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# Government, innovation and technology policy: an international comparative analysis

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**Abstract:** This paper undertakes a comprehensive analysis of the changing role of government with respect to domestic technology development in developing countries. Firstly, developing countries are categorised into two groups: those that possess the potential to create new technologies and those that do not. There are 11 countries in the first group and the present analysis is restricted to five countries that belong to this category. The paper analyses in depth the fiscal and non-fiscal instruments that these countries have employed to stimulate investments in R&D in the enterprise sector. The basic conclusion of the paper is that for financial instruments such as tax incentives and research grants to succeed a strong emphasis needs to be placed on non-fiscal measures, the most important of which is human resource development.

**Keywords:** innovation policy; developing countries; R&D; patents; high technology exports; research grants; tax incentives; human resource development.

**Reference** to this paper should be made as follows: Mani, S. (2004) 'Government, innovation and technology policy: an international comparative analysis', *Int. J. Technology and Globalisation*, Vol. 1, No. 1, pp.29–44.

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## 1 Introduction

Innovation policy is defined as a set of instruments and institutions that aid in the local generation of technology. This may also include adaptation of imported technologies to local conditions. In particular, in the context of developing countries, it involves more of the latter. Innovations are created by formal Research and Development (R&D) activity by firms and other technology creating agents such as universities and other public and private research institutes. It can also manifest itself in the form of a host of non-R&D

activities, such as the purchase of capital goods, non-routine engineering, etc. Most of these activities, although important, are not amenable to precise empirical quantification. Furthermore, these activities are less likely to be impacted upon by public policies, compared to R&D. Hence, in my study, innovation policy is equated more with R&D policy, although efforts are made at times to include non-R&D activities.

R&D activity is an important input to domestic technology development, especially when carried out at the enterprise-level. There is now enough consensus on the fact that R&D is one of those activities that cannot be left entirely to the private sector. This consensus is based on the powerful theoretical result enunciated by Arrow in one of his much-cited papers [1]. He argues that if R&D activities are left entirely to the private sector, this will soon lead to under-investment. This is based on the fact that private sector firms fail to recoup a full return from their investment in R&D due to their difficulty in appropriating the full return from their own research efforts. This is despite the existence of institutional mechanisms, such as patenting, which bestow at least a temporary monopoly to generators of technology. Economists have attempted to capture this by computing the spillover gap or, in other words, the gap between private and social rates of return, for a sample of innovations. Available empirical estimates of the spillover gap indicate that the desire to under-invest in R&D exists in free market economies such as the USA, Western Europe and Japan. In order to reverse this trend, governments have been putting in place a whole host of fiscal measures to encourage enterprises to commit more resources to R&D. These fiscal measures manifest themselves in the form of various types of tax subsidies and research grants. There is now a considerable amount of research on the efficacy of these instruments to stimulate R&D activities, especially in the context of developed market economies.

Whilst the arguments for stimulating industrial R&D in the developed countries are very clearly articulated, it is not the same case in developing countries. This is because developing countries are perceived to be mere assemblers or, at best, 'imitators' of technologies that are usually imported from developed countries through a variety of channels. Given this state of affairs, firms in developing countries are not expected to commit resources to R&D merely to 're-invent the wheel'. Instead, they are advised to open up their production and trade regimes in such a way that technology can easily flow into their economies. At best, what is expected is that some adaptive R&D will be conducted, since all technologies are location-specific and, consequently, any technology that is imported from abroad will have to be adapted to local conditions.

However, this familiar argument assumes much less significance in the context of a number, albeit small, of developing countries becoming creators of technologies in their own right. Against this background, the purpose of the study is to survey the various policy instruments that some developed and developing countries are using to increase investment in R&D by their respective enterprise sectors. The study begins with an analysis of the role of government with respect to promoting innovation in five Type 1 countries, namely, Malaysia, Singapore, India, South Africa and Brazil, all of which have the potential to create new technologies on their own [2]. The study concludes with the experience of Israel, which has a very peculiar but effective innovation policy. The six cases highlight the supportive role of the state regarding the promotion of industrial R&D in enterprises.

The basic hypothesis being tested in the study is whether countries can stimulate investment in R&D in their enterprise sector merely by fine-tuning financial instruments, such as research grants and tax incentives. This is because the arguments for government support for private sector R&D are based on the ‘appropriability problem’. However, I argue that, in the case of developing countries, a mere fine-tuning of the financial instruments, whilst necessary, is not sufficient. For financial instruments to succeed and bear fruit, non-fiscal policy instruments are required, the most important of which is the policy on human resources development. To restate my argument, the financial instruments for promoting industrial R&D can succeed only if the country has a sufficient number of technically trained personnel who can engage in R&D. This implies that an entire structure of innovation has to be in place, which includes the employment of R&D scientists and engineers in organisations within a country, in order for fiscal incentives to work. This is the hypothesis that is tested through a series of carefully selected country case studies.

The study assumes greater significance in the context of four discernible trends, with regard to technology development, which affect developing countries. These are:

- The recent slowing down of investments in R&D across the world: There has been a statistically significant slow down of investment in R&D by business enterprises, especially in the OECD countries, since the mid 1980s. The same period also witnessed a significant reduction in the government funding of business enterprise R&D investments.
- The lack of evidence of internationalisation of R&D: Empirical studies by Patel and Pavitt [3] and Patel and Vega [4] showed that a large proportion of the US patents granted to the largest companies in the world are still based on research conducted in their home countries
- The growing imperfections in the market for new technologies: According to estimates made by Ashish, Fosfuri and Gambardella [5], the market for disembodied technologies does show considerable year-to-year fluctuations and is actually shrinking in size. Increasingly, many of the technologies are being transferred within large transnational corporations (TNCs), namely between the parent firm and its affiliates.
- The lack of evidence of spillovers from Foreign Direct Investments (FDIs): There is very little empirical evidence to show that there are positive spillovers to local unaffiliated companies from the operations of TNCs. In countries such as Singapore, where there is explicit evidence of such positive spillovers, these are the direct result of explicit public policies pursued by the government to engineer such spillovers to local companies.

## **2 Conceptual framework**

The conceptual framework underlying the study is the National Systems of Innovation (NSI) framework introduced into the literature by Freeman [6] and subsequently extended and re-interpreted by Lundvall [7] and Nelson [8]. Two different approaches to the study of the NSI are discernible (Table 1).

**Table 1** Approaches to the study of national systems of innovation

<i>Approaches</i>	<i>Scope</i>
1 Narrow definition of the NSI, e.g., Nelson [8]	The main emphasis of this framework is to analyse the impact of national technology policies on firms' innovative behaviour. Innovative behaviour or activity is measured in terms of formal activities related to the R&D system and the science base. The narrow definition of NSI includes organisations and institutions involved in searching and exploring, such as R&D departments, technological institutes and universities.
2 Broad definition of the NSI, e.g., Lundvall [7]	In this version, the emphasis is on learning, rather than the creation of knowledge itself. The concept of learning implies that the competitiveness of individual firms and entire systems of innovation reflects the ability to learn. The new trends in production and in the labour market, which are increasingly knowledge based, means that knowledge building and learning are becoming more and more crucial for economic growth and competitiveness. It is also argued that learning and especially learning new skills and competencies is essentially a collective and interactive process which cannot flourish in a pure market economy. Hence the emphasis in this approach is more on the efficacy of networks of firms and how they undertake innovative activity than on formal activities related to the R&D system and the science base.

It must be stressed that Nelson's own definition of innovation is much broader than merely equating it with input (R&D expenditure) or output (patents) measures. He defines innovation as "to encompass the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation" [8, p.4]. However, all the 15 country studies in his comparative analysis define the term in a formal sense.

In this study, I employ a combination of the two approaches but, of course, I place more emphasis on tracing the impact of national technology policies on the innovative activity of the firms measured in the formal sense of the term. However, I do take into account the interaction of firms with various elements in the system, such as the higher education sector or human resource development. Thus, although my framework contains the more pronounced features of the so-called narrow approach of Nelson [8], at the same time it combines elements of the latter approach by Lundvall [7].

### **3 Structure of the country studies**

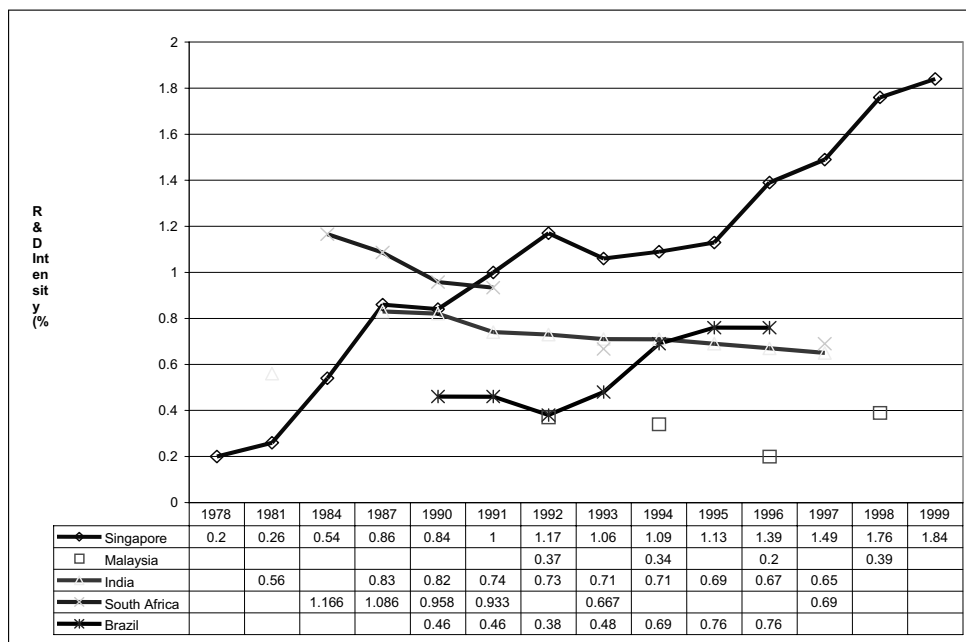
The country studies are presented in such a way that the results are comparable to each other. Each country study commences with an analysis of the policy outcomes. Three separate indicators of policy outcomes are discussed, namely: trends in over all research intensity; the record with respect to patenting by inventors from the five countries; and trends in the high-tech content of manufactures exported. This is followed by a discussion of the structure of the innovation policies in the countries, decomposing the policies into their fiscal and non-fiscal components. However, no effort is made to link specific policy

components with outcomes. The case on Israel is presented in such a manner that the lessons of the Israeli case are easily drawn for other countries. The paper is based on a primary survey of innovation policy instruments and outcomes, collected from the ministries of science and technology in the selected countries.

#### 4 Trends in overall research intensity

Research intensity has shown a dramatic increase in the case of Singapore, whilst it has tended to reduce in the case of South Africa and has remained stagnant in the case of the other three countries (Figure 1). In Singapore, the overall research intensity has shown sharp increases especially in the period since 1991. I argue that this is largely due to the result of various policies put into effect by the state to enhance the research consciousness of Small and Medium Enterprises (SMEs), especially at local level. The main component of state intervention in the area of technology development has been to increase the availability of scientists and engineers who are then available to the industrial sector to conduct R&D projects being carried out within the enterprises (Table 2). In fact, the density of scientists and engineers has shown a significant increase only in the case of Singapore. This can entirely be attributed to a conscious policy of the Singaporean state to increase enrolment at the tertiary level, particularly enrolment for science and engineering courses: approximately 75% of enrolments in polytechnics and about 62% of university enrolments are in Science and Technology (S&T) related subjects. The situation is entirely the opposite in the other countries. All of them have low densities and, in the case of South Africa, the figures actually show a declining trend.

**Figure 1** Trends in overall research intensity, 1978-1999



**Table 2** Density of research scientists and engineers engaged in R&D (number per 10,000 labour force)

	<i>Singapore</i>	<i>Malaysia</i>	<i>India</i>	<i>South Africa</i>	<i>Brazil</i>
1978	8.4				
1981	10.6		7.09		
1984	18.4		7.57		
1987	15.3		7.64		
1990	27.7		9.05	33	
1991	33.6				
1992	39.8	2.1	7.47		
1993	40.5				7
1994	41.9	5.8			
1995	47.7				6
1996	56.3	5.1	8.24		
1997	60.2				7
1998	65.5	5.8		16.3	
1999	69.9				

## 5 Record with respect to patenting

Among the five countries, Singapore has the best patenting record in the USA. Another important feature of Singapore's performance is the growing share of local companies. India shows a similar trend in this area. However, many of the Indian patents in the USA are obtained by government research institutes (GRIs) due to an explicit policy followed by the network of GRIs that comes under the ownership of the Council for Scientific, and Industrial Research (CSIR) [9,10]. Finally, most of the Singaporean patents are granted in areas of high technology and a small number of the patents taken by India and South Africa also fall into this category, although this is not the case with the other two countries. The patenting record further shows that the innovation policy followed by Singapore, with its emphasis on increasing the supply of research scientists and engineers, has been quite successful.

**Table 3** Patenting record of inventors from Singapore, Malaysia, South Africa, India and Brazil

	<i>Singapore</i>	<i>Malaysia</i>	<i>S Africa</i>	<i>India</i>	<i>Brazil</i>
1994	30(30)*	5(0)*			30(63)*
1995	26(38)	5(0)	74(22)*	22(45)**	35(37)
1996	54(37)	7(0)	67(28)	22(50)	37(35)
1997	54(54)	13(0)	54(20)	38(61)	30(50)
1998	80(55)	14(0)	50(12)	62(63)	49(47)
1999	112(50)	20(0)	39(10)	80(69)	54(44)

\*Figures in brackets indicate percentage share of local companies in the total number of patents that are granted in the US.

\*\*The India data includes those granted to local companies and government research institutes.

## 6 High-technology exports

Singapore has one of the highest high-tech export intensities in the world (Table 4). Malaysia also has a growing high-tech content. With such low research intensities and (relatively speaking) a poor patenting record, Malaysia's export performance in this area is largely contributed by the assembly of imported components and, as such, may not be attributed to its innovation policy. India has become a growing exporter of high-tech services, such as computer software, but its record with respect to exports of high-tech hardware is dismal and this shows the weaknesses in its innovation system.

**Table 4** High-technology content of exports of manufactures (percentage share in total manufactured exports)

	<i>Singapore</i>	<i>Malaysia</i>	<i>India</i>	<i>South Africa</i>	<i>Brazil</i>
1989	37.23	38.39	4.27		6.34
1990	39.97	38.23	3.98		6.53
1991	40.11	38.24	4.71		5.24
1992	44.82	38.96	4.06	4.83	4.97
1993	46.42	41.13	4.27	4.73	3.98
1994	50.71	44.25	4.8	4.91	4.62
1995	54.16	46.13	5.83	5.77	4.91
1996	55.71	44.41	6.9	5.7	6.25
1997	57.04	49.02	6.56	7.59	7.59
1998	59.07	55.04			9.49

The above analysis shows, with regard to all three indicators, that Singapore performs best, Malaysia and South Africa show the worst results, while India falls in the middle. I argue that this is largely due to the nature and quality of their respective innovation policies.

## 7 Structure and content of innovation policy across the five countries

A detailed survey of their innovation policies [10] shows that all except for Singapore have narrowly interpreted their innovation policy to mean flow of financial resources from government to the enterprise sector (Table 5). This financial flow has manifested itself in the form of tax incentives, a variety of research grants and, in some cases, government-backed venture capital. With the exception of Singapore, none of the countries have placed any great emphasis on improving the quantity and quality of scientific and technological manpower.

I shall now summarise the main findings with respect to the structure and content of innovation policy across the five countries; each of the five is dealt with separately.

**Table 5** Structure and content of innovation policy across Singapore, Malaysia, South Africa, India and Brazil

Country	<i>Fiscal Instruments</i>			
	<i>Tax Incentives for R&amp;D</i>	<i>Research Grants</i>	<i>Government-backed Venture Capital</i>	<i>Non-Fiscal Instruments</i>
Singapore	Double deduction on R&D expenses for both manufacturing and services	Research incentive schemes for companies; Innovation development scheme; Funds for industrial clusters; Promising local enterprises scheme	Techno-entrepreneurship fund: the government launched a US\$ 1 billion investment fund to attract more venture capital activities to Singapore.	Strengthening tertiary education in S&T fields at the university and polytechnic levels; Engineering positive spillovers to local small and medium enterprises from FDI; Strengthening the technological infrastructure by setting up 13 GRIs in areas of high technology
Malaysia	Nine different types of tax incentives for R&D	Industry R&D grant scheme; Technology acquisition fund; Intensification of research in priority areas; Commercialisation of R&D fund; Multimedia grant scheme; Demonstrator applications grant scheme	No specific policy on venture capital industry	Not clearly articulated
South Africa	Poorly defined tax incentive scheme	Innovation fund; Technology and Human Resources for Industry Programme (THRIP); Support Programme for Industrial Innovation (SPII); Partnership in Industrial Innovation	No specific policy on venture capital industry	Strengthening the technological infrastructure: some reforms of GRIs

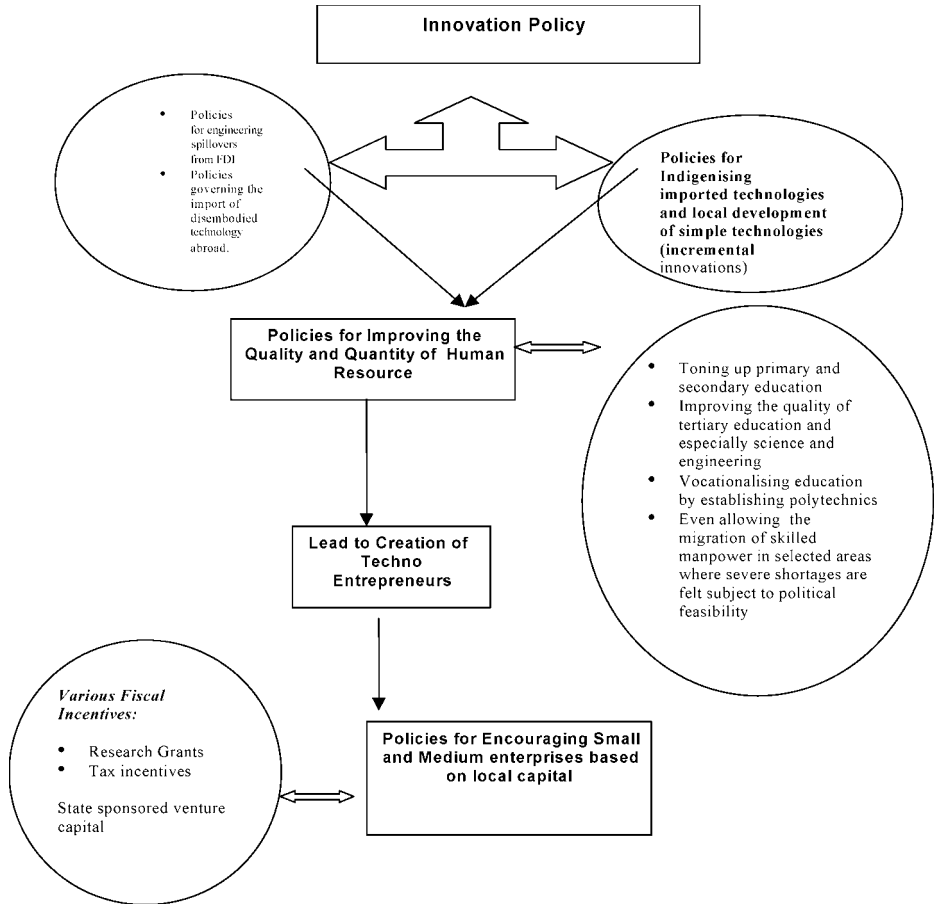
**Table 5** Structure and content of innovation policy across Singapore, Malaysia, South Africa, India and Brazil (continued)

<i>Country</i>	<i>Non-Fiscal Instruments</i>			
	<i>Tax Incentives for R&amp;D</i>	<i>Research Grants</i>	<i>Government-backed Venture Capital</i>	<i>Fiscal Instruments</i>
India	A variety of direct and indirect tax incentives for R&D, but poorly administered	Program aimed at technological self-reliance; Fund for technology development and application; Home grown technology program; Technology projects on mission mode	Government backed venture capital funds; Reasonably well articulated public policies for the development of venture capital	Strengthening the technological infrastructure by reforming the GRIs
Brazil	Five different types of tax incentives for R&D	Three different types of research grants and loans administered by two different agencies of the government	The INOVAR project – in its initial stages.	Strengthening the technological infrastructure by reforming the GRIs

### 7.1 Singapore

Broadly, Singapore's innovation policy has followed the sequencing that is outlined in Figure 2. The ultimate goal of the innovation policy of the country was to enhance local development of technology through the medium of technology-based SMEs. The key to this was the creation of a pool of technically trained personnel who would emerge as techno-entrepreneurs and also as skilled workers in other firms. At the same time, the state encouraged positive spillovers from foreign companies operating in the country through a variety of instruments [11]. Fiscal incentives, such as grants and tax incentives, were put into operation only after a critical mass of this technically trained human resource was developed. In short, the country placed much emphasis on human resource development in the earlier years and subsequently on fiscal measures. This is an ideal sequence for other Type 2 countries to follow if they want to progressively transform themselves into Type 1 countries.

**Figure 2** Sequencing of innovation policy in Singapore



## 7.2 Malaysia

Examination of the Malaysian case shows us that the major weakness of its innovation system is the shortage of technically skilled manpower to engage in R&D. This is not to say that the government does not encourage education and training. On the contrary, the standard indicators of the government’s commitment towards human capital efforts, such as the proportion of total expenditure incurred on education, compare very favourably with Singapore and, indeed, even with developed countries such as Japan and the USA. However, in terms of an indicator such as enrolment ratios at tertiary level, Malaysia’s performance is very poor compared to Singapore, Japan and the USA. However, as argued in this study, what matters is not merely to increase the enrolment ratio *per se*, but to increase enrolment in S&T related subjects. In this regard, despite awareness of the problem within government circles, it is not clear what efforts the government is mounting to popularise university-level enrolments in S&T related subjects. Until the government finally commits itself to a concrete strategy in this direction, mere provision of even sophisticated fiscal instruments for encouraging innovation is unlikely to bear fruit. It must be emphasised, with regard to the demand for innovation, that enterprises in

both Malaysia and Singapore are subjected to the same or very similar pressures in view of their export-oriented manufacturing sector. Another important contrast between the two countries is the fact that Malaysia does not have any specific instruments to engineer positive spillovers from the numerous multi-national companies (MNCs) that operate in its manufacturing sector. This is because the country does not have a strong technology-based SME sector that can be a stable source of supply. What is required in Malaysia is some fine-tuning in its human resources development policy. This is precisely the lesson that the experience of Singapore teaches us.

### *7.3 South Africa*

In the case of South Africa, its policy makers have shown considerable sophistication in innovation policy formulation. Policies, especially the technology policy of the country (referred to as the White Paper on Science and Technology [12]), have been framed after considerable consultation with stakeholders. The policies, as well as the institutions that support S&T in general, have been subjected to detailed reviews. South Africa is also one of the few countries from the developing world to explicitly use the NSI approach. However, my analysis shows that this subscription to seemingly sophisticated terms and concepts is more in form than in content. The innovation policy has been backed by a detailed technology foresight study through which a set of approximately 12 broad priority areas has been identified. Three types of research grants have been established and administered by three different agencies, and these grants have been targeted at the foresight priority areas. Of the three, the Innovation Fund was found to be the largest, whilst the Technology and Human Resources Improvement Programme (THRIP) was the most innovative in that it sought to address one of the most fundamental weaknesses of the NSI, namely, the shortage of technically-trained personnel. None of the instruments has effectively addressed, or is poised to address, the severe shortage of skilled manpower, not only for simple manufacturing but also for research. As a result, the research intensity of the country is very low (especially considering its elaborate technology infrastructure) and most of the patents granted to inventors from South Africa are individually owned. Moreover, the rate of growth in patenting has been virtually stagnant over the last ten years or so. Finally, given the fact that the manufacturing sector is highly concentrated (despite explicit efforts by the government to promote SMEs), the demand for innovations appears to be very low in the South African context. What is thus called for at this stage is a human resources development policy, from primary level through to tertiary level, in order to increase enrolments for science engineering education. At the same time, industrial policies are required to stimulate domestic competition between enterprises.

### *7.4 India*

Whilst there is a large pool of technically-trained personnel in India, its density of Research Scientists and Engineers (RSEs) is one of the lowest. However, there is no appreciation of this issue as a problem in policy circles. The country has very few research grants specifically for the enterprise sector and those that it does have are largely utilised by public sector enterprises. The technological infrastructure of the country is fairly sophisticated (at least by Developing Country standards). The network of laboratories under the umbrella of the CSIR forms an important component of this

technological infrastructure. The interaction of these labs with the enterprise sector, despite efforts to enhance it, is still very low. Part of the difficulty arises from the low demand for innovations from the enterprise sector. Tax incentives are not very popular because of their impermanent nature. However, efforts are under way to have a more proactive innovation policy. The analysis of the Indian experience thus shows that the country does indeed have a serious shortage of scientists and engineers for R&D in the enterprise sector. This is paradoxical, as India does have a very large pool of scientists and engineers. This low RSE density may be attributed to a combination of factors, such as the low demand for innovations by Indian enterprises and a lack of attractive incentive systems (especially of the financial variety) to R&D scientists and engineers. Thus, a concerted effort is required in India, not only to design and implement attractive fiscal incentives for innovation but also to increase the RSE density.

### 7.5 *Brazil*

Brazil is the most technologically developed country in Latin America, accounting for nearly one-half of the region's total R&D expenditure. My study began by examining the characteristics of the enterprise sector in the country and finding that it is largely composed of foreign companies and, now privatised, public sector enterprises. Enterprise-level R&D expenditure showed sharp increases up to 1997 and, thereafter, it has shown reductions. The patenting record of Brazilian inventors in the USA has improved in the 1990s, and most of the patents were granted to local companies, but one company alone accounted for the largest share.

Government intervention in technology development manifested itself in four areas:

- 1 It placed restrictions on the import of foreign technology. Most of these restrictions were removed or diluted as part of the liberalisation strategy of the 1990s and, consequently, the cost of purchasing disembodied technology registered some significant increases during the post-liberalisation phase.
- 2 It initiated a number of schemes through which domestic technology development is financed. In terms of instruments, these can be classified as loans and grants, tax incentives and venture capital. My analysis shows that there has been a significant reduction in loans and grants, specifically since the mid-1990s. Tax incentives have registered good increases and they seem to have been effective in raising R&D investments by enterprises (if the data on R&D are a true representation of the phenomenon). The venture capital industry is in its nascent stage but efforts are being made to develop it on a sustained basis.
- 3 It intervened to create an adequate supply of highly trained scientific manpower. Whilst there appears to be no supply bottlenecks, the demand for scientists and engineers appears to be very low, as indicated by the very low density of scientists and engineers.
- 4 The *Ministerio da Ciencia e Tecnologia* (MCT), the main administrative agency responsible for innovation policy in the country, seems to be aware of the problems faced by the innovation system in the country. It is in the process of giving shape to a new policy on innovation and has introduced new research grants but it has not addressed the fundamental weakness of the innovation system, namely the low RSE density in Brazil.

## 8 Lessons from the case of Israel

Our analysis of the Israeli experience shows that research grants have been very useful in encouraging innovation in the context of Israel. This is because Israel has always had a steady supply of well-trained scientists and engineers and its skill intensity in manufacturing has always been very high. Israel has the world's highest per capita number of engineers and scientists. The following quantitative dimension of the country's civilian labour force of two million is extremely important to observe. Workers in professional, technical, scientific and academic positions account for 25% of the labour force. Skilled workers make up another 24%. Approximately 38% of the labour force has more than 13 years of education and over 17% has 16 years or more. More than 30% of university students specialise in fields with high industrial R&D potential – engineering, mathematics, physical sciences and medicine.

The number of engineers and scientists engaged in R&D accounts for about 10% of people employed in those establishments that actually carry out R&D (Table 6). In fact, the relative share of professionals engaged in R&D has actually doubled over the last seven years or so. This significant increase in the number of skilled scientists and engineers is attributed to two main factors, namely, the university system, especially during the 1990s, and immigration. However, I argue that this was, to a large extent, facilitated by the substantial immigration of extremely qualified scientists and engineers, particularly from the erstwhile Soviet Union. Israel's civilian labour force numbered 2.2 million (Table 7). At the outset, it is important to note that the number of scientists can be an underestimation as only those who are registered with the Centre of Absorption have been included. It shows that, over time, the 'scientist content' of immigration into Israel actually increased to nearly a quarter of total immigrations.

**Table 6** Scientists and engineers engaged in R&D in the Israeli manufacturing industry

	<i>Total Employed Persons in Manufacturing Establishments Engaged in R&amp;D (in thousands)</i>	<i>Professionals Engaged in R&amp;D (in numbers)</i>	<i>Practical Engineers and Technicians Engaged in R&amp;D (in numbers)</i>
1990	93.7	5197(5.5)*	3104 (3.3)*
1991	89.9	6055 (6.7)	3345 (3.7)
1992	83.8	6398 (7.6)	3158 (3.8)
1993	81.5	6437 (7.9)	3434 (4.2)
1994	81.2	7199 (8.9)	3223 (4.0)
1995	78.4	6791 (8.7)	3383 (4.3)
1996	81.2	7919 (9.8)	3558 (4.4)

\*Professionals are employed persons with an academic education or with a similar level of education (i.e. persons who have not yet completed their academic studies, and yet are employed in positions requiring an academic degree)

\*\*Practical engineers and technicians are employed persons with diplomas of practical engineers/technicians or with a similar qualification (e.g. those who have practical experience, laboratory technicians and draftsmen)

As a percentage of total employed persons in manufacturing establishments engaged in R&D

**Table 7** Share of scientists in total immigration to Israel, 1989-1998 (in numbers)

	<i>Total Immigration</i>	<i>Scientists Registered at the Centre of Absorption</i>	<i>Share of Scientists (%)</i>
1989	24,050	280	1.16
1990	199,516	2,250	1.13
1991	176,100	5,310	3.02
1992	77,057	7,630	9.90
1993	76,805	9,200	11.98
1994	79,844	10,140	12.70
1995	76,361	10,965	14.36
1996	70,919	11,700	16.50
1997	67,990	12,500	18.39
1998	56,693	13,275	23.42

The Israeli labour market has also successfully absorbed a significant portion of the 750,000 (approximately) immigrants who have arrived since 1989. It is the availability of this crucial input, namely, the supply of technically trained manpower, which has made the research grant scheme a success. This is because the main barrier that these scientists faced was availability of capital. Research grants are better than venture capital because the repayment terms of grants are very attractive. Also, the success rate in securing the grant is likely to be much higher than in the case of venture capital. The main lesson of the Israeli experience is that research grants, although *prima facie* market-unfriendly, require an adequate supply of technically trained personnel. Developing countries that are short of this crucial input are unlikely to follow Israel's example by merely moving to a grant-based system. Israel itself is experiencing a shortage of skilled manpower and, unless this is redressed, the ability of the research grant system to show similar success in the future is somewhat doubtful. Also, our analysis, although preliminary, does indeed show that the administration of the research grant system is very efficient. The Office of the Chief Scientist (OCS) has the sole responsibility of awarding research grants. In contrast, most developing countries have a number of agencies working in splendid isolation and therefore at cross-purposes. Furthermore, the replicability of the Israel experience very much depends on the position of the country with respect to its inherent potential to create new technologies on its own. Thus, Israel is likely to be a model only to Type 1 developing countries. It can be argued that, for this set of countries, both phases, namely, the 'R&D penetration phase' and the 'Silicon Valley phase' [13], are relevant. The Israeli experience also shows us that research grants are successful in initiating R&D by enterprises when they are not targeted to a specific sector or technology or, in other words, when they are horizontal [13]. Finally, it is also necessary to have research grants and venture capital as a complementary source of financing. Venture capital is required to initiate small and medium high-technology enterprises, whilst research grants are required to encourage these enterprises to take on R&D projects once they are established and in a position to expand and diversify. Again, Israel has got this right.

## 9 Conclusions

First of all, my analysis shows that explicit innovation policies by national governments are relevant even in a phase of so-called globalisation. Innovation policies consist of both fiscal and non-fiscal measures. Fiscal measures consist of tax policies, designed to encourage investments in R&D, and research grants, which are targeted at specific R&D projects. The most important non-fiscal policy is the one on human resources development. The basic hypothesis underlying the study was that fiscal instruments are effective only if the country has a sufficient supply of technically trained scientific manpower that can perform R&D functions effectively. Countries that have put in place schemes to increase the supply of high quality scientific manpower also have effective innovation policies. Our analysis of five Type 1 developing countries confirms this proposition. Of the five countries selected for in-depth examination, only Singapore has an effective innovation policy, in the sense that it has been continuously raising its research intensity, has a growing number of patents granted to its local enterprises and has one of the greatest high-tech export intensities in the world. Malaysia and South Africa, on the contrary, have established a variety of research grants to stimulate R&D projects but, so far, have not been successful as they have serious shortages of technically trained manpower. India and Brazil have a large supply of technical manpower but not enough working in enterprises as R&D scientists. It is thus seen that countries need to fine-tune the non-financial component of their innovation policies. In this context, the experience of a developed country, namely, Israel is extremely illuminating. The Israeli experience is rather unique in the sense that it uses mainly one financial instrument, namely, the research grant scheme implemented by the OCS. The effectiveness of this scheme in raising the nature and extent of innovative activity in the country has been the subject of a very lively and informed debate in Israel. In the present paper I not only take stock of this debate but also subject it to a detailed empirical scrutiny. There are two basic conclusions. The phenomenal growth of the venture capital industry (originally promoted by the state) is now becoming a competitor to the research grant scheme but the main lesson for developing countries is the fact that it is the adequate supply of high quality human resource that has played a part in making the research grant scheme a successful instrument. The research grant scheme is thus an effective way for the state to work with the market in promoting innovations in enterprises. All six cases analysed in the study underscore the need for, and importance of, dovetailing policies on human resources development as an integral component of a nation's innovation policy. The government still has an important role to play in enabling the markets to function better.

## Acknowledgement

This paper is based on my book, *Government, Innovation and Technology Policy, An International Comparative Analysis*, Cheltenham: Edward Elgar (2002). All the data tables and figures in the paper are taken from the above book. The paper benefited from comments made by the participants at an International Workshop at UNU/INTECH, Maastricht, November 5-6, 2001 and, in particular, by Sanjaya Lall, Martin Bell, Azriel Hemar, B. Bowonder, J. Vinanchiarachi, William Blankley, Lawrence M Rausch, Lynn Mytelka, Keith Smith and Rajah Rasiah and two anonymous referees. I am also grateful to Nicole Mankinen for her help in the preparation of this paper. The usual disclaimer

holds good. Finally, the views expressed herein are those of the author and do not necessarily reflect the views of the United Nations.

## References and Notes

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- 2 Type 1 countries are those developing countries that have the potential to create new technologies on their own. This is measured by the number of patents that are issued to inventors from these countries in the USA. There are 11 such Type 1 developing countries. They are Argentina, Brazil, China, Hong Kong, India, Malaysia, Mexico, Singapore, South Africa, South Korea and Taiwan. All other developing countries are termed Type 2 countries.
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- 9 This is an area where the CSIR has been able to reach its targets. There has been a change in the patenting record (both Indian and foreign) of the Council since 1994. The Council has been successful in securing 591 Indian patents and 101 foreign patents (cumulatively) since 1994. Although the patenting record of the CSIR has improved, much of it is accounted for by just one laboratory, namely, the National Chemical Laboratory (NCL), which was always considered to be the best among the 40. However, there are no data to measure the contribution of the royalty from patents to the operational expenditure of the Council. See Mani [10] for details.
- 10 Mani, S. (2002) *Government, Innovation and Technology Policy, An International Comparative Analysis*, Cheltenham: Edward Elgar.
- 11 The main instrument for engineering spillovers to local companies from affiliates of MNCs is known as the Local Industries Upgrading Programme (LIUP). For details of this program see Mani [10, pp.138–140].
- 12 Available from: [http://www.dst.gov.za/legislation\\_policies/white\\_papers/Science\\_Technology\\_White\\_Paper.pdf](http://www.dst.gov.za/legislation_policies/white_papers/Science_Technology_White_Paper.pdf)
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