants	Brazil
New consumer markets	49	9	2	5	7	2	9	15	4
Low-cost Labor	50	2	0	3	1	0	29	12	3
New partnership possibilities	20	22	5	5	14	4	12	14	3
New corporate markets	23	22	3	5	17	3	7	15	4
Access to skilled labor	6	22	7	3	14	6	30	10	2
New opportunities in outsourcing	16	9	1	3	7	2	46	12	4
Acquisition opportunities	15	20	2	5	13	5	8	22	9
R&D activities	11	20	5	4	22	7	24	6	3
Greater efficiency in supply chain	17	26	6	2	22	5	10	9	3

Source: EIU (1994:11)

Table 10.3. *FDI flows to and from India*

	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008
Inward flows[a]	79	237	3,585	5,472	5,627	4,323	5,771	7,606	20,336	25,127	41,554
Global share[b]	0.15	0.11	0.26	0.67	0.89	0.76	0.79	0.78	1.4	1.3	2.5
Outward flows [a]	4	6	509	1,397	1,679	1,879	2,179	2,978	14,344	17,281	17,685
Global share[b]	0.01	0.00	0.04	0.19	0.31	0.33	0.23	0.34	1.03	0.81	0.95

Note: (a) In millions of current US$ prices and at current exchange rates;
(b) Global share is percentage of total world flows.
Source: UNCTAD Handbook of Statistics 2009

The macro-economic contrast is mirrored at a sectoral level. For instance, the country enjoyed a green revolution which, since the 1970s, has enabled it to grow enough food for itself. Again, for a country that was once dismissed as a mere exporter of "communicable disease",[13] by 2008, it had the world's third largest pharmaceutical industry in volume terms (and 14th by value) (Department of Pharmaceuticals, 2009), and was the largest exporter of software services (Parthasarathy, forthcoming). But pockets of productivity, especially in services, co-exist with an informal sector, which employed 89 percent of the workforce in 2000 (Dutz, 2007:187).[14] While 99 percent of employment in agriculture (which employed 61 percent of the workforce) was informal, it was 80 percent in manufacturing and 31 percent in services. The varying incidence of informality in these economic sectors is reflected in labor productivity figures (Table 10.4). Consequently, total factor productivity (TFP) in South Asia in 2005 was barely 6 percent of what it was in the US (World Bank, 2008:54).

This chapter will explain these contrasts in terms of a changing policy environment. After independence, India adopted an autarkic public sector enterprise (PSE) led import substitution led industrialization (ISI) developmental model. While the policy environment managed to create capabilities and competencies in a few sectors, as Section 2 will describe, internal and external barriers to the flow of ideas and resources ensured that the country was relatively poor, illiterate and isolated. But private initiative, trade and foreign investment, and innovation drove a change in policy direction since the 1980s has emphasized that economic growth. Thus, as India becomes more integrated with the world economy (see Table 10.5 for data on growing trade), Section 3 will provide more evidence of how its potential and opportunities are becoming attractive. The policy shift notwithstanding, the legacy of the past is still in evidence. Ironically, in what is likely to soon be the most populous country, it is most evident as a shortage of hands. Section 4 will describe why the lack of widespread access to quality education has resulted in an acute skills shortage. Section 5 will describe recent efforts to broaden our understanding of the innovation system by examining institutional initiatives to embrace the hitherto ignored informal sector. 'Inclusive innovation' (Dutz, 2007) initiatives attempt to learn from the informal sector and to partner it to generate innovation. The chapter will conclude by discussing the predicament of India's historically specific system of innovation and the options for linking it to global innovation networks.

Table 10.4: *Changes in Labor Productivity relative to Agriculture, by economic sector*

Sector	1983	1988	1995	2000
Agriculture and allied activities	100	100	100	100
Mining and quarrying	615	641	628	971
Manufacturing	243	272	293	352
Electricity, gas, and water	912	1,101	1,186	1,797
Construction	367	253	294	258

[13] Soon after then Indian Prime Minister Indira Gandhi imposed a national emergency and suspended many political freedoms on 24 June 1975, former US ambassador to India Daniel Patrick Moynihan said, "When India ceased to be a democracy, our actual interest there just plummeted. I mean, what does it export but communicable disease?" See: http://www.indianexpress.com/oldStory/20981/

[14] The unorganized (or informal) sector consists of all private enterprises that operate on a proprietary or partnership basis with less than ten workers (NCEUS, 2009:3). Workers in the sector workers suffer from seasonality of employment, the absence of a formal employer-employee relationship and lack social security protection.

Trade, hotels, and restaurants	312	319	311	321
Transport, storage, and communications	376	424	411	453
Financial, insurance, and real estate businesses	1,673	1,825	2,211	2,276
Personal, business, and community services	221	261	231	358

Source: Dutz (2007:26)

Table 10.5. *Trade and the Indian economy (*billions of constant 2000 US$, indices and percentage)

	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008
Imports of goods and services	10.8	19.4	65.1	67.3	74.3	86.8	100.7	146.6	182.6	198.2	233.6
Volume index[a]	..	..	100.0	101.4	105.8	130.4	143.4	223.8	274.7	325.5	289.3
Percent of GDP)	9	9	14.2	13.7	15.5	16.1	19.9	22.7	25.2	24.7	28.0
Exports of goods and services	11.4	19.0	60.9	64.3	78.4	82.9	106.3	122.0	145.0	155.8	175.8
Volume index[a]	..	..	100.0	108.5	129.4	133.9	155.5	180.4	207.9	209.8	232.2
Percent of GDP	6.0	7.0	13.2	12.8	14.5	14.8	18.1	19.9	22.2	21.2	22.7

Note: (a) 2000 = 100
Source: World Development Indicators

10.2 The post-independence system of innovation

Despite a long scientific tradition and a history of technological achievements, at the time of its independence India’s infrastructure for science and technology (S&T) was limited to a few universities, and laboratories of the Council for Scientific and Industrial Research (CSIR) which was founded in 1942 (Tyabji, 2000). After independence, under the first Prime Minister Jawaharlal Nehru, policy making was influenced by the premise that, “….in an underdeveloped country like India, science must be made the handmaiden of economic progress, with scientists devoting their work to augmenting productivity and ending poverty” (Guha, 2007: 215). An early manifestation of this influence was the Scientific Policy Resolution of 1958 "to foster, promote and sustain the cultivation of sciences and scientific research in the country and to secure for the people all the benefits that can accrue from the acquisition and application of scientific knowledge."[15]

Since then, the state, especially the central government, has led S&T spending, as Table 10.6 shows. This spending is supported by an institutional structure in which are prominent the Defense Research and Development Organization (under the Ministry of Defense), the Department of Atomic Energy, the Department of Space, the Indian Council for Agricultural Research (under the Ministry of Agriculture), and the Ministry of Science and Technology (Table 10.7). This ministry houses the Department of Science and Technology (DST), which organizes, coordinates and promotes S&T activity in the country, the Department of Scientific and Industrial Research (DSIR), which oversees the 37 laboratories of the CSIR and promotes technology development and its utilization, and the Department of Biotechnology. Although other ministries, such as the Ministry of Information and Communication Technologies, also undertake S&T work, their budgets are relatively small.

[15] See http://www.dst.gov.in/stsysindia/spr1958.htm for the full text of the Resolution.

Despite the investments and the creation of an institutional structure, the pay-offs have arguably been limited. The notable exceptions were the green revolution, which, after the droughts in 1966 and 1967, has allowed the country grew enough food to feed itself, and the creation of capabilities and competencies in the space and atomic energy programs that few countries can match. As the latter two programs are considered to be of strategic importance, they not only benefit from significant shares of R&D spending (Table 10.7), but also from being directly under the Prime Minister's Office. By contrast, the Ministry of Science and Technology is under an independent Minister of State.

The limited payoff can be understood in against the backdrop of the broader economic environment in which S&T policy operated.[16] After independence, the state was assigned a central role in coordinating the development process and it spelt out its priorities in Five-year plans, the first of which was launched in 1951. In 1956, an Industrial Policy Resolution was announced and it grouped industry into three categories: the first, including heavy and strategic industries, was reserved exclusively for the public sector. In the second, public sector efforts would supplement pre-existing private sector ability while gradually bringing the latter under public sector control. The third, the light and consumer goods industry, was left to the private sector. Thus, the public sector and PSEs came to occupy the "commanding heights of the economy".

The investments made in the public sector in the second and third Five years (1956-1966) led to an annual 9 percent growth rate in manufacturing value added between 1959 and 1966 (Ahluwalia, 1985). But that fell to 5 percent over the next fifteen years, with negative growth in total factor productivity, a decline in the growth rate of labour productivity and capital stock, and an increase in capital-output rations. Although India's savings ratio compared favourably with the rest of the world, there were at least three reasons why it proved difficult to transform the savings into economic growth.

[16] Details of India's economic strategy are from Ahluwalia (1985) unless otherwise mentioned.

Table 10.6. *National expenditure on R&D, sectoral shares, and share of GDP*

	1981	1991	1996	2001	2002	2003	2004	2005	2006	2007
R&D expenditure[a]	36.7	83.6	96.6	156.8	160.1	163.5	175.8	199.9	229.6	248.2*
Percentage share:										
Central	76.3	77.0	69.5	..	67.7	67.7	64.9	62.5	62.0	60.4
State	7.8	9.2	8.8	..	8.7	8.8	8.4	8.0	7.7	7.5
Private	15.9	13.8	21.7	..	19.3	19.3	22.3	25.0	25.9	27.7
Higher education	..	..	..	..	4.20	4.2	4.4	4.4	4.4	4.4
Percent of GDP	..	..	0.69	0.84	0.81	0.80	0.79	0.84	0.88	0.87

Note: Annual R&D survey conducted between two years. Data are reported as the second year.
(a) In billions of constant 1999-2000 Rupees; *Estimated
Source: Calculated from GoI (2009:75)

Table 10.7: *Distribution of Central sector R&D expenditure (Percentage)*

	1981	1991	1996	2002	2003	2004	2005	2006
Council of Scientific and Industrial Research	11.9	8.2	7.9	7.7	8.2	8.2	8.4	8.0
Defense Research and Development Organization	13.7	22.3	26.8	27.5	24.6	26.4	24.6	29.6
Department of Atomic Energy	12.7	9.0	9.4	9.7	9.9	9.5	10.0	9.82
Department of Biotechnology	..	1.4	1.4	1.2	1.5	1.5	1.8	1.7
Ministry of Communication and Information Technology	0.93	1.1	0.7	1.12	0.63	0.65	0.74	0.89
Ministry of New and Renewable Energy	0.69	0.52	0.13	0.17	0.16	0.13	0.09	0.08
Ministry of Earth Sciences	..	0.91	0.88	1.0	1.2	1.1	1.3	1.3
Department of Science and Technology	7.0	3.9	4.3	3.2	5.4	5.6	7.2	6.6
Department of Space	9.7	12.6	17.7	16.5	17.7	17.4	16.8	14.9
Indian Council of Agricultural Research	16.8	9.0	8.3	11.9	10.5	9.9	10.2	9.8
Indian Council of Medical Research	1.6	1.5	0.97	1.5	1.5	1.3	1.6	1.9
Ministry of Environment and Forest	0.64	5.3	4.7	2.7	2.3	1.6	1.6	1.3
Other Ministries	..	..	..	..	16.5	16.5	15.7	14.0

Note: Annual R&D survey conducted between two years. Data are reported as the second year.
Source: Calculated from GoI (2009a:78-79)

First, a decline in infrastructure investment, a public sector monopoly, affected the entire economy. This was compounded by time and cost-overruns in implementation, and inadequate management and maintenance of assets.

Second, industrial and trade regulations were restrictive for both the public and private sectors. The origins of most administrative regulations are traceable to the Industrial Development and Regulation Act of 1951, which made licensing mandatory for all industrial production, whether to establish new facilities or to expand capacity. While licensing was meant to direct resources industries of national importance, and prevent the concentration of economic power, it only succeeded in creating a regulatory regime with a bewildering array of controls, implemented in an ad-hoc fashion with little coordination, all of which proved inimical to innovation and entrepreneurship.

A third reason was the slow growth in agricultural incomes, restricting demand in an agrarian economy. Although limited domestic demand need not constrain growth, as many East Asian economies have shown, India’s economic policy was influenced by export pessimism. Evidence of India’s inward looking ISI strategy was the decline in the share of world trade from 2 percent in 1950 to 0.4 percent in 1990 (Ahluwalia, 1996:21). High tariffs shielded domestic products from imports, both to conserve foreign exchange and for infant industry protection. In practice, an obsession with self-reliance meant that protection was given to anything produced in the country, with little international exposure. As ISI was carried deeper, capacities were established for a small domestic market even for products where economies of scale are crucial.

Technologies developed at CSIR for domestic conditions struggled for acceptance by industry, which preferred to import easy-to-implement packages from abroad. This reflected, in part, the lack of financial and engineering resources with CSIR to build technologies to industrial scale (Krishnan, 2010).[17] Writing on the Indian electronics industry, Sridharan (1996) points to a dilemma of import substitution: it either meant producing with local inputs that were typically obsolete or relying on imported inputs for anything state of the art. But, until 1991, since royalty payments were tightly regulated and patent enforcement was weak, foreign sources transferred as little technology as they could get away with, and even that was often obsolete. Thus, ISI not only discouraged innovation but also prevented India from exploiting its comparative advantage in labor-intensive sectors such as electronics assembly.

Another aspect of the Indian economy was the scant attention paid to attracting FDI. The Foreign Exchange and Regulation Act (FERA) 1973 disallowed foreigners from owning more than 40 percent equity in any domestic firm. The government displayed its willingness to apply FERA when IBM had to close its operations in 1977, following IBM’s unwillingness to dilute its equity in its Indian subsidiary (Sridharan, 1996). Although 100 percent equity was allowed in export processing zones (EPZs), administrative hurdles and inadequate infrastructure made them less attractive than those in other Asian countries.

By the late 1970s, as it became evident that India was not enjoying the economic growth that many Asian countries were, the government began to tinker with the policy framework to create, what the Sixth plan (1980-85) described as, “efficient ISI”. There were changes in the licensing and import regime, even though tariffs continued to be among the highest in the world. While the Technology Policy Statement of 1983 reiterated the importance of technological self-reliance, and the need to develop indigenous technology to solve India’s problems, it also emphasized the need to develop technologies that were internationally competitive and had export potential.[18]

Emblematic of the 1980s were key policy initiatives for information technology (IT). To ensure that India could become to software what Taiwan and Korea were to hardware (Lakha 1990), the government announced the Computer Policy of November 1984, and the Computer Software Export, Development and Training Policy of December 1986 (Subramanian, 1992).

[17] Krishnan also writes of “bad blood” between industry and the CSIR after technology imports were made contingent on CSIR verifying that it did not have an equivalent technology. While this did not stop imports, it led to delays.

[18] See http://www.dst.gov.in/stsysindia/sps1983.htm for the full text of the Statement.

The 1984 policy recognized software as an 'industry', making it eligible for various allowances and incentives. It also lowered duties on software imports, and made software exports a priority. The 1986 policy aimed at increasing India's share of world software production. The means to do this was the 'flood in, flood out' feature: firms in India were provided liberal access to global technologies to encourage "thousands of small software companies in the country and thereby increasing export as well as local development" (Dataquest, 1987:87). Industry was to be independent, with the government stepping in to provide only promotional and infrastructure support. Overall, this policy was an explicit rejection of ISI and the ideology of self-reliance in the software sector.

In 1990, the government established the Software Technology Parks (STPs), which were export zones dedicated to the software industry. In addition to financial incentives, the STPs also offered crucial data communication facilities. Indian firms capitalized on the STPs to pioneer a Global Offshore Delivery Model, by establishing software factories with the technology, quality processes, productivity tools, and methodologies of the customer workplace (Parthasarathy, forthcoming). Firms focused on adopting industry-wide certification norms, such as the Software Engineering Institute's five-level Capability Maturity Model (SEI-CMM), to codify quality procedures in the development process. By June 2002, 85 firms were certified at Level 5, the highest level of the SEI-CMM, compared with 42 in the rest of the world, with Polaris Software being the first firm in the world to obtain CMMi Level 5 certification.[19]

The easing of the administrative regime, along with higher infrastructural investment, led to faster industrial growth and a near 3 percent annual increase in manufacturing TFP in the 1980s. But the gains were blunted by a deteriorating fiscal situation and, in mid-1991, a balance of payments crisis forced the government to turn to the IMF for a fiscal stabilization plan.[20] This plan was accompanied by a structural adjustment program to:

> "….increase the efficiency and international competitiveness of industrial production, to utilize for this purpose foreign investment and foreign technology to a much greater degree than we have in the past to increase the productivity of investment, to ensure India's financial sector is rapidly modernized, and to improve the performance of the public sector, so that the key sectors of our economy are enabled to attain an adequate technological and competitive edge in a fast changing global economy".[21]

In July 1991, the Rupee was devalued by 24 percent and made convertible on the current account. On the trade front, a single negative list replaced import licensing, eliminating discretionary decisions and delay. The import-weighted tariff came down from 87 percent to 33 percent in 1994-95. A new Statement of Industrial Policy was issued on 24 July 1991.[22] Among its goals was the "encouragement of entrepreneurship, development of indigenous technology through investment in research and development, bringing in new technology, dismantling of the regulatory system". To that end, licensing was abolished for all but 18 sectors where strategic or environmental issues were involved, and industries exclusively

[19] www.nasscom.org/artdisplay.asp?cat_id=205. Although SEI upgraded the CMM model to CMMi (Capability Maturity Model Integration) in 2000, the broad philosophy of the five-stage model remains the same. For details, see www.sei.cmu.edu/cmm/cmm.html.

[20] For an extended discussion of the factors leading to the crisis, see Little and Joshi (1994).

[21] http://indiabudget.nic.in/bspeech/bs199192.pdf

[22] See http://siadipp.nic.in/publicat/nip0791.htm for full text of the Policy.

reserved for the public sector were reduced to 6. The policy permitted FDI in most sectors of the economy and India demonstrated its seriousness in this pursuit by joining the Multilateral Investment Guarantee Agency in April 1992.[23] FERA was scrapped and replaced with the Foreign Exchange Management Act (FEMA) 2000 to facilitate foreign trade and currency management.

To address S&T challenges in a new century, the government announced a Science and Technology Policy in 2003.[24] Amongst other things, the policy calls for functional autonomy and freedom to universities and other academic, scientific and engineering institutions in order to foster research of the highest international standards by attracting young people to careers in science and technology. It calls for promoting close interaction between private and public institutions in science and technology and to establish an Intellectual Property Rights (IPR) regime that maximizes the incentives for IPR generation and protection, besides providing a strong, supportive and comprehensive policy environment for effective commercialization of such inventions. Emphasizing the importance of information to the development of science and technology, the policy wants to ensure high-speed access to information, both in terms of quality and quantity, at affordable costs, besides creating digitized, valid and usable content of Indian origin.

To ensure access to technologies, royalty payments were eased[25] and foreign trademarks and brands could be used freely in the domestic market. Following accession to the World Trade Organization (WTO), and signing of the Trade-Related Aspects of Intellectual Property Rights (TRIPS), India amended its Patents of Act of 1970 thrice – in 1999, 2002 and 2005 - to make Indian patent laws TRIPS-compliant.[26] Amendments included, for instance, extension of patent life from 5 to 14 years to a TRIPS-mandated 20 years; granting of product patents for pharmaceutical and therapeutic innovations whereas previously only process patents were available; and the limited patentability of software, especially embedded systems. India also signed the Patent Cooperation Treaty (PCT) in 1999.

10.3 The changing institutional structure and its implications for knowledge flows

Tinkering with the policy framework in the 1980s, and the tighter embrace of liberal economic policies in the 1990s, grew the Indian economy by a factor of 1.7 between 1980 and 1990, by 1.7 between 1990 and 2000, and by 1.8 between 2000 and 2008 (Table 10.2). Annual TFP growth also increased from 0.2 percent in the 1960s and 1970s to more than 2 percent in 1993-2004 (Dutz, 2007:26). But, as Table 10.1 also shows, per capita GDP (in constant 2000 US$) only grew by a factor of 1.4, 1.4 and 1.6 for the three periods respectively; similarly, the GDP per person employed (in constant 1990 PPP$) grew only by factors of 1.3, 1.4 and 1.5. There was also wide variation in TFP improvement: between 1993

[23] See http://siadipp.nic.in/policy/fdi_circular/fdi_circular_1_2010.pdf for the most recent statement on FDI.

[24] See http://www.dst.gov.in/stsysindia/stp2003.htm for the full text of the Policy.

[25] Automatic approval was given for technology imports requiring royalty payments up to 5% of domestic sales and 8% of domestic sales. For lump sum payments, the limit for automatic approval was set at Rs.10 million.

[26] The full text of the amendments are available at http://ipindia.nic.in/ipr/patent/patact_99.PDF, http://ipindia.nic.in/ipr/patent/patentg.pdf and http://ipindia.nic.in/ipr/patent/patent_2005.pdf respectively.

and 2004, TFP in services grew by nearly 4 percent annually, whereas it was just over one percent in manufacturing (Dutz, *ibid.*).

India's economic ties to the rest of the world are growing by larger orders of magnitude in comparison with the growth of its GDP. As Table 10.5 shows, imports went up by a factor of 1.8 between 1980 and 1990, by 3.4 between 1990 and 2000, and by 3.6 between 2000 and 2008. The corresponding figures for exports were 1.7, 3.2 and 2.9. The share of imports as a percentage of GDP have grown from 9 percent in 1980 to 28 percent in 2008, while the share of exports has grown from 6 percent to nearly 23 percent in the same period. A notable aspect of the growth in imports and exports has been the growth in the share of services, as tables 10.8 and 10.9 show. Among service imports, Other Services overtook Transport as the biggest category in 2002. Within Other Services it is Other Business Services that accounted for a third of all service imports in 2006. Among service exports, Other Services have grown to more than three-fourths of total service exports. The biggest component here is Computer and Information services, followed by Other Business Services (which captures India's growing presence in the business processing activities).

Another sign of India's growing ties to the world economy is the growth in FDI: inward flows grew from 0.15 percent of the world total to just 0.26 percent in 2000, but shot up to nearly 2.5 percent in 2008; outward flows grew from a negligible share of the world total in 1980 and in 2000, to nearly one percent by 2008, as table 10.3 shows. Tables 10.10 and 10.11 shows that over this period, the US, Germany and the UK were important sources of FDI, whereas the US and the UK have a much larger share of India's investments abroad than continental Europe. Cumulatively, between January 2000 and March 2009, the top three recipients of FDI were Services (21 percent), Computer Software and Hardware (10 percent), and Telecommunications (7 percent) (NCAER, 2009:17). Tables 10.12 and 10.13 show that, for the period 2005-08, Services accounted for more than 24 percent of total FDI inflows and the largest share went to Financial Services.

Table 10.8: *Break-up of service imports to India (Total and percentage)*

	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007
Total services[a]	3.0	6.1	19.2	20.1	21.0	24.9	35.6	48.0	63.5	77.2
Share of total trade	17.3	22.4	29.5	30.8	26.8	25.8	25.6	26.1	27.5	26.5
Percentage of service trade										
Transport	60.0	56.1	45.4	42.3	40.5	37.4	37.1	42.0	39.7	40.3
Travel	3.8	6.5	14.0	15.0	14.2	14.4	13.5	12.5	11.6	11.4
Other services	36.2	37.4	40.6	42.8	45.3	48.2	49.4	45.5	48.8	48.3
Communications	..	..	0.6	1.3	4.8	2.5	1.6	1.4	1.4	..
Construction	..	..	0.7	2.3	2.9	4.9	2.3	1.4	1.4	..
Insurance	5.3	5.7	4.2	4.0	4.2	4.7	4.9	4.7	4.2	..
Financial services	..	..	6.7	8.9	6.8	2.0	2.2	2.4	2.1	..
Computer and info.	..	..	3.0	4.5	4.3	2.8	2.6	3.3	3.5	..
Royalties & license fees	0.4	1.2	1.5	1.6	1.6	2.2	1.7	1.6	1.5	..
Other business services	28.3	28.2	22.5	18.6	19.4	28.4	32.8	29.7	33.8	..
Personal services	..	..	..	..	..	..	0.2	0.2	0.2	..
Government services	2.2	2.4	1.5	1.5	1.3	0.8	1.0	0.9	0.8	..

Notes: (a) In current US$ and exchange rates
Source: UNCTAD Handbook of Statistics 2009

Table 10.9: *Break-up of service exports from India (Total and percentage share)*

	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007
Total services (a)	3.0	4.6	16.7	17.3	19.5	23.9	38.3	55.8	75.4	89.7
Share of total trade	26.0	20.4	27.4	28.4	26.5	26.9	30.2	34.7	37.1	36.0
Percentage of service trade										
Transport	15.0	20.7	11.9	11.8	12.7	12.6	11.4	10.2	10.1	9.8
Travel	52.2	33.7	20.7	18.5	15.9	18.7	16.1	13.4	11.9	12.4
Other services	32.8	45.6	67.4	69.7	71.4	68.7	72.5	76.3	78.0	77.8
Communications	..	..	3.6	6.4	4.0	4.1	2.9	3.5	2.9	..
Construction	..	..	3.0	0.4	1.2	1.2	1.4	1.8	0.5	..
Insurance	1.2	2.7	1.5	1.6	1.7	1.7	2.2	1.7	1.5	..
Financial services	..	..	1.7	1.8	3.1	1.5	0.9	2.6	2.8	..
Computer and info.	..	..	28.3	42.7	45.6	49.7	42.7	39.4	38.7	..
Royalties & license fees	..	0.0	0.5	0.2	0.1	0.1	0.1	0.2	0.2	..
Other business services	27.8	42.5	24.9	13.6	13.9	9.3	21.3	26.2	30.8	..
Personal services	..	..	..	..	..	..	45.8	145.8	217.8	..
Government services	3.7	0.3	3.9	3.1	1.8	1.1	0.9	0.6	0.4	..

Notes: (a) In current US$ and exchange rates
Source: UNCTAD Handbook of Statistics 2009.

Table 10.10: *Geographic sources of FDI flows to India (Percentage share)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Denmark	0.39	0.24	-0.11	0.37	0.24	0.55	-0.04	0.33	0.13
Germany	0.05	3.5	3.5	7.2	9.3	8.3	4.0	8.6	4.3
Norway	..	..	..	..	..	-0.05	..	..	..
Sweden	..	0.69	0.85	-1.1	..	0.62	0.64	1.2	0.84
UK	12.1	3.6	7.4	7.3	8.7	14.7	0.94	5.3	2.0
USA	2.6	3.9	16.3	8.2	19.7	9.5	9.0	15.5	6.3

Source: OECD Trade database

Table 10.11: *Share of India's investments abroad (for select countries) (Percentage share)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Denmark	-0.02	0.01	-0.05	0.02	0.06	0.14	0.05	0.03	0.06
Germany	-2.7	0.71	2.8	-1.4	0.51	0.13	0.32	1.02	0.31
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	..
Sweden	1.1	-0.47	0.07	-0.34		-0.01	-0.03	-0.04	-0.03
UK	10.4	3.4	0.09	0.61	-1.3	8.42	3.4	0.76	..
USA	..	..	-0.95	6.7	12.7	29.2	3.1	8.0	10.0

Source: OECD Trade database

Table 10.12: *Share of service sector FDI inflows in total FDI inflows to India (percent)*

Category	2005	2006	2007	2008
Financial	7.9	17.2	7.0	12.1
Non-Financial Services	0.0	0.4	3.0	2.6
Banking Services	1.9	1.2	2.9	1.9
Insurance	1.6	0.7	1.4	2.1
Outsourcing	0.3	0.3	0.7	1.1
Research & Development	0.5	0.3	0.4	1.3
Other Services	4.2	15.3	2.6	3.3
Sector total	16.4	35.4	18.0	24.4

Source: NCAER (2009:19)

Table 10.13: *FDI in India in the service sector (US$ million and percenteage share)*

Category	2005	2006	2007	2008	Cumulative FDI	Share
Sector total	714.6	3938.8	3445.1	8043.6	16142.1	100.0
Financial	344.2	1912.2	1345.9	3982.9	7585.2	47.0
Non-Financial Services	0.4	47.4	576.9	689.0	1313.7	8.1
Banking Services	82.9	131.8	552.0	847.2	1613.8	10.0
Insurance	69.7	74.6	276.8	636.9	1057.9	6.6
Outsourcing	11.4	32.0	126.7	372.8	542.9	3.4
R&D	22.0	36.9	73.0	433.3	565.2	3.5

Source: NCAER (2009:19)

Table 10.14: *US admissions under temporary visas (H1B and L1), 1992-2008*

	Worldwide Admissions		Indian admissions (percent)		India's global rank	
	H-1B	L1	H-1B	L1	H1-B	L1
1996	144,458	140,457	20.24	1.61	1	13
1998	240,947	203,255	25.96	1.90	1	12
2000	355,605	294,658	28.81	4.05	1	7
2001	384,191	320,480	27.19	4.85	1	7
2002	370,490	313,699	21.89	6.51	1	4
2003	360,498	298,054	21.07	7.30	1	3
2004	386,821	314,484	21.60	7.36	1	3
2005	407,418	312,144	25.13	9.12	1	3
2006	431,853	320,829	29.11	10.41	1	1
2007	461,730	363,536	34.14	14.16	1	1
2008	409,619	382,776	37.77	16.50	1	1

Source: Yearbook of Immigration Statistics, US Department of Homeland Security, various years.
http://www.dhs.gov/files/statistics/publications/yearbook.shtm

Flows of trade and investment have also been accompanied by increased flows of human capital. Just one indicator of the phenomenon is that Indians became the largest beneficiaries of H1B admissions (and, later, L1 too) to the US (Table 10.14).[27] Driving this phenomenon has been the demand for Indian software professionals and the services of Indian software firms. However, these flows have not been one-way. Following the demand slump for IT in the US in 2001, India's share of H1-B admissions declined and an estimated 35,000 professionals returned to India (Singh 2003). More broadly, Saxenian (2006) refers to the growing 'brain circulation' between Silicon Valley and India that is triggering entrepreneurship and innovation in both regions.

Despite the perception of India as an attractive location for R&D, investments under that category were only 3.5 percent of the total FDI in services. Likewise, amidst the growing acknowledgement of the importance of the R&D and innovation, and the changing legal environment after India joined the WTO, R&D as a share of GDP grew from approximately 0.7 percent to 0.9 percent between 1995-96 and 2006-07 (Table 10.6). However, India's R&D investment grew 2.6 times in real terms and aspects of this growth merit mention. First, analyzing India's record of scholarly publications from the Thomson-Reuters Web of Science database of about 10,000 journals, Adams et al (2009) say that after being in "slumber" in the 1980s, India "started to awaken" in the 1990s and "striking growth" after 2000. Table 10.5 confirms, the number of publications increased by 6640 between 1995 and 2000, whereas it increased by 31,775 between 2000 and 2005. India's strengths have long been in agriculture and the chemical sciences. Recently growth in output has been in the medical sciences reflecting the growing importance of the pharmaceuticals industry, while the growth in output in engineering reflects the growth in R&D outsourcing. The US is India's most important research publication partner, while Asian countries are edging out established European partners (Table 10.16). But, according to Adams et al (2009), India collaborates less than other G8 countries or even, say, Brazil.

Second, US patent data presented by Krishnan (2010:52-54), shows that eleven times more patents were granted to Indian inventors or assignees in the period 1995-2008 than in 1976-1994. The data also shows that MNCs accounted for more than half the patents in both periods, although 71 percent of MNC patents in the earlier period were in Chemistry-related areas (mostly pharmaceuticals) whereas in the latter period it was in IT. The share of Indian firms increased from less than 8 percent to 16 percent, with 82 percent of patents being Chemistry-related in the latter period. Indeed, of the top twenty leading patenting firms, sixteen were in the pharmaceuticals industry. The CSIR led the growth in share of Indian academic and research institutions from just over 10 percent to more than 22 percent. With 990 patents (more than the cumulative figure for the twenty leading Indian firms), the CSIR was the single largest Indian recipient of US patents between1995 and 2008. Despite the overall increase in US patents, a study on innovation, based on patents granted by European and Japanese and the US patent offices, ranks India 58 out of 82 countries for the period 2002-05 (EIU, 2007a). Table 10.17 shows patents obtained with international partnership.

[27] The H1B classification enables employment up to six years in a specialty occupation, which requires the theoretical and practical application of specialized knowledge requiring completion of a specific course of higher education. The L classification applies to intra-firm transferees who, within the three preceding years, were employed abroad continuously for one year, and who will be employed by a branch, parent, affiliate, or subsidiary of that same employer in the US in a managerial, executive, or specialized knowledge capacity for up to seven years.

Table 10.15: *Research papers published from India by subject, 1995-2005 (Total and percentage)*

	1995	2000	2001	2002	2003	2004	2005	Total papers
Total papers	50,912	57,522	59,315	66,454	73,195	78,354	89,297	689,938
Percentage share								
Agriculture	21.7	23.0	22.8	21.8	19.9	18.3	18.5	145,408
Biological Sciences	20.3	16.9	16.2	15.7	14.9	13.6	14.0	112,760
Chemical Sciences	25.0	25.8	26.2	25.2	25.1	27.0	26.5	179,024
Earth Sciences	3.1	2.8	2.8	1.7	1.6	1.4	1.4	14,439
Engineering	7.2	8.0	8.3	9.2	11.8	13.3	13.4	67,834
Mathematics	3.6	2.7	2.7	2.8	2.4	2.1	2.0	20,279
Medical Sciences	7.8	10.5	10.8	12.0	13.9	13.5	13.6	76,188
Physical Sciences	11.2	10.5	10.4	11.7	10.3	10.7	10.7	74,006

Source: GoI (2009a:59)

Table 10.16: *India's leading research publication partners*

1999-2003		2004-2008	
USA	6,725	USA	10,728
Germany	2,667	Germany	4,284
UK	2,137	UK	3,646
Japan	1,908	Japan	3,017
France	1,393	France	2,402
Canada	927	South Korea	2,074
Italy	822	China	1,665
China	674	Canada	1,590
Australia	643	Australia	1,338
Netherlands	563	Italy	1,309
South Korea	558	Switzerland	1,067
Taiwan	540	Taiwan	1,102
Switzerland	493	Russia	940
Russia	482	Netherlands	874

Source: Adams et al (2009: Table 3)

Table 10.17: *Indian patents with international cooperation, 2000 to 2006*

	Foreign ownership of domestic inventions			Patents with foreign co-inventor(s)		
	EPO	USPTO	PCT	EPO	USPTO	PCT
Total Patents	3717	4006	6421	3717	4006	6421
Total co-operation abroad	1575	2390	2133	1215	1430	1575
Denmark	0	0	0	2	1	6
Germany	152	65	142	152	67	137
Italy	8	3	6	16	4	13
Norway	1	0	1	1	2	2

Sweden	26	5	31	14	3	22
United Kingdom	129	11	219	86	36	110
United States	878	2183	1280	774	1217	1056
European Union (27)	520	126	612	425	179	478
Brazil	0	0	0	0	2	4
China	3	1	8	10	10	20
Estonia	0	0	0	0	0	0
South Africa	0	0	0	5	3	6

Source: OECD Patent database

The third aspect of R&D spending has been the growing share of the private sector. Table 10.18 shows that, as a share of total sales in all industries, R&D spending grew from approximately 0.5 percent in 2002-03 to 0.7 percent in 2005-06. The table also draws on a sample of 1,108 firms from 41 industries to show where in the private sector R&D expenditure is highest. Going by R&D as a share of sales in 2005-06, the defence industry leads, followed by drugs and pharmaceuticals, and vegetable oils. However, the drugs and pharmaceuticals industry has 156 firms conducting R&D, 86 more than the second placed biotechnology, and 96 more than third placed transportation. When one compares R&D spending per firm, it is drugs and pharmaceuticals, followed by transportation and information technology. On an aggregate basis, it is drugs and pharmaceuticals, followed by transportation, with information technology a distant third.

The prominence of drugs and pharmaceuticals, whether indirectly in terms of publications, or more directly in terms of patents and R&D investments, can be understood in terms of how the legacy of the past, and recent policy changes, have shaped the industry. While the "1970 Patents Act propelled Indian firms onto a reverse engineering path and laid the foundation for a strong domestic industry" (Chaturvedi et al., 2007:569), the strengthening of patent laws in line with the TRIPs agreement has facilitated the internationalization of Indian pharmaceutical firms and their increased partnership with foreign MNCs (Chittoor et al., 2008). Similarly, the gradual easing of the Drug Prices Control Order, which was formulated in 1979 to restrict the prices of essential drugs, with the Drugs (Price Control) Order of 1995, and the Pharmaceutical Policy of 2002, has facilitated the growth of the industry.[28] The 2002 policy abolished virtually all licensing requirements for the industry, allowed 100 percent FDI, and called for the establishment of a Pharmaceutical Research and Development Support Fund.

More broadly, according to a 2007 survey of 137 firms in 18 manufacturing and service sectors, conducted by the National Knowledge Commission, 70 percent strongly agreed that innovation was good for business (NKC, 2007b).[29] Of the 58 large firms in the sample, 81 percent strongly agreed that innovation was increasingly critical to growth and competitiveness in the liberal economic climate whether measured by number of employees or annual revenue; however, 42 percent of large firms since 1991.[30] The survey found an

[28] The full text of the Drug (Price Control) Order of 1995 and the Pharmaceutical Policy of 2002 are available at http://pharmaceuticals.gov.in/

[29] The Commission was established on 2 October 2005 for a three year period as an advisory body to the Prime Minister to build institutional frameworks focusing "on five key areas of the knowledge paradigm – access to knowledge, knowledge concepts, knowledge creation, knowledge-application and development of better knowledge services" (NKC, 2007a:1).

[30] Large firms in the survey had an annual revenue of more than Rs.1000 million, medium firms between

inverse relationship between 'innovation intensity' and firm size, whether measured by number of employees or annual revenue; however, 42 percent of large firms were "highly innovative" whereas the figure was 17 percent for SMEs.[31] As Figure 10.1 shows, the focus of innovation for large firms was operations, followed by sales and marketing. The only firms for whom R&D was the focus were those in the pharmaceuticals industry. Further, the survey also found that 76 percent of large firms introduced incremental innovation while breakthrough innovations were limited to 37 percent.

Table 10.18: *R&D expenditure in the private sector*
(by industry groups spending more than 0.67 percent as a share of sales in 2005-2006)

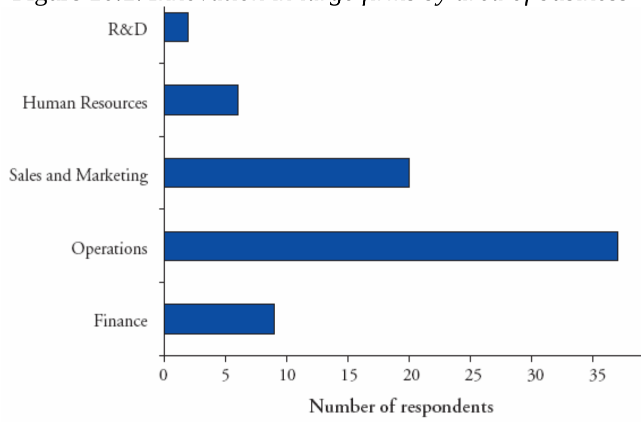
	2002-03	2003-04	2004-05	2005-06			
Sectors	Percent	Percent	Percent	Percent	R&D units	Average per unit[a]	R&D expenditure[a]
Defence industries	5.0	4.8	6.2	4.6	7	22.4	157
Drugs and pharmaceuticals	2.2	2.6	3.7	3.8	156	181.2	28269
Vegetable oil	2.5	3.1	3.3	3.8	3	117.0	351
Medical and surgical appliances	3.7	3.5	2.9	2.9	11	10.9	120
Scientific instruments	2.9	2.8	2.6	2.4	9	5.4	49
Information technology	1.3	1.8	1.6	1.7	20	153.3	3066
Prime movers	0.60	0.67	1.2	1.5	3	134.7	404
Telecommunications	1.4	2.2	1.5	1.4	30	32.9	987
Biotechnology	1.0	1.1	1.1	1.1	70	39.7	2777
Transportation	0.8	0.8	1.0	1.1	60	174.5	10472
Photographic raw film and paper	0.84	0.76	0.84	1.0	3	19.7	59
Agricultural machinery	1.6	1.5	1.3	0.84	8	60.8	486
Machine tools	1.4	1.2	0.74	0.81	11	6.5	71
Glue and gelatin	0.82	0.66	0.63	0.81	4	5.0	20
Industrial machinery	1.0	1.2	1.0	0.8	29	13.7	397
Soaps, cosmetics and toilet preparations	0.93	0.99	1.1	0.76	10	137.2	1372
Commercial offices, household equipment	0.65	0.78	0.88	0.72	11	23.2	255
Consultancy services	0.70	0.67	0.64	0.67	2	1.50	3
Total (for 41 sectors)	0.46	0.54	0.62	0.66	1108	56.6	62684

Notes: (a) in millions of current Rupees
Source: GoI (2009a:89-90)

Rs.1000 million and Rs.100 million, and small firms had less than Rs.100 million.

[31] Innovation intensity was defined as "the percentage of revenue derived from products/services which are less than three years old." Highly innovative firms were defined as "those that have introduced a 'new to world' innovation during the course of their business in the last five years" (NKC, 2007:9).

Figure 10.1: *Innovation in large firms by area of business*



Source: NKC (2007b:16)

Table 10.19: *Distribution of publicly funded extramural R&D projects by institution types*

Types of Institutes	1990-95		1995-2000		2001-2006	
	Number of Institutions	Share by value	Number of Institutions	Share by value	Number of Institutions	Share by value
Universities/ Colleges	576	35.6	836	31.7	2046	32.9
Deemed Universities	16	8.4	24	6.3	127	7.3
Institutes of National Importance	9	12.2	11	9.8	56	12.1
National Laboratories	233	33.8	274	42.5	680	27.4
Others	261	10.0	346	9.7	923	20.0
Total	1095	100	1491	100	3832	99.7

Source: Abrol, Upadhyay and Sikka (2006:11)

Table 10.20: *Qualifications of R&D labor force and share by sector (on 1 April 2005)*

	PhD	Graduate	Undergraduate	Diploma	Other
Total	20399	44367	35170	9767	6472
Central sector	48.4	48.0	36.3	31.9	26.5
State sector	28.2	7.0	1.6	1.6	7.5
Public sector industry	2.4	5.4	13.1	10.8	11.5
Private sector industry	21.0	39.7	49.0	55.7	54.5

Source: Calculated from GoI (2009a:97-78)

Firms rated their external barriers to innovation as being greater than internal barriers. More than half of all firms mentioned the lack of collaboration with universities and R&D labs. Although the share of the private sector in extra-mural research funded by the central sector is growing (see category of Others in Table 10.19), this growth is from a small base. In the sectors of defense, atomic energy and space, where more than 50 percent of central R&D resources are spent, research has thus far taken place within the confines of the public sector. Indeed, the largest concentration of researchers with PhDs and graduate degrees work in the central sector (Table 10.20). In the absence of data on private sector extramural spending, the promise of private-public research partnerships awaits fulfillment (Abrol, Upadhyay and Sikka, 2006).

However, the biggest barrier to innovation for all firms was "skill shortages due to lack of emphasis on industrial Innovation, problem solving, design, experimentation" (NKC, 2007:32) in the education curricula. Wadhwa et al (2008) also argued the point that the quality of the technical labor force in India is low. They add that Indian university and post-graduate degrees are weaker than their US or European counterparts and on-the-job training programs in India must fill the gap in formal training. This leads us to examine the institutional barriers in the education system that fails to produce the kind of graduates that an innovative industry would like.

10.4 Access to quality education as the overwhelming barrier to innovation

The Indian higher education system in its current form originated during colonial rule in the country when a few centers of higher education were established with the limited purpose of serving British interests (VijayRaghavan, 2008). Although investments in education doubled between 1960-61 and 1980-81 to account for nearly 3 percent of GDP (Table 10.21), according to the WDI, less than 2 percent of the Indian population (older than 15 years) had completed tertiary education in 1985. In 1986, a National Education Policy (NEP) was adopted to expand education at all levels, reduce inequalities, emphasize the importance of socio-cultural diversity, and integrate the country internationally.

But the NEP failed to increase spending to either improve access or the quality of the educational system. A rapid expansion of higher education in the 1990s (Table 10.22), was driven by the private sector, especially in professional education (Choudhary, 2008), as public expenditure on higher education as a share of total public spending on education marginally declined between 1990-91 and 2005-06 (Table 10.21). In 2007-08, annual public spending per student in higher education in India was US$400, whereas Brazil, China and Russia invested, respectively, an average of US$3,986, US$2,728, and US$1,024 (Hussain 2007). According to Altbach (2005), although India is "rushing headlong toward economic success….India's colleges and universities, with just a few exceptions, have become large, under-funded, ungovernable institutions. At many of them, politics has intruded into campus life, influencing academic appointments and decisions across levels. Under-investment in libraries, information technology, laboratories, and classrooms makes it very difficult to provide top-quality instruction or engage in cutting-edge research."

Inadequate resources have created a two-tier system wherein a small number of institutions (typically central universities or institutions of national importance – see Tables and 10.18 and 10.21) are islands of excellence: thus, 30 institutions award 65 percent of PhDs in science, while 20 institutions award 80 percent of PhDs in engineering (Dutz, 2007:139). As the NKC (2007a:43) points out, contrasts in quality and access are a:

> "….serious cause for concern at this juncture. The proportion of our population, in the relevant age group, that enters the world of higher education is about 7 percent. The opportunities for higher education in terms of the number of places in universities are simply not adequate in relation to our needs. Large segments of our population just do not have access to higher education. What is more, the quality of higher education in most of our universities leaves much to be desired."

The fragmentation of education in India is further manifest in the UGC regulations and policies defining the relationship between universities and their affiliated colleges (Singh 2003). Most colleges can neither issue degrees on their own, nor determine their own syllabi or examinations. Instead, they are affiliated to universities, which authorize their functioning and determine administrative and academic rules. Affiliating universities typically demand only a minimum attendance of students, determine a common syllabus for courses at affiliated colleges, and establish examination rules. These rules require colleges to conduct internal practical and theory exams for each course while the university conducts an external final theory exam at the end of each semester. Beyond this, however, the universities are unable to respond to the diverse demands of students, especially with the increasing number of affiliated colleges. Singh (2003:3200) summarizes the affiliation process as a central problem of higher education in India:

> “Anyone concerned with academic standards of Indian universities cannot but feel unhappy at the ravages wrought by the system of affiliation with which we started in 1857.…[T]here is no limit to the number of colleges which can be affiliated to a university. Nor have any specific rules to earn the status of affiliation been laid down at any stage.…As of today, therefore, hardly any university has a set of rules which ensure that a college will faithfully comply with [any] requirements before it can be affiliated.…What undermines their standing as a university is the fact that they have to carry the unwanted cargo of a large number of affiliated colleges and quite a few of them do not measure up even to what would be regarded as the barest minimum.”

The consequence of this system is that students lack the

> “…ability to analyze or solve problems, relate problems to different contexts, communicate clearly and have an integrated understanding of different branches of knowledge.…At present, the design of curriculum and syllabi is reflective of the entrenched examination system under which the student is asked to face a question paper at the end of the year, or in some universities, at the end of the semester. This archaic examination system, ostensibly used as a means of certifying the ability of students, unfortunately does not really test the kind of skills they require to be successful in either the pursuit of pure theoretical knowledge or in practical real world situations.” (GoI, 2009b:17)

Table 10.21: *Expenditure on education*

	1961-62	1970-71	1980-81	1990-91	2000-01	2002-03	2003-04	2004-05	2005-06
Percentage of GDP	1.5	2.1	3.0	3.8	4.3	3.8	3.5	3.4	3.5
Percentage of public exp.	11.7	10.2	10.7	13.4	14.4	12.6	12.0	12.1	12.7
Percentage of expenditure									
Elementary education	..	..	..	46.3	47.6	48.8	49.8	51.5	53.1
Secondary education	..	..	..	32.2	0.3	32.2	32.0	30.9	29.4
University and higher ed.	..	..	..	13.5	14.7	12.9	12.4	11.7	11.7
Other				8.1	6.1	6.1	5.8	5.9	5.8

Source: Compiled from http://education.nic.in/stats/Timeseries0506.pdf and GoI (2009a:111).

Table 10.22: *Growth of recognized educational institutions*

	1960-61	1970-71	1980-81	1990-91	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Primary	380,062	498,999	613,058	712,391	845,007	883,667	896,656	974,525	1,042,251	1,061,061
Secondary and upper secondary	17,329	37,051	51,573	79,796	126,047	133,492	137,207	145,962	152,049	159,667
Colleges for general education	967	2,285	3,421	4,862	7,929	8,737	9,166	9,427	10,377	11,698
Colleges for professional education (a)	..	..	..	886	2,223	2,409	2,610	2,751	3,201	5,284
Universities (b)	45	82	110	184	254	272	304	304	343	350

Notes: (a) Includes colleges of Architecture, Education, Engineering and Technology, and Medicine.
(b) Includes Central Universities (20), Institutes of National Importance (13), Institutions Deemed to be Universities (101), State Universities (216). The numbers in the brackets give the break-up for 2005-06.
Source: http://education.nic.in/stats/Timeseries0506.pdf

10.5 The quest for inclusive innovation

The discussion in the previous sections is limited to the formal sector, and reflects the marginal status of the informal sector in debates about innovation. The origins of these innovations mean that the channels for their diffusion and value-addition are minimal, in contrast to the channels that exist for innovation in the formal sector. Further, to the extent that innovation from the informal sector diffuses, there is little formal documentation or acknowledgement of the source. Yet, any discussion that leaves out the informal sector ignores the activities of a majority of the population that has long relied on its own ingenuity to solve local problems simply because it has no one else to turn to. But the wide dissemination, whether commercially or otherwise, of grassroots innovations face challenges including the high transactions costs for scouting and documentation, the need for value-addition and finance, and ambiguous IPR (Dutz, 2007).

Thus, there is a need for institutional support and a prominent source in India is Honeybee, a network of innovators, entrepreneurs, scholars, policy makers, and non-governmental organizations (NGOs), which was founded in 1988-89 in the state of Gujarat, to support knowledge generation and innovation in the informal sector.[32] The network uses the Honeybee metaphor to refer to the collection (extraction) of pollen (knowledge) from flowers (innovators), without disenfranchising innovators, and to the connection of different flowers through pollination to ensure communication and sharing between users and innovators.

The network uses various ways to source innovation, prominent among, which is the *shodh yatra* (journey of exploration). Volunteers undertake these yatras, which began in 1998 and are organized twice a year, over 7-10 days across hard to access rural areas. The purpose of these yatras is to identify new knowledge and to disseminate existing practices gathered by

[32] http://www.sristi.org/hbnew/

the network that are of local significance. Other sources of innovation include *shodh sankalp* (a network of experimenting farmers) to create a collaborating learning environment, individual submissions, agricultural fairs, and the scanning of old literature. After conducting prior art search to ascertain novelty, and obtaining authorization from the innovator, in the form of a Prior Informed Consent, the network has a database with more than 10,000 entries.

The documentation of innovations, and the management of the Honeybee database, is done by SRISTI (Society for Research and Initiatives for Sustainable Technologies and Institutions), which was established in 1993 to provide organizational, intellectual and logistics support to the network.[33] Another member of the network, GIAN (Grassroots Innovation Augmentation Network) was established in 1998 to offer IPR protection to innovations in the database.[34] By February 2009, GIAN had enabled the filing of 40 patents in India, of which 19 have been awarded and, of the seven patents filed in the US, four have been awarded. GIAN has also incubated and commercialized more than 50 innovations. To facilitate this process, GIAN has established the Grassroots Innovation Design Studio with the National Institute of Design to provide design inputs to innovations. It has also links with the programs of the DST and the DSIR, such as the Technopreneur Promotion Program (Tepp), to encourage entrepreneurship among innovators.

In an acknowledgement of the value of informal and grassroots innovation, the Government of India established the National Innovation Foundation (NIF) in 2000 to make the country a leader in innovation, especially in sustainable technologies.[35] Besides building a multilingual, online National Register of Innovations, which will also maintain the SRISTI database, the NIF organizes a biennial competition for grassroots innovation and tradition knowledge. The six competitions held thus far have attracted 112,235 entries. The NIF aims to build stronger ties between innovators in the formal and the informal sectors, and an instance of this is signing of an agreement with CSIR to provide technical assistance and value addition to entries in the national registry.

The interest in the learning from the informal sector, and using it as a partner in innovation, has also extended to the formal sector, including MNCs. With markets in industrial economies maturing, other markets, especially the estimated four billion consumers with the lowest incomes at the 'bottom-of-the-pyramid' (BoP), are becoming attractive (Prahalad 2006). The BoP is a potentially vast and yet largely untapped market, as the majority owns few consumer products. But there are challenges when entering the unfamiliar conditions in this market as infrastructural inadequacies, socio-cultural diversity, and affordability, mean that existing metrics for 'lead' users do not work. It is against this backdrop that India is attractive. First, India's inadequate infrastructure demands identification of needs and technological solutions, which are difficult to conceive of, and turn into product ideas, for researchers in the affluent world. Second, India's vast, poor but socially and culturally diverse environment serves as a laboratory of similar challenges faced in many other countries. Thus, for instance, IT firms such as Hewlett Packard (HP), Microsoft, Motorola and Siemens, have established research centers to specifically address the BoP market.

[33] http://www.sristi.org/cms/en

[34] http://west.gian.org/

[35] http://www.nif.org.in/

An instance of their work is HP's involvement with the 'i-community' in Kuppam district in the state of Andhra Pradesh from 2002-06, where half the population of 300,000 lives in poverty. HP became involved with the project to create "public-private partnerships to accelerate economic development through the application of technology while simultaneously opening new markets and developing new products and services" (Dunn and Yamashita, 2003:48). For HP, whose products are unaffordable to most Indians, Kuppam was a 'learning lab' to "divine the needs of customers by probing at underlying problems and transferring that understanding to the innovation process" (*ibid*.:50). In Kuppam, HP developed an easy to carry solar powered digital camera with a small printer. This was given to women in self-help groups to help them generate income by taking photographs at social events or wherever there was a need. HP saw the Kuppam effort as a 'lighthouse account' to guide subsequent product development for India and elsewhere.

Interest in accessing the BoP goes beyond simply serving an untapped market. Indeed, a segment of innovation and product development introduced as responses to the needs of the BoP market is exportable, and has helped some firms to identify new markets in the affluent world. The examples include an affordable X-ray system with outstanding diagnostic precision developed by GE for the poor; ATM machines that use a thumbprint recognition system by Citibank originally intended for illiterate, slum-dwellers; low cost cell phones, with longer battery life, that assume illiterate users, developed by Motorola; and PCs developed by HP in India that run on car batteries to combat power outages.[36] Thus, initiatives to extend the reach of IT to the poor, have not only led to innovation and created domestic market opportunities, but also offered a platform to export innovative products.

10.6 Conclusion

If the increasing trade and investment flows in the past decade are any indication, the perception that India is attractive to the rest of the world as a place to business is not without substance. Perceptions have changed because of the country's decision to seek greater integration with the world economy by unshackling its large and growing population and economy from the autarkic ISI model adopted in the 1950s. The unshackling has also led to a greater appreciation of innovation as evident in the increased flows of human capital and knowledge when measured by indicators such as the mobility of professionals, international patenting and collaborative research publications. There are three aspects of India's approach to innovation that are noteworthy. First, and at the risk of oversimplification, India's strength has been in process innovation. As surveys reveal, firms have focused on operational and incremental innovation. Process innovation has also been the basis for the international success that India's software service and pharmaceuticals industries have enjoyed thus far.

Despite the growing appreciation of innovation, perception does not always match reality as the past continues to cast a long shadow to limit the extent of India's integration with global innovation networks. It might only be a matter of time before some of these limitations wither away as policy initiatives, such as the NKC, attempt to create the institutional framework for a different India. But other issues, especially education, will require a longer time horizon

[36] For expanded discussions of these examples, see Nilekani, (2006) and Giridharadas (2007).

since it will take at least ten years of schooling and training before a generation is provided with the skills required in an economy where IT-driven innovation plays a central role.

Finally, Indian raises questions about our conception of innovation. The informal sector has thus far been mostly ignored in discussions about innovation and the measurement of innovation. It is only recently being acknowledged as a site where innovation does occur and about the need for inclusive innovation. There is growing effort to not only document and capture these innovations but to also use the socially deprived as partners in the innovation process. In other words, it is possible that there is a significant mismeasure because innovation systems are narrowly understood. Thus, working with the historically specific innovation system in the country, and overcoming the legacy of limited access to education emerge as crucial to ensuring the tighter integration of India with global innovation networks.

10.7 References

Abrol, Dinesh Kumar; Vinod Kumar Upadhyay and Pawan Sikka. 2006. Financing of S&T in India. http://ssrn.com/abstract=1477257

Adams, Jonathan; Christopher King and Vinay Singh. 2009. *India: Research and Collaboration in the New Geography of Science.* http://science.thomsonreuters.com/ m/pdfs/grr-India-oct09_ag0908174.pdf

Ahluwalia, Isher Judge. 1996. India's Opening up to Trade and Investment. Charles Oman (ed.). *Policy Reform in India.* Paris: OECD.

Ahluwalia, Isher Judge. 1985. *Industrial Growth in India: Stagnation since the Mid-Sixties.*

New Delhi: Oxford University Press.

Altbach, Philip G. 2005. Higher education in India. http://www.thehindu.com/2005/04/12/ stories/2005041204141000.htm

Banerjee, Rangan and Vinayak P. Muley. 2008. *Engineering Education in India*. Department of Energy Science and Engineering, Indian Institute of Technology, Mumbai. http://www.me.iitb.ac.in/~rangan/research_projects/EnEdu.pdf.

Chaturvedi, Kalpana; Joanna Chataway and David Wield. 2007. Policy, Markets and Knowledge: Strategic Synergies in Indian Pharmaceutical Firms. Technology Analysis and Strategic Management. 19(5):565-588.

Chittoor, Raveendra; Sougata Ray, Preet S Aulakh and M B Sarkar. 2008. Strategic responses to institutional changes: 'Indigenous growth' model of the Indian pharmaceutical industry. Journal of International Management. 14:252-269.

Choudhary, Sujit Kumar. 2008. Higher Education in India: a Socio-Historical Journey from Ancient Period to 2006-07. *The Journal of Educational Enquiry* 8(1):50-72.

Dataquest. 1987. The new software policy: Dr.Seshagiri clarifies. January, 82-95.

Department of Pharmaceuticals. 2009. Annual Report. http://pharmaceuticals.gov.in/

Dunn, Deborah and Keith Yamashita. 2003. Microcapitalism and the Megacorporatism. *Harvard Business Review*. 81(8):46-54.

Dutz, Mark (ed.). 2007. *Unleashing India's Innovation: Towards Sustainable and Inclusive Growth.* Washington DC: The World Bank.

Economist Intelligence Unit (EIU). 2007b. *Sharing the idea: The emergence of global innovation networks.* http://www.gencat.cat/diue/doc/doc_41824369_1.pdf

Economist Intelligence Unit (EIU). 2007a. *Innovation: Transforming the way business creates.* http://graphics.eiu.com/upload/portal/CiscoInnoSmallFile.pdf

Economist Intelligence Unit (EIU). 2004. *World investment prospects: The revival of globalization?* http://graphics.eiu.com/files/ad_pdfs/WIP_2004.pdf

Geiger, Thierry and Sushant Palakurthi Rao (eds.). 2009. *The India Competitiveness Review 2009.* http://www.weforum.org/pdf/ICR2009.pdf

Giridharadas, A. 2007. An online revolution reaches India's poor: glaring poverty prompts innovation. *International Herald Tribune.* October 11.

Government of India (GoI) 2009b. *Report of the Committee to Advise on Renovation and Rejuvenation of Higher Education.* http://www.academics-india.com/Yashpal-committee-report.pdf

Government of India (GoI) 2009a. *Research and Development Statistics 2007-08.* New Delhi: Ministry of Science and Technology, Government of India.

Guha, Ramachandra. 2007. *India after Gandhi: The History of the World's Largest Democracy.* New York: Harper Collins.

Hussain, Shabana. 2007. Higher education spending: India at the bottom of BRIC. http://www.business-standard.com/india/news/higher-education-spending-india-atbottombric/273649/

Joshi, Vijay and Ian Little. 1994. *India: Macroeconomics and Political-Economy 1964-1991.* New York: Oxford University Press (for the World Bank).

Krishnan, Rishikeha T. 2010. *From jugaad to Systematic Innovation: The Challenge for India.* Bangalore: Utpreraka Foundation.

Lakha, Salim. 1990. Growth of Computer Software Industry in India. *Economic and Political Weekly.* 25(1):49-56.

National Commission on Enterprises in the Unorganised Sector (NCEUS) 2009. *The Challenge of Employment in India: An Informal Sector Perspective. Volume 1 – Main Report*. http://nceus.gov.in/The_Challenge_of_Employment_in_India.pdf

National Council of Applied Economic Research (NCAER). 2010. *FDI in India and its Growth Linkages.* http://dipp.nic.in/ncear_Report/FDI_NCAER.pdf

Parthasarathy, Balaji. Forthcoming. The Computer Software Industry as a Vehicle of Late Industrialization: Lessons from the Indian Case. *Journal of the Asia Pacific Economy*.

National Knowledge Commission (NKC) 2007b. *Innovation in India.* National Knowledge Commission. http://www.knowledgecommission.gov.in/downloads/documents/NKC_Innovation.pdf

National Knowledge Commission (NKC) 2007a. *Report to the Nation 2006.* Government of India. http://www.knowledgecommission.gov.in/downloads/report2006/eng/NKC%20Report%20to%20the%20Nation%202006.pdf

Nilekani, Nandan M. 2006. In Asia: The CEO of Infosys on Obstacles to Innovation in China and India. *Business Week* 4002:36.

Parthasarathy, Balaji. Forthcoming. The Computer Software Industry as a Vehicle of Late Industrialization: Lessons from the Indian Case. Journal of the Asia Pacific Economy.

Raghavan, V.K. 2008. Knowledge and human resources: Educational policies, systems, and institutions in a changing India. *Technology in Society* 30(3/4):275-278.

Saxenian, Annalee. 2006. *The New Argonauts: Regional Advantage in a Global Economy*. Cambridge, MA: Harvard University Press.

Singh, Amrik. 2003. Academic Standards in Indian Universities: Ravages of Affiliation. *Economic and Political Weekly*. 38(30):3200-3208.

Singh, S. 2003. India calling. www.businessworldindia.com/Nov1003/coverstory02.asp.

Sridharan, Eswaran. 1996. *The Political Economy of Industrial Promotion: Indian, Brazilian, and Korean Electronics in Comparative Perspective 1969-1994.* Westport, CT: Praeger.

Subramanian, C.R. (1992) *India and the Computer: A Study of Planned Development.* New Delhi: Oxford University Press.

Tyabji, Nasir. 2000. *Industrialisation and Innovation: The Indian Experience.* New Delhi: Sage.

United Nations Conference on Trade and Development (UNCTAD). 2005. *World Investment Report 2005: Transnational Corporations and the Globalization of R&D.* New York and Geneva: United Nations.

Wadhwa, Vivek;, Kim de Vitton, U, and Gary Gereffi. 2008. How the Disciple Became the Guru. http://ssrn.com/abstract=1170049

World Bank. 2008. *Global Economic Prospects: Technology Diffusion in the Developing World.* Washington DC: The World Bank.

Chapter 11: Brazil

Flavia Carvalho, Gustavo Britto, and Eduardo da Motta Albuquerque, Fundaçao de Desenvolvimiento da Pesquisa (FUNDEP)

11.1 Introduction

This chapter provides an overview of the emergence and growth of the Brazilian innovation network. Collaborative innovation networks have a key role in enhancing innovation and its economic outcomes at the national level. The economic outcomes of innovation rely heavily on the level of the human resources involved in innovative activities, especially at firm level. In addition, the ability of actors in the innovation network to interact with each other, both domestically and globally, is determinant for the evolution of a global production network into a global innovation system.

To better understand how actors of the innovation system interact, this chapter presents a series of data on important aspects of the Brazilian science, technology and industrial base. The focus is on how the innovation system is shaped in Brazil, how institutions and policies work in order to foster innovation and further develop this network into a player in the global innovation system.

The chapter is divided in six sections, besides this introduction. The next section presents some general information about Brazilian economy, followed by a section on innovative patterns of Brazilian firms provided by the recent innovation survey. Section 4 considers the status of human resources and scientific development of the country and section 5 describes how knowledge flows take place and how cooperative arrangements for innovation take place at the national and global level. The main actors involved in the innovation network and how policies are drawn to foster innovation among firms are presented in section 6. Section 7 provides some concluding remarks

11.2 The Brazilian economy

Brazil’s economy was subject to dramatic structural changes since the early 1990s. For a decade, a series of policies was implemented with the intention to jumpstart a new cycle of economic growth by inaugurating a new economic model inspired by the Washington Consensus. Trade and financial liberalization policies rapidly opened the local economy and the state’s role in the economy was significantly reduced by the privatization of many stated owned enterprises. Combined, these policies brought back large sums of capital flows to the economy and contributed to the success of the stabilization plan in the mid 1990s. With the current account being kept balanced by capital flows and the inflation under control, the short cycle of economic growth was fuelled by the raising purchase power of the population and the increase of private sector investments, both local and foreign.

The success of the new model proved to be short lived. By the end of the 1990s the fixed exchange rate, combined with the ever increasing deficit trade deficit and the unwillingness of financial markets to finance the balance of payments deficits showed that a change of course was needed. Hence, in the first decade of the 21st century, following important changes in the political landscape, industrial, technological and social policies back to the fore. Table 11.1 presents some key indicators over two years. Together with a favorable international economic landscape, the new policies led to a consistent increase of the rate of economic growth through the decade while inflationary pressures were kept under control. As a result, employment and social indicators have been improving in the past years. According to the National Bureau of Geography and Statistics

Table 11.1. *General indicators - Brazil*

	2000	2007
A. Economic performance		
Population	171,279	189,335
GDP (R$ billions)	1,101.3	1,833.6
GDP per capita (R$)		9,569.9
Real GDP growth (%)	4.3	5.7
PPP	1.252	1.39551
Productivity -manufacturing (1991=100)	145.91	
Current account BOP (% of GDP)	-3.75731	0.10945
Inward FDI stocks	122,250	287,697
Outward FDI stocks	51,946	162,218
Investments (% GDP)	16.80	18.65
B. Education		
Illiteracy rate in population > 15 years	20.1%	12.9%
Students in tertiary education (2000=100)	100	142.05
Public expenditure on education (percent GDP)	4.01	5.06 (2006)
Public expenditure on education - tertiary		.7559 (2005)
C. Science and technology		
Imports - Capital goods (US millions)	9,690	24,935
Exports - Capital goods	8,221	22,845
Expenditures on R&D (% GDP)	0.94	1.02
Researchers (per 1.000 population) - FTE	0.8396	1.3276
Patents (triadic patent families)	32.648	65.0202
Exports ICT	2,513.122	3,380.403

Source: IPEADATA, UNCTAD World Investment Reports, OECD S&T Indicators.

Table 11.2. *Distribution of population by age gap (in thousands)*

	Total	Male	Female
>100	25	2	22
90-99	216	75	141
80-89	1,544	628	915
70-79	4,559	2,032	2,526
60-69	8,190	3,786	4,403
50-59	12,514	5,999	6,514
40-49	19,273	9,328	9,944
30-39	25,289	12,320	12,968
20-29	29,985	14,862	15,127
10-19	35,302	17,810	17,490
5-9	16,576	8,419	8,156
0-4	16,386	8,331	8,055
Total	169,872	83,602	86,270

Source: IBGE, Censo Demográfico, 2000.

(IBGE), the rate of unemployment in metropolitan areas fell from around 13 percent in 2002 to under 8 percent in 2009. As a result, absolute poverty levels have been reduced as well as economic inequality. The Gini coefficient fell from 0.589 in 2002 to 0.548 in 2008, the lowest value in the series. The economy’s strength was recently put to test by the recent global financial crisis and the county managed to promptly recover from recession.

While there have been marked improvements over past decades, growth rates are below those of other fast growing developing economies, and social indicators are far behind those of countries of similar per capita income. The degree of informality in the economy is very high, and responded for over 50 percent of the GDP in 2004. Agriculture, construction and domestic services are by and large the sectors with the highest rates of informality (OECD, 2006). Table 11.2 shows the degree of informality, coupled with a relatively young population may pressure the unemployment rates as more young people enter active age, showing the size of the challenges that lie ahead

These indicators reflect, and are influenced by, weak educational indicators as well as an immature innovation system. The next sections will describe the state of development of Brazil’s national innovation system and how knowledge flows among its agents.

11.3 Innovation activities and its main actors in Brazil

The importance of technological change and innovation as determinants of a country’s competitiveness and growth performance has moved to the centre of the economic literature in the last decades (Fagerberg et al., 2007). The pursuit of a better understanding of these key factors, particularly their role as the long sought connection between economic growth and economic development has to renewed efforts to improve data collection. As a result, innovation surveys have become a regular data source for innovation in several countries, including many developing ones, partially as a result of an endeavour concocted by international institutions such as the OECD, the World Bank and IDB, partially by the efforts of local research and statistics institutions.

The Brazilian Innovation Survey (PINTEC) carried out by IBGE, now on its third edition, provides important information on the state of innovative activities carried out by Brazilian firms. It also contains data on the cooperative arrangements for innovation, the main sources of information for innovation, the types of cooperative activities, etc. PINTEC follows the Oslo Manual, which was developed by OECD and widely applied on European innovation surveys. The sample of the 2005 edition of the survey comprises 89,162 domestic firms and 1,893 foreign firms, totalling 91,055 firms. The group of innovative firms is much smaller, with 29,951 firms (32.9 percent of total) declared having performed product and/or process innovation between 2003 and 2005.

Innovation activity is understood as more than R&D activities; as a matter of fact, in Brazilian firms a significant part of innovation expenditures takes place through the acquisition of mew machinery and equipment, software and also training activities. From the total of innovative firms, only 6,021 (20 percent) declared that their R&D activities have a strong or average role for innovation (IBGE, 2007).

Another key aspect of innovative activities in Brazil that has been brought to light by PINTEC is the difference in the patterns of innovation between domestic and foreign firms operating locally. Out of the more than 89 thousand domestic firms, 5,537 have declared expenditures in internal R&D, a mere of 6.2 percent of the total. For foreign firms, on the other hand, the share of R&D was 33.3 percent. That means to say that, in relative terms, the number of foreign firms that have internal R&D expenditures is five times bigger than the same group of domestic firms. Table 11.3 shows that while domestic firms spent a total of over R$7.2 billions, foreign firms spent R$4.9 billion. Considering the number of firms in each group, the average expenditure of a foreign firm is obviously higher.

It is important to note that foreign firm’s innovative activities impact positively on domestic firms in Brazil. One study has shown that the competition with foreign firms in some sectors tends to stimulate innovation by domestic firms (De Negri and Salerno, 2005). Another study found positive vertical spillovers through backward linkages with foreign firms (Gonçalves, 2003). Table 11.4 shows the sectoral breakdown of R&D expenditures in the manufacturing industry. The most innovative sectors for domestic firms (in terms of total R&D expenditure) are Oil and Gas, Other Transport Equipment (where aerospace industry is placed) and Chemicals & Pharmaceuticals. For foreign firms Automotive and Auto Parts, Chemicals & Pharmaceuticals, and Electronic Equipment are the most innovative sectors.

Table 11.3: *Absolute R&D expenditures of firms, 2003-05 (in R$ 1.000)*

	Internal R&D	External R&D	Total	percent
Domestic	6,698,048	547,843	7,245,891	59.18%
Foreign	3,689,442	1,308,781	4,998,223	40.82%

Source: PINTEC, 2005.

Table 11.4: *R&D expenditures in manufacturing sectors according to capital ownership (in R$ 1,000)*

	Domestic Firms		Foreign Firms	
	Internal R&D	External R&D	Internal R&D	External R&D
Total Manufacturing	3,877,494	388,148	3,157,859	555,922
Food & beverages	187,929	13,067	105,621	6,551
Tobacco	…	1,612	20,792	…
Textiles	53,568	2,296	2,033	781
Clothing	27,936	1,269	…	…
Leather products	66,373	6,672	…	…
Wood products	19,785	644	…	…
Pulp and paper	61,390	3,102	23,975	3,531
Edition& printing	8,058	570	10,711	…
Oil & Gas	944,785	133,157	5,138	1,156
Chemicals and pharmaceuticals	453,613	34,944	410,762	136,415
Rubber and plastics	97,671	16,912	96,902	2,922
Non metallic materials	83,750	7,831	28,664	820
Metallurgy	107,385	4,120	70,022	15,405
Metal products	56,421	4,680	30,762	557
Machinery and equipment	220,852	10,113	150,200	12,941
Informatics equipment	54,753	21,997	98,628	13,066
Electric devices & machinery	145,657	5,568	249,181	11,763
Electronic equipment	134,045	28,736	277,307	157,228
Medical instruments	149,854	5,757	20,477	…
Automotive and auto parts	173,233	21,654	1,519,320	185,844
Other transport equipment	750,091	58,838	24,079	…
Furniture	80,345	4,609	6,558	4,518

Source: IBGE: PINTEC, 2005.

Differences between innovative activities from foreign and local firms are not only quantitative, but also qualitative. The types of innovation informed by foreign firms are frequently associated with the 'D' side of R&D, i.e., the development of products or their adaptation to the local market requirements. This trend has shown signs of change in recent years, as Brazilian branches of large multinationals have started to lead innovative processes in their global value chains (Gomes, 2003; Araújo, 2005). An illustrative case comes from the automotive industry. General Motors Brazil became the main responsible for the development of a small car platform for developing markets, in a project named 'Blue Macaw', which took place in early 2000s (Queiroz and Quadros, 2005). In fact, the huge expenditures by foreign firms in internal R&D in the automotive sector reveal the great role that these firms have in the Brazilian innovation system.

Another distinction between the innovative activities of domestic and foreign firms is the fact that domestic firms do more process innovation (26.4 percent of domestic firms), whereas foreign firms have shown balanced share of process and product innovation (around 50 percent for each), as is shown on Table 11.5. The sectors that carry out more product innovation also differ by capital ownership. Domestically, leather and shoes are the leader, and metallurgy and automotive, in which most of the firms are concentrated, lead for foreign firms

A study with data from the previous innovation survey found that 24.6 percent of foreign firms could be considered innovative vis-à-vis 1.15 percent of domestic firms (De Negri and Salerno, 2005). However, the authors also point out that, when analysed in relative terms (R&D expenditures/ revenues) the distance between their innovative efforts is not that big: 0.62 percent for domestic and 0.75 percent for foreign firms (Araújo, 2004, quoted in De Negri and Salerno, 2005). In absolute terms, domestic firms spent R$ 2.03 billions (US$1.12 billion) in R&D activities in 2000, and multinationals spent R$1.7 bi (US$930 million).

Regarding the local distribution of expenditures on R&D, the public sector has historically responded for the largest share – most of it is destined to universities and research institutes (OECD, 2006). In 2000, public expenditures on R&D were 56.6 percent of the total; in 2008 the government spent 53.6 percent (MCT, 2010). The expenditures of the private sector are still less than desirable, since private innovation is usually more commercially oriented – and should respond for a larger share of expenditures if a country wants to advance in terms of economic and technological development.

The degree of newness of innovative products also differs according to firm ownership. Although relatively less innovative in terms of product innovation, domestic firms account for an important amount of new products, in different degrees of newness. Table 11.6 shows that most innovative domestic firms carry out what is known as ‘defensive innovation’, i.e., undertaking innovation to follow their competitors. The boldest innovations – new to the world – takes place in fewer firms, regardless of capital ownership. These indicators show that multinational firms still keep the more noble part of the innovation at their headquarters or in their main R&D facilities

Table 11.5: frequency of process & product innovation in innovative firms by capital ownership

Process Innovation		*Product Innovation*	
Domestic	Foreign	Domestic	Foreign
23.541 (26.4%)	963 (50.8%)	16.827 (18.9%)	957 (50.6%)

Note: Percentages among same ownership status firms
Source: IBGE, PINTEC 2005.

Table 11.6. *Degree of newness according to capital ownership*

New to firm		*New national market*		*New World*	
Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
14.486	539	1.978	337	363	81

Source: IBGE, PINTEC 2005.

Table 11.7. *Innovative behaviour by firm size (percent of firms)*

Employees	Innovation Rate	Product	New Products National	Process	Process new to sector - BR
10 - 49	28.9	17.0	2.1	23.1	0.9
50-99	40.6	22.8	3.7	33.2	1.2
100-249	55.5	31.1	6.5	44.8	3.8
250-499	65.2	35.9	9.4	56.0	6.1
>500	79.2	58.1	33.4	68.4	27.1

Source: IBGE, PINTEC 2005.

Table 11.8. *Percentage of innovative firms with or without cooperation arrangements.*

	Product	Process
Firm alone	89.5	9.2
Another firm in the group	1.2	0.7
Firm in cooperation with other firms/ institutes	5.0	3.0
Other firms and institutes	4.0	87.1

Source: IBGE, PINTEC 2005.

The innovation rate is much higher for larger firms, as it would be expected, given that these are the firms with more resources available to commit to the rather risky and expensive innovative activities. Table 11.7 shows the innovation rate increases with firm size. It is worth mentioning that, on average, foreign firms tend to be larger than their domestic counterparts. Table 11.8 shows the percentage of innovative firms that introduced new products or processes either alone or together with another partner. This table reveals that firms rely strongly to external sources, that is, mostly other firms and institutes, when carrying out process innovation. Product innovation, on the other hand, is still mostly done in house, alone, by firms in Brazil.

The available data and studies show whereas innovation activities are gaining strength among local firms, both foreign and domestic, there are still important differences in terms and quantity and quality of expenditures on R&D.

11.4 Human resources and scientific development in Brazil

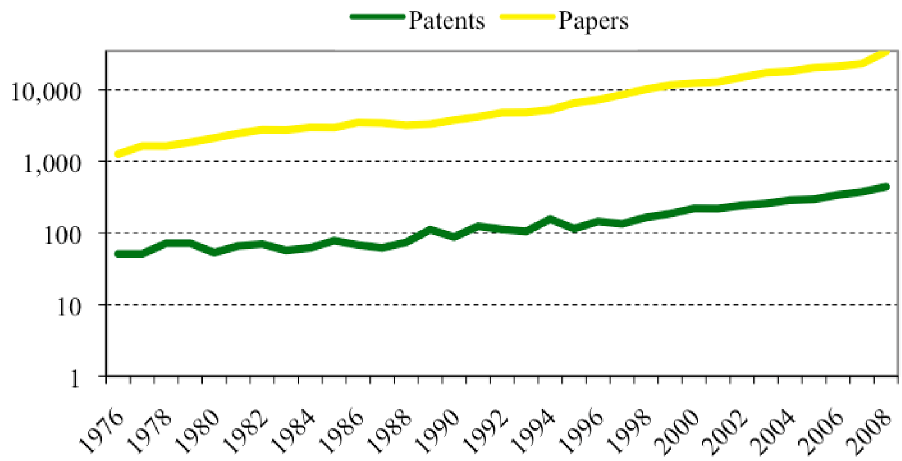
While R&D and innovation are important determinants of industrial development and economic growth, human resources are the main a fundamental part of national innovation system. As mentioned above, in this area Brazil still needs to bridge some gaps between science generation and technological development. Apart from increasing the amount of resources destined to R&D, both public and private, the main challenge that the Brazilian national innovation system faces is the difficulty in turning scientific effort into commercially profitable innovations. Part of the explanation can be found in when the state of the country’s educational system is considered.

Scientific publications have grown steadily in the past years, along with the number of post-graduate degrees per year (OECD, 2006). The number of scientists and engineers in the country has been growing steadily, and currently around 47,000 new engineers graduate every year in Brazil. By means of comparison, China graduates 75,000 people in engineering and computer sciences per year, and India, 60,000 (The Economist, 2010). Table 11.9 shows the that the graduates in the field of social sciences are six times more than engineering graduates in the country.

The problem is intensified by the fact that most post-graduates (scientists) in Brazil work in the public sector. In Korea and the US, around 80 percent of researchers work in the private sector; whereas in Brazil the total of researchers in this sector is of around 26 percent (OECD, 2006). A result of this low engagement of scientists in the private sector is the relatively small number of triadic patents. Moreover, most of the patents are held by the public sector (universities and public enterprises such as Petrobras).

Another important factor is the relatively scarce number university-industry partnerships, one of the most important types of cooperation due to its role in bridging the gap between pure science and applied technological knowledge. This is an important aspect to be considered in Brazil, where in spite of great scientific advances accumulated in the past 25 years, innovative capabilities still lag behind the possibilities brought by the scientific evolution in Brazil (Zanotto, 2002). Figure 11.1 shows the evolution between the number of papers produced and patents applied during 1976-2008.

Figure 11.1. *The science & technology gap in Brazil: patents and paper production 1976-2008*



Source: ISI Web of Knowledge, USPTO.

Table 11.9. *Graduates in tertiary education, per area*

	1995	2008
Exact sciences	22,703	61,528
Social sciences	146,066	328,239
Engineering	16,526	47,098
Total	245,887	800,318

Source: INEP, Ministry of Education, 1995, 2009.

Table 11.10 shows that Brazil has recently seen a boom of private institutions of tertiary education. Most of these institutions concentrate on areas such as management and social sciences (OECD, 2006). The number of vacancies in public institutions is still behind demand, even with the consistent increase, which has been observed over the past 15 years. As a means to counterbalance the lack of vacancies in public institutions, the government provides funding for tertiary education for the poorest students (PRO-UNI). A policy to establish quotas for minorities in some public universities is also being applied since 2001. However, access to tertiary education in the country is still limited to a small privileged share of the population – with over 29 millions of people between 20-29 years, tertiary enrollment reaches less than 10 percent of the population in this age range.

Another key indicator is related to the educational level of the workforce dedicated to R&D. Considering only innovative firms, only 1.3 percent of the total workforce is involved with R&D. Of this number, only 13.4 percent have a post-graduate degree and 45 percent have a graduate degree. As a whole, Brazil has 1.32 researcher (Full Time Equivalent) per each 1.000 people employed. Table 11.11 presents the total number of researchers working in innovative firms, by level of qualification

Table 11.10*: Institutions and student registrations per year*

	2008		*1995*	
	Institutions	Registrations	Institutions	Registrations
Public	236	1,273,965	210	598,579
Federal	93	643,101	57	353,235
State	82	490,235	76	201,974
Municipal	61	140,629	77	43,370
Private	2,016	3,806,091	684	529,353
Total	2,252	5,080,056	894	1,127,982

Source: Ministry of Education, INEP, 2009.

Table 11.11. *Human resources working on R&D in innovative firms, by level of qualification - 2005*

Total HR in R&D	Post-grad	Grad	High-school	Other
83,944	11,283	38,071	24,082	10,508

Source: IBGE, PINTEC 2005.

11.5 Knowledge flows and innovation networks

The increasing speed of technological change demands a more effective response mechanism by actors in the innovation system. A close connection between those who create and transform knowledge into profitable goods helps actors in reacting to technical change - and this association of different actors is the central piece for creating an effective and efficient innovation network.

An important source of knowledge flows between actors is through cooperative arrangements for innovation. These arrangements can be established between actors within as well as with other foreign institutions. Significant associations can take place between firms, either competitors or in related sectors, or between firms and research institutes or universities. Studies have shown that innovation has become an increasingly collective activity (Chesborough, 2003; Lundvall and Borrás, 1997) that involves a number of actors, the elements of an innovation system. According to Lundvall and Borrás (1997), networks "involve information exchange, interactive learning and direct cooperation" (p. 102). Due to its importance for the dynamics and evolution of national innovation systems, cooperation has become widely studied and innovation surveys devote special attention to understanding how the phenomenon takes place.

PINTEC has a section devoted to understanding cooperation among Brazilian firms. The 2005 innovation survey registered a rise in cooperative activities of firms in comparison with the 2003 survey. The share of manufacturing firms that declared to have participated in a cooperative arrangement rose from 3.8 to 7.2 percent from 2003 to 2005 (IBGE, 2007). The growth was even stronger among small and medium sized firms (with less than 500 employees). In firms with more than 500 employees, there was a small decline in the percentage of cooperative firms.

Despite of the observed growth, the share of cooperative firms Brazil is much lower than that of in surveys carried out in developed countries. A study from OECD has shown that one in every ten European firms cooperated in the period 2002-04, or one in every four of the innovative firms (OECD, 2007). In Germany, the share of cooperative firms reached 50 percent (Fritsch and Lukas, 2001).

Among industrial sectors, chemicals and pharmaceuticals, and food and beverages are the leaders in cooperation among Brazilian firms, followed by machinery and equipment, rubber and plastic products, and metal products. Table 11.12 shows that among services firms, which were surveyed for the first time in the 2005 edition of the survey, the share of cooperative firms reached 24 percent, making this the leading sector in terms of cooperation for innovation (IBGE, 2007). Within services, IT services are the leading sector in cooperation.

Table 11.12. *Innovative and Cooperative firms by sector*

Sector	Innovative	Cooperative	percent C/I
Total industry	29,951	2,139	7.1
Total services	2,418	582	24.1

Source: IBGE, PINTEC 2005.

Table 11.13: *Cooperation for Innovation - by type of partners and R&D partnerships, per number of firms*

Partner	R&D Partnership	Other Partnerships
Clients/consumers	773	790
Suppliers	747	1083
Competitors	146	246
Other firm group	294	261
Consultancies	339	433
Universities/Research institutes	663	404
Training Centres	207	474

Source: IBGE, PINTEC 2005.

The types of cooperation declared by local firms are shown in table 11.13. Vertical partnerships (between clients, consumers and suppliers) are the most frequent type of cooperation among Brazilian firms. The second most usual type of cooperation is between firms and universities and research institutes. Partnerships with competitors are the less frequent type of cooperation.

Table 11.14 distinguishes the location of partners for innovation. In Brazil, domestic partnerships are still predominant. Only a very small share of firms cooperates with foreign partners. The most frequent international partnership is, not surprisingly, of foreign firms and other firms from the group. Another important information contained in the table is the number of firms, which cooperate with a subsidiary abroad. The number (39) is relatively small if compared with other types of cooperation, but may indicate that Brazilian firms are expanding the range of cooperation and using their foreign presence as a means to enhance innovation and technological capabilities. De Negri and Salerno (2005) have also shown that domestic firms engaged in foreign operations have a higher tendency to engage in innovative activities. Foreign partnerships are rare among domestic Brazilian firms given the few cases of internationalized Brazilian firms, and the even smaller number of Brazilian multinationals that innovate on a global basis.

Table 11.14. *Types of cooperation by capital ownership and location of partner*

Partner	*Domestic*		*Foreign*	
	Local	Abroad	Local	Abroad
Customers	1131	57	143	31
Suppliers	1087	107	138	51
Competitors	317	23	23	10
Another firm of the group	79	39	23	220
Consultancies	428	22	53	11
Universities	599	14	113	…
Training Centers	461	…	58	4

Source: IBGE, PINTEC 2005.

Table 11.15. *Sources of Information for Innovation, by capital ownership*

	Domestic	Foreign
Suppliers	19,740	789
Clients	18,881	872
Competitors	13,749	495
Training centres	4,832	231
Consultancies	3,800	262
Universities	3,686	231
Other firms/ group	563	852

Source: IBGE, PINTEC 2005.

Cooperative arrangements between foreign firms and local partners have an important role as knowledge disseminators in Brazil. As important executors of R&D and innovation in Brazil, foreign firms have a very important role as disseminators of new technologies, managerial practices and other kind of innovation among domestic firms.

Regarding the sources of information for innovation, Brazilian firms declared to resort more to suppliers, followed by clients and competitors. Table 11.15 shows that universities are ranked sixth, right below training centres, as a source of knowledge for innovation. In the case of foreign firms, clients and other firms from the group are the main sources. One way to interpret this trend may be the fact that foreign firms are more often part of a larger conglomerate than their domestic counterparts and therefore it is natural to have sister firms as important sources of information.

The figures in patenting with foreign ownership or patents with a foreign co-inventor corroborate the previous trend of low foreign partnerships and, possibly, a more limited insertion of local firms in global innovation networks. Table 11.16 shows that the number of cooperative patenting is quite small, though numbers have slightly increased in the past 15 years. Developed countries, in special the USA, are the most immediate markets and partners to these patents, indicating that those are the most important markets for Brazilian products.

Table 11.17. *Number of Patents – by date of reference.*

	1995	2000	2008
Foreign ownership of domestic inventors	4	5	5
Domestic ownership of Foreign Inventors (total)	25	58	89
EU27	7	16	21
USA	16	42	63
Patents with foreign co-inventor	25	58	89
EU27	7	10	21
USA	15	42	63

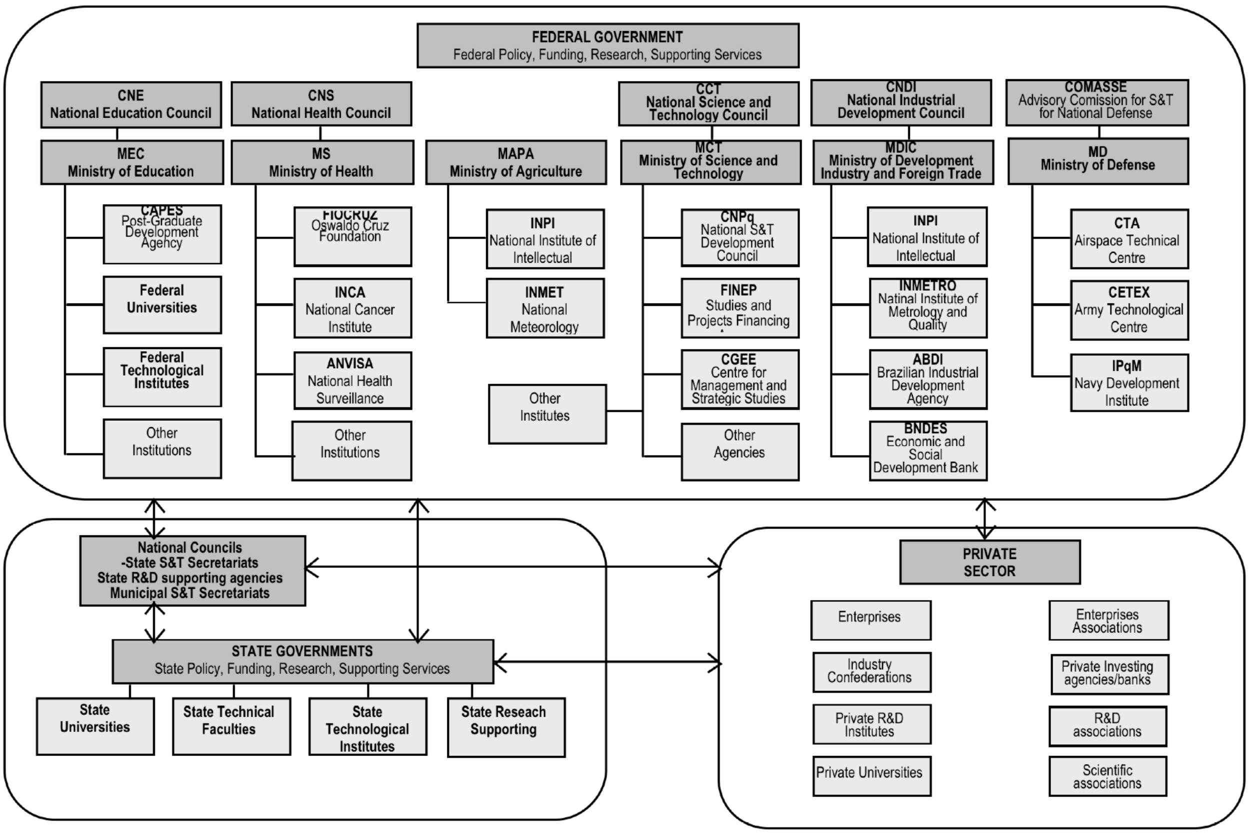
Source: OECD Statistical Database.

11.6 Institutional arrangements for innovation in Brazil

To have a more effective and successful innovation network, governments can elaborate policies designed to bringing important actors together and to stimulate innovation and interaction among them. This constitutes may be the greatest challenge to be overcome in order to improve the Brazilian national innovation system by having a larger number of local firms integrated with global innovation networks. Similarly to many developing countries, Brazil has an immature national innovation system characterized by the existence of partial connections between the scientific and the technological dimensions (Albuquerque, 2004; Rapini et al., 2006). Government policies for innovation seem to be, until now, insufficient to bring together actors into a more cohesive network.

Figure 11.2 shows all institutions involved in the Brazilian national innovation system. The system is a complex gathering of federal and state institutions working under the tutelage ministries, such as Education, Industry and Trade, Agriculture, Science and Technology, Health, and Defence. The coordination of so many institutions is sometimes difficult. Communications flows can be disrupted by fragmentation, and joint action between institutions is a constant challenge. However, there has been renewed efforts by the federal and state governments to foster the convergence of initiatives of institutions working on similar issues in order to achieve better aggregated results.

Figure 11.2. *Institutions in the National Innovation System in Brazil*



Source: elaborated by the authors, based on OECD, 2006.

Among the main policies recently implemented, it is worth highlighting the Industrial, Technological and Foreign Trade Policy Plan (PITCE), announced in the end of 2003. Its main objective is to increase the competitiveness of the Brazilian industry by fostering innovation. PITCE targets particular sectors considered strategic, such as IT, pharmaceuticals and capital goods. PITCE is considered a successful return of policy efforts to recover the capacity of the government to carry out coordinated industrial policies (Arroio, 2007). The policy also aims to support small and medium enterprises and the development of local productive arrangements.

Apart from PITCE, another instrument to promote S&T is the Sectoral Funds. Created in the late 1990s, the funds were designed to give financial support to key sectors. Continued and expanded by the government, the funds also have an important role funding innovation projects. The number of funds rose from 4 to 15 from 2000 to 2005. Currently, there are 26 sectoral funds operating in diverse areas of development, from biofuels, energy, airspace industry, to nuclear, nanotechnology and biotech.

PINTEC presents data on the use of government policies by both domestic and foreign firms. Government funding for R&D and technological innovation projects is by far the most used mechanism by firms located in Brazil. Table 11.18 lists some of the main policy instruments for supporting innovative activities in Brazil. The benefits of the Innovation Law, the Informatics Law, as well as R&D project funding when jointly undertaken by firms and universities/research institutes, still have a limited scope, due to not only the small innovative propensity of Brazilian firms but also to the lack of information on how such incentives work and can be accessed. Although also low, foreign firms make relatively more use of innovation support programs.

11.7 Concluding remarks

The main purpose of this chapter was to highlight the main characteristics of innovation in Brazil, its main actors and how innovation agents associate. With data from the latest Innovation Survey carried out in the country, we drew an outline of how innovation takes place in domestic as well as foreign firms from several sectors.

Table 11.18: *Use of Innovation Support Programs, by capital ownership*

Program	Domestic	Foreign
Innovation Law	164	58
Informatics Law	290	54
R&D Projects; U-I partnerships	420	53
Funding of R&D/ Innovation projects	3828	102
Researcher in-company scholarship	63	11
Venture Capital	395	6
Total of Firms by ownership	89162	1893

Source: IBGE, PINTEC, 2005.

In Brazil, multinationals innovative activity plays a very important role for the evolution of the country’s innovation system. These firms are also important due to the fact that, by being part of the industrial structure for such a long time, they contribute with the dissemination of knowledge, technology and managerial practices. The more the agents in the innovation system interact with each other, the easier and swifter is the exchange of knowledge and the more the country benefits from the dissemination of knowledge.

Cooperation among agents for innovation becomes more important as the speed of technological changes intensifies, the costs for innovation increases and with it uncertainty and risk. For this reason more and more industries, in all countries, resort to cooperative arrangements in order to make innovation activities more effective and efficient. Cooperation among actors is still rather limited in Brazil, and international partnerships are even more rare. This constitutes a deterrent in placing the country within a global innovation network. It also hampers the success of the international insertion of domestic firms. The scarcity of cooperative activities is in par with the still timid extent with which firms in Brazil perform innovative activities in general. Though having achieved significant advances in its scientific field, the development of scientific discoveries into marketable innovative products is not an easy, straightforward process. In this regard, specific educational policies to graduate more scientists and engineers, along with a plan to make more of these professionals to work in the industry, would be a starting point to reverse this gap. Promoting a stronger, more constant relationship between the scientists that in Brazil concentrate in the public& educational sectors with the firms that ultimately will generate innovation is another aspect that deserves the attention, for a more effective, successful innovation system to set up.

Recently, innovation has become a concern of industrial policies that want to strengthen the country's competitiveness in sectors considered essential but still underdeveloped in the national realm, such as IT, pharmaceuticals and capital goods. It is still essential that Brazilian policies stimulate an interactive environment among the different actors in the innovation system. In special, firms need to tap universities as a central source of knowledge and innovation. Stronger linkages between the actors that generate pure knowledge with those who turn then into a profitable asset are essential for the country to bridge the gap that still persists between the country's scientific achievements and its innovative capacity.

11.8 References

Araújo, R.D. 2005. Esforços tecnológicos das firmas nacionais e estrangeiras. In: De Negri, J., Salerno, M.S., *Inovações, padrões tecnológicos e desempenho das firmas industriais brasileiras*, pp. 119-164. Brasilia, IPEA.

Arroio, A.C.M. 2007. Development, Innovation and Public Policy: the Brazilian Experience in Support of Micro and Small Enterprises. *Redesist Research Paper* 03/07.

Benfratello, L. and A. Sembenelli 2002. Research joint ventures and firm level performance. *Research Policy* 31: 493-507.

Bernardes, A.T. and E.M. Albuquerque 2003. Crossovers, thresholds and interactions between science and technology: lessons for less-developed countries. *Research Policy* 32: 865-885.

Cassiolato, J.E. e*t al.*, 2001. Local systems of innovation in Brazil, development and transnational corporations: a preliminary assessment based on empirical results of a research project. Druid Summer Conference 2001.

Chesbough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Boston: Harvard Business School Press.

Chesbough, H., W. Vanhaverbeke, and J. West, eds. 2006. *Open Innovation: Researching a New Paradigm.* Oxford: Oxford University Press.

Cohen, W., R.R. Nelson, and J. Walsh 2002. Links and impacts: the influence of public research on industrial R&D. *Management Science*, 48:1-23.

Cortes, M., Pinho, M., Fernandes, A., Smolka, R. & Barreto, A. (2005), Cooperação em empresas de base tecnológica: uma primeira avaliação baseada numa pesquisa abrangente. *São Paulo em Perspectiva* vol 19 (1), 0. 85-94, jan-mar.

Cruz, C.H.B, 2000. A universidade, a empresa e a pesquisa que o país precisa. *Parcerias Estratégicas* 8: 5-30.

De Negri, J., G. Arbix, and M.S. Salerno, 2007. *Internationalization generates quality jobs and improves the competitiveness of Brazilian firms*. Paper presented at 1st MEIDE Conference, UNU-MERIT, Maastricht – The Netherlands.

De Negri, J., and M.S. Salerno, 2005. *Inovações, padrões tecnológicos e desempenho das firmas industriais brasileiras.*

Fabrizio, K. 2006. The Use of University Research in Firm Innovation. In: Chesbrough, H., Vanhaverbeke, W. and West, J. eds, *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press, pp. 134-160.

Gonçalves, J. E. P. (2003), *Empresas estrangeiras e Transbordamendtos de Produtividade na Indústria Brasileira: 1997 – 2000*. Dissertação de Mestrado apresentada ao Instituto de Economia – UNICAMP.

Hagedoorn, J. 2002. Interfirm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy* 31: 477-492.

IBGE, *Pesquisa da Inovação Tecnológica 2005*. Rio de Janeiro, IBGE, 2007.

Iglesias, R. and P.M. Veiga 2002. Promoção de Exportações via Internacionalização das Firmas de Capital Brasileiro. In: BNDES, *O desafio das Exportações.*

Ministério de Ciência e Tecnologia – MCT (2010), Indicadores de recursos aplicados em Ciência e Tecnologia. Fonte.

Narin, F., K. Hamilton, and D. Olivastro 1997. The increasing linkage between US technology and public science. *Research Policy* 26: 317-330.

Narula, R., and A Zanfei 2006. Globalization of Innovation: the Role of Multinational Enterprises. In: Fagerberg, J, Mowery, D., Nelson, R., *Oxford Handbook of Innovation***,** Oxford: Oxford University Press, pp. 318-345.

OECD 2008. *Open Innovation in Global Networks*. Paris: OECD.

OECD 2006. *Brazil*. OECD Economic Surveys, Vol. 2006/18 Paris: OECD.

Perkmann, M. and K. Walsh 2007. University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews*, 9: 259-280.

Queiroz, S. and R.Q. Carvalho 2005. Empresas Multinacionais e Inovação Tecnológica no Brasil. *São Paulo em Perspectiva*, Vol 19 (2), mai-jun, pp.

Rapini, M., E.M. Albuquerque, L.M. Silva, S. Souza, H. Righi, and W. Cruz 2006. Spots of Interaction: an Investigation on the Relationship Between Firms and Universities in Minas Gerais, Brazil. *CEDEPLAR-UFMG Texto para Discussão N. 286*, fevereiro.

Teece, D. 1992 Competition, cooperation and innovation – organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behaviour and Organization***,** 18: 1-25.

Tether, B. 2002. Who cooperates for innovation, and why – an empirical analysis. *Research Policy* 31: 947-967.

Veuglers, R. 1997. Internal R&D expenditure and external technology sourcing. *Research Policy* 26: 303-315.

Yusuf, S., and K. Nabeshim, *How Universities Promote Economic Growth*. World Bank: Washington D.C.

Zanotto, E.D. 2002. Scientific and technological development in Brazil: the widening gap. *Scientometrics*, Vol. 55: 383-391.

Chapter 12: South Africa

André Buys and Hendrik Marais, Human Sciences Research Council (HSRC)

12.1 Introduction

South Africa underwent radical constitutional transformation in 1994 when a new government took office following the first all-inclusive democratic election which was won by the African National Congress of Mr Nelson Mandela. In principle, that change of government represented a transformation from a pro-white system of official and unofficial discrimination – which included the science, technology and innovation (STI) system of the country – to a black majority government officially committed to a non-racial society. The overarching policy of democratic governments since 1994 has been to eradicate inequalities of the past, to reconnect the country to the international community and in the process to provide conditions for sustained growth. Some of the transformation brought about in the science, technology and innovation system included the introduction of the national system of innovation concept, comprehensive institutional reviews, changes to governance and national STI priorities and a range of associated policies and strategies. Several recent 'before-after' reviews of the development of the South African STI system have shown that changes at the policy level have been extensive, but that the implementation of those policies and strategies have in many cases lagged too far behind (NACI, 2002; Mouton, 2006; OECD, 2007; Marais and Pienaar, 2009). The STI system of the country could indeed be described as one in transition – the political context of this chapter.

This chapter starts by offering thumbnail sketches of the nature and performance of the economy of South Africa, before providing detailed information on the main actors of the national system of innovation and their activities. Institutional arrangements and policies are next described, followed by an overview of the country's learning systems and technological capabilities and the chapter concludes with an assessment of the performance of the national system of innovation.

12.2 Nature of the economy

South Africa has the most advanced economy in Africa. The country has abundant natural resources and well-developed financial, legal, communications, energy and transport sectors. As Figure 12.1 illustrates, South African productivity declined sharply during the 1980's as a result of regional military conflict, internal political unrest, trade and financial sanctions and disinvestment. This decline was halted with the political transformation in 1994. Economic recovery was initially slow, but the economy has been in an upswing since 1999 with an average annual economic growth rate of about 5 percent. The economic growth rate dropped to about 3 percent in 2008 when economic activity was adversely affected by the world recession, energy shortages and slowing domestic consumption.

South Africa is a middle-income country with a gross domestic product (GDP) per capita of $10,178 in 2009 EKS$. However, South Africa is not a typical middle-income country. It has an extreme dual economy consisting of a highly-developed financial and industrial economy that exists alongside a large underdeveloped informal economy. The 'second economy' (broadly defined here as the informal sector, unskilled agriculture, unemployed and discouraged work-seekers) in South Africa is large (52 percent of the labour force). Various studies have shown that the 'second economy' contributes only between ten to fifteen percent of GDP. Table 12.1 shows a breakdown of the population in these sectors.

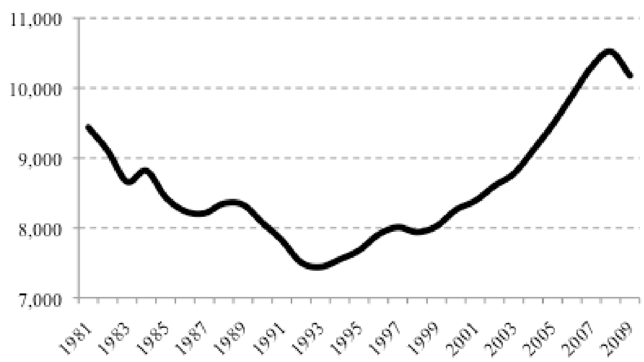
The developed formal sector (or 'first economy') is comparable in most respects to the average country in the European Union and has a high potential for growth and development. However, the large underdeveloped second economy is a daunting developmental challenge. The main threats to the country's long-term economic growth and political stability are large wealth disparities (GINI coefficient of 0.666), unemployment and discouraged work-seekers (32.4 percent of labour force), poverty (47.1 percent of population live below national poverty line), a high incidence of HIV/AIDS (11 percent of population HIV+) and violent crime (0.5 murders p.a. per 1,000 people).

Table 12.1. *Employment in South Africa, in thousands (1st quarter, 2010)*

		Employment
First economy		9,062
Formal sector (non-agricultural)	8,974	
Skilled agriculture	88	
Second economy		9,889
Informal sector (non-agricultural)	2,009	
Agriculture (unskilled)	562	
Private households	1,169	
Unemployed	4,310	
Discouraged work-seekers	1,839	
Total Labour force		18,951
Not economically active		12,399
Population 15–64 yrs		31,350
Total population		49,300

Source: Statistics SA, 2010a.

Figure 12.1. *GDP per Capita in South Africa, in 2009 EKS$*



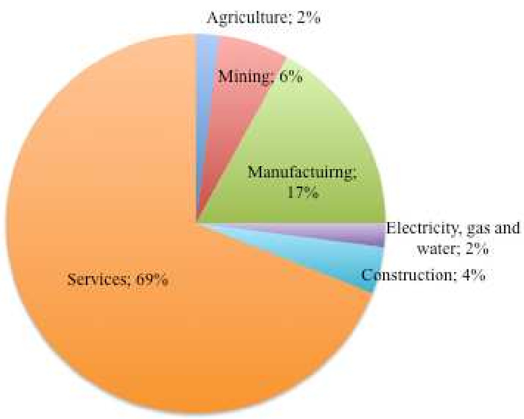
Source: The Conference Board Total Economy Database, January 2010.

The developed formal sector (or first economy) is comparable in most respects to the average country in the European Union and has a high potential for growth and development. However, the large underdeveloped second economy poses a daunting developmental challenge. The main threats to the country's long-term economic growth and political stability are large wealth disparities (GINI coefficient of 0.666), unemployment and discouraged work-seekers (32.4 percent of labour force), poverty (47.1 percent of population live below national poverty line), a high incidence of HIV/AIDS (11 percent of population HIV+) and violent crime (0.5 murders per 1,000 people every year on average).

Although South Africa has a resource-based economy, it has moved away from primary resource-based industries such as agriculture, fishing, forestry, mining and quarrying, which now contribute only 10 percent to GDP. South Africa has followed the Scandinavian resource-intensive industrialisation model rather than the Latin-American and African models. Labour intensive industries such as food and beverages, textiles and clothing and footwear have declined, whereas capital intensive sectors have grown. The minerals-energy complex (petro-chemical, metallic minerals processing, plant and machinery) and electricity, construction, transport equipment, agro-processing, brewing, paper and pulp now contributes 24 percent to GDP. South Africa's exports also resemble that of a capital-abundant rather than labour abundant country. The decline in export-orientated manufacturing is seen as one of the main reasons for the high rate of unemployment in the economy.

South Africa's formal economy has also shifted from labour-intensive agriculture, mining and manufacturing to knowledge-intensive service industries. Figure 12.2 illustrates the structure of GDP in 2010, highlighting that services contributed 69 percent to GDP. South Africa has therefore entered the post-industrialisation phase in line with high-income developed countries. These structural changes in the economy can be partly explained as the unintended consequences of a highly regulated labour market and trade union power that has inhibited the growth of labour-intensive industries by inflating the cost of labour.

Figure 12.2. *Contribution to GDP by industrial sectors*



Source: Statistics South Africa, 2010b)

Government policy is to "eliminate the second economy". The Accelerated and Shared Growth Initiative for South Africa (ASGISA) launched in 2006 aims at halving unemployment and poverty by 2014. It is widely accepted that GDP growth of between 6 and 7 percent per annum is required to reverse the unemployment trend (SA Presidency 2006).

The size distribution of firms is important as it is well known that firm size relates to capabilities such as R&D and innovation. The South Africa economy is dominated by a relatively small number of large corporations. They have considerable pricing power due to a lack of competition (i.e. import parity pricing). The positive value role they play lies in the creation and accumulation of innovative capacity that also leaks to other sectors. Small and medium-size enterprises (SME) are, however, important for employment creation. SMEs produced only 36 percent of GDP (2002) but provided 72 percent of employment, whereas large firms (utilities excluded) provided less than 5 percent of employment. South Africa has a low level of entrepreneurship. Less than 6 percent of adults own and manage a start-up business. This is the lowest amongst developing countries. Only 1.3 percent of such businesses survived for more than 3.5 years, compared to a mean of more than 10 percent in developing countries (NACI 2006:18).

12.3 The economic performance of South Africa

Table 12.1 presents some of South Africa's key economic indicators for the period 2005 to 2009. Multifactor productivity grew at an average annual rate of 3.0 percent from 1996-2005 (Productivity SA 2007). GDP growth in South Africa is driven by total factor productivity (primarily technology growth and efficiency), and has overtaken labour and capital's contribution to GDP growth (OECD 2007). This is attributed to openness (spill-over and upgrading), private sector participation and investment. Notwithstanding the recent growth of total factor productivity, it is still only around average for a middle-income country.

Table 12.2. *Key economic indicators*

	2005	2006	2007	2008	2009
GDP, PPP (current international $ million)	398,757	433,212	467,390	492 ,55	492,684
GDP per capita, PPP (current international $)	8,504	9,141	9,768	10,109	10,244
GDP growth (annual percent)	4.97	5.32	5.10	3.06	3.2
Inflation, CPI (percent change)	2.1	3.2	6.1	9.8	7.2
Unemployment (percent)	26.7	25.5	23.0	23.1	24.3

Source: South African Reserve Bank, International Monetary Fund, World Bank Development Indicators, Statistics SA.

South Africa is ranked 54th in the world out of 139 countries on the Global Competitiveness Index (World Economic Forum 2010). The country benefits from its large domestic market size (ranked 24th) and does well on measures of the quality of institutions and factor allocation, such as financial market development (9th), the accountability of private institutions (2nd), intellectual property protection (24th) and goods market efficiency (40th). South Africa is also highly ranked in more complex areas such as business sophistication (38th) and innovation (44th), benefiting from good scientific research institutions (ranked 29th) and strong collaboration between universities and the business sector in innovation (ranked 24th).

On the other hand, South Africa has some enduring weaknesses. The country ranks 97th in labour market efficiency, with inflexible hiring and firing practices (135th), a lack of flexibility in wage determination by companies (131st) and poor labour-employer relations (132nd). Furthermore, the country’s low university enrolment rate of 15 percent (99th) could jeopardise its future innovation performance. South Africa’s infrastructure (ranked 63rd), particularly the transport, energy and telecommunications infrastructure, has suffered from 20 years of under-investment and lack of competition. The business costs of crime and violence (137th), and the sense that the police are unable to provide protection from crime (104th) do not contribute to an environment that fosters competitiveness. Another major concern remains the health of the workforce (business impact of tuberculosis: 135th; HIV/AIDS: 138th) (World Economic Forum 2010).

12.4 The main actors and their activities in the national innovation system

The *key actors* that finance and perform R&D in South Africa are the business sector, the public research institutes and the universities, as well as international R&D collaborative activities. Business enterprises are the dominant actor as shown in Table 12.3. Figure 12.3 shows that the business sector funded 58 percent of all R&D activities, making it comparable in this regard to that of Europe (50 percent) and North America (60 percent).

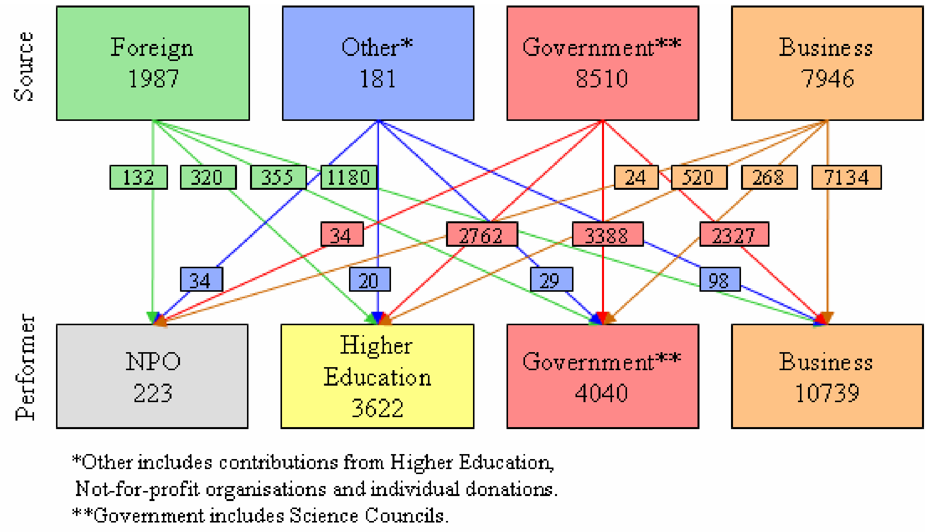
Table 12.3. *Gross expenditure on R&D (GERD)*

R&D expenditure (R billion) by	2006	2007	2008
Government (including Science Councils)	2.95	3.77	4.04
Higher education	2.73	3.30	3.62
Business enterprises	8.24	9.24	10.74
Not-for-profit organisations	0.23	0.21	0.22
GERD	14.15	16.52	18.62
GERD/GDP ratio	0.92%	0.95%	0.93%

Source: NACI 2009

Business funded 45 percent of R&D and performed 58 percent. Most business R&D was performed by large firms (72 percent) of which 20 percent was performed by multinationals. State corporations like Denel, Eskom (e.g. through its Pebble Bed Modular Nuclear Reactor project), Transnet, and the recently privatised Sasol made a large contribution (25 percent performed) to BERD. 28 percent of BERD was performed in the services sector which is high for a middle-income country. Business funding of University R&D is relatively high (14 percent of R&D performed by Universities). Foreign research funding contributed 10.7 percent to GERD and 18 percent of BERD (NACI 2009).

Figure 12.3. *Major flows of funding for R&D in South Africa, 2007/08 (R millions)*



Source: NACI 2010

South Africa's expenditure of 0.93 percent of GDP on R&D in 2008 is typical of a developing country. Most developing countries invest less than 1 percent of GDP in R&D, whereas the United States and the European Union spent 2.7 percent and 1.8 percent of GDP on R&D respectively (NACI 2009). The contribution of South Africa to global R&D expenditure is extremely small, only 0.4 percent of the world's total. It is clearly in a different league than Brazil, India and China that contributed 1.6 percent, 2.2 percent and 9.2 percent respectively (NACI 2009). Because of its very low domestic expenditure on R&D, South Africa's industries are dependent on foreign knowledge and technology for upgrading and innovation. South Africa's minor contribution to the global knowledge pool is also corroborated by other indicators: 0.55 percent of scientific (ISI) publications in 2006 (unchanged since 1995 when it was 0.51 percent), 0.058 percent of patents in USPTO in 2008 (NACI 2009).

South Africa has 18,573 researchers or 385 per million inhabitants. According to UNESCO Institute for Statistics estimates (September 2009) there were 1063 researchers per million inhabitants in the world in 2007. Researcher per million inhabitants in Oceania (4262), Europe (2515) and Americas (2013) were far higher than the world average, whereas research densities were low in Asia (742) and Africa (169). Although the figures for China (1017), Brazil (625), South Africa (385) and India (136) are below average, the normalised figures for these high-population dual-economy countries have to be treated with caution. Expressed as researchers per GDP the picture changes drastically with South Africa having 65 researchers per billion $ (current PPP), comparable to Greece (63 researchers per billion $) and Norway (68 researchers per billion $). The primary value of South Africa's domestic R&D, particularly in the business sector, should therefore be seen as the 'second face' of R&D (Cohen and Levinthal 1989), namely the enhancement of firm's ability to assimilate and exploit existing information rather than the generation of new information.

The role and performance of large enterprises, esp. MNEs vis-a-vis SMEs. A key feature of globalisation is the increasingly important role of Multinational Enterprises (MNEs) as vehicles for Foreign Direct Investment (FDI). Economic theory recognises that MNEs can benefit economic growth in developing countries through generating positive externalities (so-called spill-over effects). These spill-over effects occur predominantly through the R&D and innovation of MNEs, their outsourcing to local firms and their training of local labour. However, the extent to which South Africa benefits from spill-over effects of MNEs remains to be empirically investigated. One empirical study of 55 German firms in South Africa (Gilroy, Gries, Naudé, Schmidt and Bauer, 2001) found that direct technology transfers as a way of knowledge sharing were almost non-existent in the behaviour of these firms. The researchers found that the reason for this non-transfer were that these firms were only serving the domestic market with final products and services.

Many large South African enterprises have expanded their operations into the rest of Africa and beyond. Mining houses led the way, followed by manufacturers and financial institutions. Some examples are Steinhoff International (one of the top five furniture groups in Europe, and the largest in Africa), Illovo Sugar (with extensive agricultural and manufacturing operations in six African countries and in the United States), Alexander Forbes (a leading independent international provider of financial and risk services, ranked in the world's top 10 risk and benefit consultants), Nampak (Africa’s largest packaging manufacturer), Sasol (a global player in chemicals and fuels, active in over 20 countries and on six continents), Dimension Data (designs, supplies and implements communication networks and information technology in 36 countries across six continents), M Cell (owner of cellular phone network operator MTN, one of the largest and quickest growing in the world), Sappi (The world's leading producer of coated wood free papers, with manufacturing facilities on three continents and marketing outlets in over 100 countries), and SABMiller (one of the world's largest brewers with a brewing presence in over 40 countries across four continents). The expansion of many South African firms into Africa and other developing countries could indicate another dynamic. Relative to the EU and other leading economies, SA is a consumer of knowledge, but in Africa and elsewhere it could also be a ‘producer’. The nature and extent of this potential spill-over has not been researched and therefore requires further investigation.

12.5 Institutional arrangements of the South African innovation system

Role players and structures. The interrelationship between structures and functions are summarised in Figure 12.4. The functions served by the different components of the South African NSI are the following:

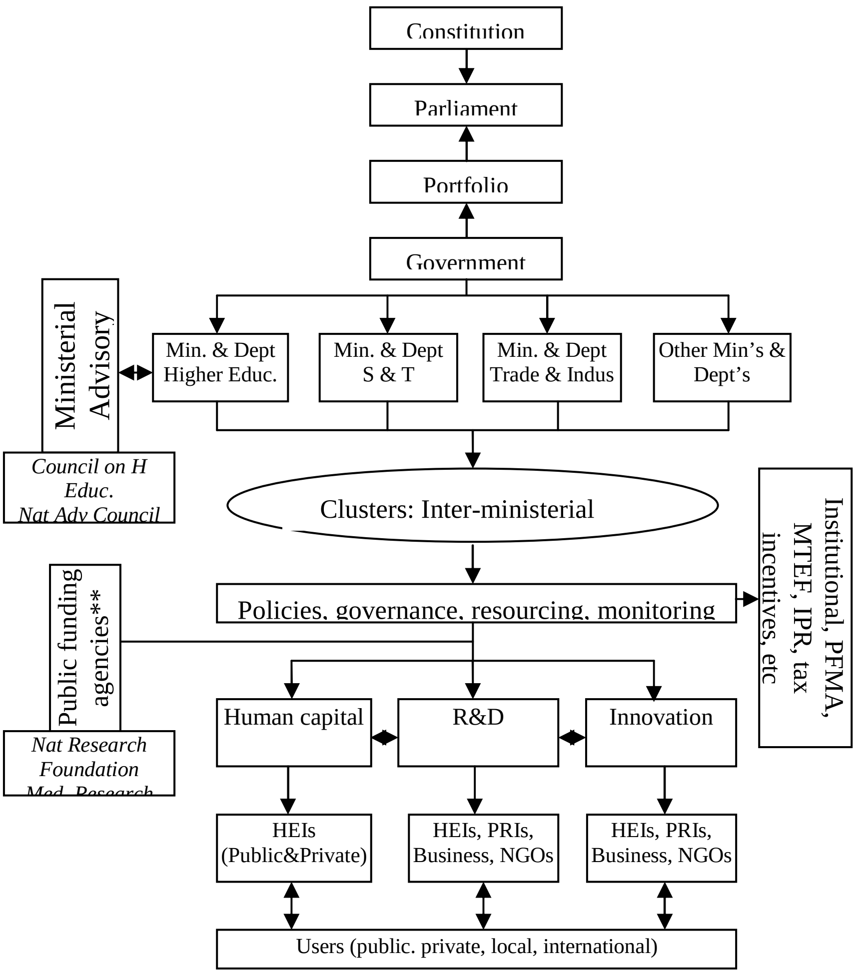
- The legislative and political oversight functions reside in the National Parliament. The Parliamentary Portfolio Committee for S&T makes recommendations to Parliament on draft legislation and its findings with regard to reports submitted by the Department of Science and Technology (DST) and its associated public entities.
- Policy-making and formulation functions with regard to science, technology and innovation reside with the following ministries and their departments: the Ministry and Department of Science and Technology (DST), charged with overseeing the resourcing and management of public NSI institutions and with direct line management responsibility for S&T. Secondly, the Ministry and Department of Higher Education and Training. Thirdly, there are departments such as Trade and Industry, and Minerals and Energy, which both fund and perform R&D and promote innovation actively. The structure provides for horizontal inter-ministerial coordination in the form of a cluster

model while vertical coordination is promoted by institutional acts, the Public Finance Management Act (PFMA) and the Medium Term Expenditure Framework (MTF; the financial plan of National Treasury for four-year periods).

- Bodies mandated to render policy advice to the government are the Council on Higher Education (CHE) that advises the Minister of Higher Education and Training and the National Advisory Council on Innovation (NACI) is at disposal of the Minister of S&T.
- The public funding function is fulfilled by a number of statutory agencies and funding bodies, principally the National Research Foundation, the Medical Research Council and the Technology Innovation Agency (TIA).
- The research performing and innovation functions are located in all 23 universities, 12 major public research institutions, several museums and government departments with research capacities, the business sector and the NGO sector.

It can be concluded firstly that the innovation system is embedded in formal government structures, as part of a parliamentary democracy, secondly that the system provides for all the functions normally associated with a STI system, and thirdly that it is reasonably well populated (see indicator sections of this report).

Figure 12.4. *Structure of the NSI*



Sources: NACI 2006 and OECD 2007

***Visions and plans**.* At least two reviews of the South African national system of innovation have concluded that this country has since 1994 – the end of apartheid and after the first democratic elections – developed an impressive array of STI policies and strategies in its drive to transform the system and to participate in the international exchange of knowledge and innovation (NACI, 2002; OECD, 2007). The rider to this positive conclusion has often been that the country was lagging in the effective implementation and monitoring of those policies and strategies; in the OECD's words, "Too little connection between strategies and their implementation." Be that as it may, before and since 1994 the country has leaned towards a structuralist rather than neo-liberal approach to industrial and innovation policy – initially as a response to international trade and financial sanctions and disinvestment and more recently as approach to accelerating the process of reducing unemployment, poverty and associated dysfunctions of the developmental state in general and the 'second economy' in particular. It would be reasonable to expect that future South African innovation policies would entail more than only addressing framework conditions, but would focus on substantive innovation issues and provide for interventionist strategies. Against this background this section offers a brief overview of the visions and plans, i.e. innovation policies, of the country.

The process of reforming the system was started with the publication in 1996 of a new consolidated policy, the *White Paper on Science and Technology* (DST, 1996), its main thrust having been to broaden the policy scope from an S&T model to a national system of innovation. The *National R&D Strategy* (DST, 2002a) subsequently provided further details on the implementation of the principles of the *White Paper* and identified new national technology missions, such as biotechnology, information technology, and technology for advanced manufacturing. The *White Paper on Education* of 1997 (DoE, 1997) emphasised the importance of Mode 2 knowledge production and the need for university R&D to contribute to development. All three policy documents acknowledged the importance of inter-institutional, interdisciplinary and international collaboration and networking.

The past ten years or so have seen the approval of at least 12 major S&T sectoral/thematic policies and strategies on e.g. biotechnology, nanotechnology and intellectual property rights and the establishment of 20 new institutions and major programmes by various government departments. A regional innovation systems strategy is currently being developed. Four of the most important recent initiatives in rearranging the policy and institutional landscape have been, firstly, the launching of the *Ten-year innovation plan for South Africa* (DST, 2007) which is intended to "ensure that public investment in scientific research not only strengthens the effectiveness of South Africa's NSI, but also yields tangible socio-economic benefits for the country". The Plan identified five so-called grand challenges, viz. strengthening bio-economy; space S&T; energy security; global change esp. climate change; human and social dynamics. Secondly, mention should be made of the founding of the Technology Innovation Agency which has the responsibility for the funding of projects concerned with the development of technological innovation. Thirdly, the government is currently in the process of establishing an inter-ministerial committee on science, technology and innovation which should greatly facilitate horizontal and vertical coordination and, fourthly, the Minister of S&T in June 2010 appointed a national committee to investigate all aspects of the NSI.

In summary, South Africa has a wide spectrum of STI policies and strategies in place or at least on the drawing board, most of which address some aspects of the brief of WP3. Many of these policy initiatives tend to focus on the upper end of the innovation value chain – i.e.

knowledge production – notwithstanding the original commitment to innovation as primary focus. Where the initiatives were focussed on innovation, they tended to be directed towards the competitiveness and industrialised end of the spectrum rather than the developmental pole.

12.6 National learning systems and technological capabilities

The human resource base of South Africa. South Africa had 18 573 researchers (full-time equivalent) or 1.5 researchers per 1000 employed in 2007. This is similar to the figure for Brazil (1 researchers per 1000 employed in 2004) and China (1.9 researchers per 1000 employed in 2007) but is far below the OECD mean of 7.4 researchers per 1000 employed (in 2005). South Africa has a shortage of highly skilled human resources. There were only 151,961 engineers and 16,682 doctoral graduates in the country in 2004 (NACI 2009).

South Africa has experienced a major scientific workforce brain drain through emigration since 1994. It is estimated that the country has lost as much as 2000 highly skilled people annually (2500 p.a. outflow, 500 p.a. inflow mostly from Africa). Many of these emigrants have world-class education and skills (e.g. 79 percent of ex-SA medical doctors in Canada have post-graduate qualifications). The majority of South African emigrants have gone to English-speaking countries such as Australia, New Zealand, Canada, US and UK. The reasons for this brain drain are primarily financial, but also better working conditions and opportunities for advancement, safety and security.

The future R&D capacity of South Africa is limited by low higher education enrolments, particularly in Science, Engineering and Technology (SET). South African industry is experiencing an acute shortage of skilled human resources. The largest gap is in skills required for research and development, design, engineering and technology management. The workforce is characterised by a low level of tertiary education. Only 4.5 percent of the 25-64 age group had tertiary qualifications in 2001 (OECD 2007:56). This is very low compared to EU and OECD averages. The number of PhDs in industry is also very low.

South Africa has 23 universities, of which the leading five universities provide world-class education and research. The Gross Enrolment Ratio in Higher Education (the ratio of students enrolling for higher education to the number of people in a comparative age cohort) is 15 percent. This is very low in comparison to North America and Western Europe (70 percent) but similar to India (12 percent) (OECD 2007). The mean for the OECD is more than 50 percent. Science, Engineering and Technology enrolments account for only 28 percent of all higher education enrolments (OECD 2007). According to a strategic national plan for higher education in South Africa, the target is to increase the enrolment at HE institutions from 15 percent to 20 percent of school leavers by 2015 (DHET 2010). Apart from the low participation rate, the drop-out rate is high. The ratio of graduates to student body is only 15 percent p.a. The student to faculty ratio is also increasing.

The number of researchers in the higher education sector has stagnated and the current research workforce is aging, with an inadequate pipeline of young researchers. The number of research publications by researchers in this sector has stagnated and the percentage contribution to world output is declining. PhD enrolments have increased, but graduations have decreased. It is fair to state that South Africa is experiencing an education crisis with an education system that is currently unable to supply the skilled human resources required for innovation and growth, particularly for a country with a high population growth rate. Although South Africa has a world class developed economy, it is faced by huge challenges in underdevelopment. The education crisis is one of the drivers of this underdevelopment, and world class firms then counter the crisis by buying foreign technology.

Sources of knowledge and technology acquisition. South Africans have made important contributions to knowledge and technology in many fields. However, of the nine South African Nobel prize laureates only three were in the Natural Sciences (Physiology or Medicine), whereas the others were in Literature (2 laureates) and Peace (4 laureates). The visibility and impact of South African science is restricted to a small number of fields: mostly in health sciences (oncology, obstetrics and gynaecology, infectious diseases and virology), life sciences (microbiology, genetics and heredity), veterinary science and food sciences. On the positive side, South African publications are in the top 1 percent of international cited publications in several of these fields.

South Africa has 12 major public research institutions, including some strong and international visible institutions in a number of scientific fields. In the health sciences, research conducted by the University of Cape Town (UCT), Wits University and the University of KwaZulu-Natal (UKZN) is of high international standing. Similarly in the field of Materials Science, Stellenbosch University compares very favourably with similar institutions in the field. Traditional strengths in Astronomy and Astrophysics are housed at UCT and the South African Astronomical Observatory, Geosciences at the Geosciences Council and Wits University. Rhodes University and the SA Institute of Aquatic Biodiversity remain internationally competitive in marine and freshwater biology.

Total annual production of scientific articles in most fields has stagnated with annual average increase in production of slightly less than 1 percent. However, engineering sciences and applied technologies have increased. The research workforce is aging with more than half of the research articles in 8 out of the 20 scientific fields, by authors over the age of 50 (NACI 2009).

International scientific collaboration, as measured in terms of co-authorship of scientific articles, has increased in most fields of science. More than threefold increase in the proportion of foreign co-authorship has been recorded for research in agriculture, biological sciences, chemical sciences, earth sciences and health sciences.

Patenting is an indicator of technical progress (improvement and innovation). Very few South African patents are granted by foreign patent offices. In 2007 only 82 SA patents were granted by the US Patent Office and 58 by the European Patent Office. South African patents as a world share of the United States Patent and Trademark Office (USPTO) was 0.058 percent in 2008 and has declined steadily from 0.121 percent in 1995 (NACI 2009).

The national knowledgebase is not in a healthy state. It is not vigorously growing or expanding, its international visibility and impact (even compared to similar sizes science systems) is confined to traditional niche areas with little evidence of new, emerging fields of science. The result of this low level of domestic knowledge production is that South African firms have to rely on foreign technology for upgrading and innovation. In both the industrial and services sectors, the acquisition of new machinery, equipment and software was the bulk of innovation expenditure and was equivalent to 2.1 percent of the turnover of innovative enterprises. Intramural and outsourced R&D accounted for 1 percent of the turnover of innovative enterprises (DST 2005).

South Africa's profile in terms of highly important sources of information for innovation is much the same as the average profile for countries in the expanded European Union (EU-27), with internal sources, clients and customers rated as highly important sources of information. Professional and industry associations, universities and public research institutes are rated quite low (DST 2005).

Table 12.4. *Key R&D figures and indicators*

Indicator	2004	2005	2006	2007	2008
Gross domestic expenditure on R&D (GERD) (Rand million)	10 083	12 010	14 149	16 520	18 624
GERD as a percentage of GDP	0.81	0.87	0.92	0.95	0.93
Total R&D personnel (FTE)	25 185	29 696	28 798	30 986	31 352
Total researchers (FTE)	14 129	17 915	17 303	18 572	19 320
Total researchers per 1000 total employment (FTE)	2.2	1.6	1.5	1.5	1.5
Total R&D personnel per 1000 total employment (FTE)	3.9	2.6	2.4	2.5	2.4
Civil GERD as a percentage of GDP	0.72	0.80	0.86	0.89	0.87
Total researchers (headcount)	30 703	37 001	39 264	39 591	40 084

Source: NACI 2009

12.7 Knowledge flows and networks in the national innovation system

International knowledge networks and collaboration have become increasingly important for South Africa's economic growth and development. The past decade has seen increases in public science, technology and innovation collaboration, trade, foreign direct investment, and collaborative partnerships. A summary of highlights from the public sector are first presented, followed by a brief discussion of international collaboration in innovation in the private sector.

Public sector initiatives. The Department of Science and Technology is the primary role-player in ensuring that South African science becomes part of the international arena of science, technology and innovation, although other government departments with an STI function, e.g. Agriculture, Health, as well as Trade and Industry have also been very active and successful in promoting international R&D collaboration. Public research institutions and most universities have in recent years very successfully established productive international collaborative ventures, ranging from joint research projects through exchange staff programmes to joint technology development initiatives. The business sector has probably set the trend with its STI related activities abroad (see above).

Relevant international public initiatives in recent years include:

- Membership or observer in multilateral organisations (e.g. the African Union, Commonwealth, OECD, and UNESCO); and participation in European Union initiatives (researchers participated in more than 180 projects under the Fourth, Fifth and Sixth Framework Programmes (participation in the Fifth Framework Programme is estimated at close to €40 million); participation in the Seventh Framework Programme is expected to be significant.

- The inauguration of the Southern African Large Telescope in 2005, which is the result of collaboration among a number of countries; this country is, with Australia, shortlisted for the Square Kilometre Array telescope.
- South Africa is playing major policy, administrative and research participatory roles on the African continent; for example nearly PPP US$7 million was budgeted in 2006 for the so-called NEPAD component of international STI relations.
- The country currently manages 32 bilateral S&T agreements, yielding a total of approximately 400 projects of varying sizes.
- About 10 percent of South Africa’s R&D is funded from non-South African sources.
- At institutional level international collaboration is a strategic priority; the largest public research institution, the Council for Scientific and Industrial Research (CSIR), is a prime example, cooperating with some 23 African countries, and earning approximately 15 percent of its contract income from international sources.
- Twenty six percent of all first enrolments for doctoral degrees in 2005 were foreign students and 25 percent of all Ph Ds were awarded to non-South Africans.

In summary, the country is becoming visible on the international radar screen and in some cases a sought-after partner in the exchange of knowledge and innovation.

Business sector. International trade and foreign direct investment (FDI) results in knowledge flows, both direct and indirect (embedded in goods). South Africa’s imports and exports as percentage of GDP are increasing, but the country’s export performance is falling behind other newly industrialised countries. Exports are dominated by resource based items such as agricultural products and mineral-based items such as gold, coal, iron and steel. However, imports of food, leather and metal products now exceed exports.

Inward FDI is considered important for the accumulation of innovation capacity by the local industry, mainly through spill-overs. South Africa experienced a period of disinvestment in the period 1985-1993 due to sanctions and fears of instability. FDI inflow has increased since 1994, but has fluctuated wildly in the past decade. For example, it fell sharply from $6.5 billion in 2005 to a net outflow of $184 million in 2006 due to large sales of foreign equity shares to local firms. It rebounded to $5.7 billion in 2007 and grew to $9.6 billion in 2008. South Africa’s annual FDI inflow of between 1 percent and 5 percent of gross capital formation is amongst the lowest in the world (East Asia 10.1 percent, developing countries 9.1 percent, developed countries 6.1 percent) (UNCTAD, 2005). Those that were established seem to have added mainly to the production capacity, but not much to the innovation capacity of the local industry.

European Union firms are the largest investors in South Africa. In many instances the investors acquired local firms to obtain local production, R&D and innovation capabilities rather than transfer such capabilities to the local industry. Examples are the purchase of specialty alloys manufacturer Avalloy by engine manufacturer Rolls-Royce and the German optics firm Carl Zeiss’s purchase of 70 percent of Denel Optronics. On the positive side, such acquisitions also result in upgrading, technology transfer and spill-overs to the local industry.

South Africa’s outward FDI has increased substantially since liberalisation of its economy. Nine South African corporates, including Sasol, Gold Fields, Naspers, Steinhoff, Sappi, MTN, Barloworld, Datatec and Bidvest, made it into UNCTAD's Top 100 list of non-financial corporations from developing countries as ranked by their 2007 foreign assets. Sasol, with foreign assets worth $8.7 billion, came in at number 22. Three South African-linked groups, BHP Billiton, Anglo American and SABMiller, were also represented on the global Top 100 list.

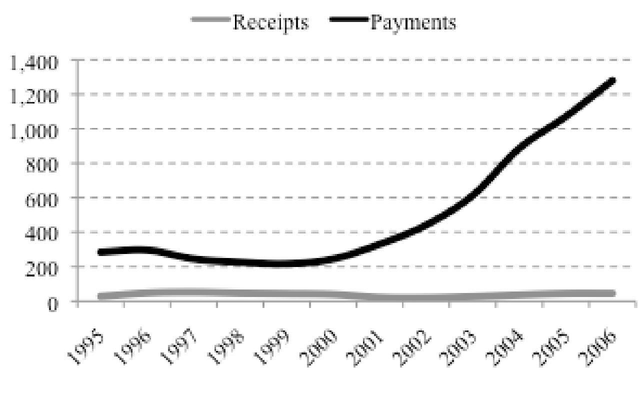
South Africa’s dependence on imported know-how has increased sharply during the past decade as measured by the technology balance of payments. The technology balance of payments registers the commercial transactions related to international technology and know-how transfers. It consists of money paid or received for the use of patents, licences, know-how, trademarks, patterns, designs,

Table 12.5. *Foreign direct investment flows*

	2004	2005	2006	2007	2008
Foreign direct investment, net (BoP, current US$ million)	-604	5612	-6112	2754	11936
Foreign direct investment (percent of GDP)	-0.28	2.31	-2.37	0.97	4.31
Foreign direct investment, net inflows (current US$ million)	701	6522	-183	5745	9644

Sources: World Bank Database & OECD Stats

Figure 12.5. *South African Technology Balance of Payments*



Source: OECD MSTI database, 2009.

technical services and for industrial research and development carried out abroad (NACI 2009:32). Figure 12.5 shows that annual technology receipts remained stagnant at between the US $200 to $300 million level from 1995 to 2000, but then increased more than five-fold from $245 million in 2000 to $1,279 million in 2006.

South Africa exports a small volume of high technology products (5.8 percent of manufactured product exports in 2008) but imports a large volume (21.9 percent of manufactured product imports in 2008). All high technology manufacturing industries in South Africa have trade deficits, and these are growing (NACI 2009:34). Table 12.6 shows that South Africa has a high percentage of Gross domestic expenditure on R&D (GERD) and Business enterprise expenditure on R&D (BERD) financed from abroad. The percentage rapidly increased from 2001 to 2004, then declined from 2005 to 2006. From 2004 to 2006 it was noticeably higher than the EU average and higher than several other comparable economies.

South Africa has an open economy since 1994 with the result that the local industry has become highly integrated in the world economy. South African firms have a preference for foreign rather than local innovation partners, indicating its need to acquired technology abroad. There has also been outsourcing and relocation of R&D overseas by South African companies after liberalisation. An example is Sasol's research centre at St. Andrews University in Scotland.

Table 12.6. *Expenditure on R&D financed by abroad*

	2001	2002	2003	2004	2005	2006
Percentage GERD financed abroad						
South Africa	6.1	..	10.9	15.3	13.6	10.6
EU-25	7.8	8.7	8.5	8.3	8.9	8.6
Russian Federation	8.6	8.0	9.0	7.6	7.6	9.4
Slovenia	7.2	3.7	9.9	11.1	7.3	5.8
Romania	8.2	7.1	5.5	5.5	5.3	4.1
Singapore	6.6	7.2	6.2	5.8	4.4	4.4
Israel	3.0	3.2	3.4	3.2	3.1	3.0
China	..	..	2.0	1.3	0.9	1.6
Argentina	1.2	1.2	1.4	1.1	0.8	0.8
Percentage BERD financed abroad						
South Africa	3.2	..	9.6	17.9	14.5	10.6
EU-25	9.5	10.9	10.6	9.9	10.8	10.0
Russian Federation	9.2	8.4	10.0	8.9	9.1	12.2
Slovenia	7.4	1.8	11.4	13.2	7.2	4.0
Singapore	9.9	11.4	9.9	8.5	5.8	6.2
Romania	4.0	5.0	4.4	6.0	5.5	3.8
China	..	..	2.6	1.5	1.0	2.0
Argentina	3.3	3.2	2.3	1.6	1.0	1.0

Source: OECD MSTI database, 2009.

The collaborative partnerships for innovation activities of South African enterprises were mainly with local partners. Many innovating enterprises, however, also had foreign innovation partners. About 13 percent of enterprises had partnerships with foreign enterprises within their enterprise group, of which 6.1 percent were in Europe and 4.2 percent in the USA. 15.7 percent of firms collaborated with foreign suppliers of equipment, materials, components or software, 8.6 percent with partners in Europe and 3.3 percent in the USA. 9.2

percent collaborated with foreign clients or customers, 4.2 percent with partners in Africa and 2 percent in Europe. 8.5 percent collaborated with foreign competitors or other enterprises in their sector, 2.5 percent with partners in Europe, 2.2 percent with the USA and 2.9 percent with Asia (DST 2005).

South Africa is also becoming more embedded in the global innovation system, e.g. foreign R&D in SA is increasing as part of the global process of vertical disintegration with international outsourcing to lower-cost suppliers. This opportunity is, however, only available to countries with low-cost and skilled labour. South Africa’s shortage of skilled labour could therefore become a major obstacle to its future participation in international innovation collaboration networks.

National and local innovation collaboration networks. South African enterprises have a high intensity of cooperative linkages, with about 40 percent of innovating enterprises having collaborative partnerships. By comparison, an average 26 percent of innovative enterprises in the EU have collaborative partnerships (DST 2005). About 23 percent of enterprises collaborated with other enterprises or institutions to develop product innovations, while a further 6.4 percent relied on other enterprises or institutions to develop their innovations. It was found that clients (or customers), suppliers and competitors (or other enterprises in the same sector) were the most important collaborative innovation partners. Innovative services sector enterprises had slightly more collaborative partnerships with these three types of partners than in innovative industrial enterprises. Collaboration rates with customers (37.5 percent) and suppliers (35.0 percent) were much higher in South Africa than in the EU (14 percent with customers and 17 percent with suppliers) (DST 2005).

South African enterprises’ rating of the importance of sources of information for innovation is similar to those of countries in the expanded European Union (EU-27). Internal sources, clients and customers are rated as highly important sources of information, but conferences, trade fairs and exhibitions are not highly rated by South African enterprises. Professional and industry associations, universities and public research institutes are also not highly rated, although South African enterprises rate them slightly higher than the EU-27 average.

In small enterprises, just over 85 percent of innovative enterprises reported that product innovations were developed mainly by their own enterprise (DST 2005). A total of 30.7 percent of medium-sized enterprises reported collaborating with other enterprises or institutions in developing product innovations, while only 5.1 percent of small innovative enterprises had any such collaboration. About 11 percent of large enterprises relied on other enterprises or institutions to develop their innovations, but this was rare (0.5 percent) in small enterprises.

The South African case provides clear evidence of the interlinking between the National and Global Systems of Innovation. The innovation networks function mainly to supplement the inadequate local supply of new knowledge. This strategy will only be limited by the absorptive capacity of its industries.

12.8 The performance of the innovation system

In conclusion, it would be fair to say that South Africa has a mature and developed National System of Innovation within the African context. South Africa has a long history and successful track record of innovations going back to the late 19th or early 20th century. However, South Africa has slipped back relative to South Korea, India and Brazil.

More than half of South African enterprises were engaged in innovation activities between 2002 and 2004 (DST 2005). This is surprising as it is higher than the European Union (EU) average of 40 percent. Even more surprising is that South Africa had a higher percentage (80.4 percent) of innovators that introduced new or improved products to the market (vs. new to the firm) than any European country. South Africa also performs relatively well in terms of the percentage share of turnover generated by the sale of new or significantly improved products (new to the market and not just new to the enterprise) compared with other countries. South Africa's 10.1 percent is higher than the percentages for Italy (9.7 percent), Greece (9.6 percent), France (9.0 percent) and the EU-27 (8.6 percent).

On almost all innovative performance indicators South Africa scores are comparable to those of the expanded European Union (EU-27). Expenditure on innovation activities by South African firms were 2.4 percent of turnover in both the manufacturing and services sectors (DST 2005), which is very similar to the EU average. For the manufacturing sector it is higher than that of Spain (1.4 percent), The Netherlands (1.8 percent) and Portugal (0.9 percent) but lower than that of Denmark (3.4 percent), Germany (5.0 percent) and Poland (3.4 percent) (Götzfried 2005). What is remarkable, however, is the high expenditure on innovation by the South African services sector. It is higher than that of any European country except the Russian Federation.

Although the expenditure on innovation activities by South African firms are relatively high, there is still a large dependence on foreign knowledge and technology for upgrading and innovation as measured by the technology balance of payments, attributable to the country's low domestic expenditure on R&D. South African enterprises have much in common with enterprises in the European Union. For example, the results for South Africa and the EU-27 profile on questions such as the factors hampering innovation and the most important outcomes of innovation for enterprises are very similar. The influence of foreign partners is also comparable to the experience of other countries. South African enterprises are very active in both R&D and innovation, and this bodes well for their future competitiveness (DST 2005).

In conclusion, it can be stated that South Africa is using Global Innovation Networks extensively, but makes limited contributions to it. South Africa has limited potential to be a contributor, with the possible exception as a provider of Africa-specific solutions.

12.9 References

Cohen, W.M. and Levinthal, D.A. (1989). Innovation and Learning: The Two Faces of R&D, *The Economic Journal*, 99, 569-596.

Department of Education. 1997. *White paper on education 3.* Pretoria: DoE.

Department of Higher Education and Training (DHET) 2010. Strategic Plan 2010 - 2015 and Operational Plans 2010-2011, Department of Higher Education and Training.

Department of Science and Technology (DST; originally Department of Arts, Culture, Science and Technology). 1996. *South Africa’s White Paper on Science and Technology: Preparing for the 21st Century*. Pretoria: Government Printer.

Department of Science and Technology (DST). 2002. *South Africa’s national R&D strategy*. Pretoria: Government Printer.

Department of Science and Technology (DST), 2005. *Main Results of the South African Innovation Survey 2005*, Published by the Centre for Science, Technology and Innovation Indicators (CeSTII) of the Human Sciences Research Council (HSRC).

Department of Science and Technology (DST). 2007. *South Africa’s 10-year innovation plan: Innovation towards a knowledge-based economy*. Pretoria: Government Printer.

Gilroy B.M., Gries, T., Naudé, W., Schmidt, K. and Bauer, N., 2001. *Multinational Enterprises in Africa: A Study of German Firms in South Africa*, International Jubilee Conference on the Economic Empowerment of Southern Africa, Glenburn Lodge, Muldersdrift, South Africa, 13 September 2001.

Götzfried, A., 2005. Science, technology and innovation in Europe. *Statistics in focus: Science and Technology* 8/2005. Published by Eurostat.

Marais, H.C. and Pienaar, M. 2009. Evolution of the South African science, technology and innovation system:1994-2009. In *Proceedings of the 2009 Atlanta Conference on Science and Innovation Policy*, ed. S. E. Cozzens and P. Catalán. IEEE. [http://smartech.gatech.edu/handle/1853/31991]

Mouton, J. 2006. Science for transformation: Research agendas and priorities in South Africa. In L. Box and R. Engelhard (eds.), *Science and technology policy for development: Dialogues at the interface*. London: Anthem Press.

National Advisory Council on Innovation Review Panel (NACI). 2002. *Evaluation of the implementation of the South African innovation policy*. Pretoria: NACI.

NACI, 2006. *The South African National System of Innovation: Structures, policies and performance. Background report to the OECD Country Review of South Africa’s National System of Innovation*. National Advisory Council on Innovation, 21 July 2006.

NACI, 2009. *South African Science and Technology Indicators 2009*, National Advisory Council on Innovation (NACI) Indicators Reference Group.

OECD, 2007. *OECD Reviews of Innovation Policy – South Africa*, Paris: OECD

Productivity SA, 2007. *National Productivity Statistics for the period 1996-2005*.

South African Presidency. 2006. *Accelerated and Shared Growth Initiative – South Africa (ASGISA) 2006*. (Available at www.info.gov.za/asgisa).

Statistics South Africa, 2010a. *Quarterly Labour Force Survey*, Quarter 1, 2010, Statistical release P0211, 4 May 2010.

Statistics South Africa, 2010b. Gross Domestic Product, First quarter: 2010, Statistical release P0441, 25 May 2010.

UNCTAD, 2005. *World Investment Report 2005*. Geneva: United Nations.

World Economic Forum, 2010. *The Global Competiveness Report 2010-2011*. Geneva: World Economic Forum.