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Government, Innovation and Technology Policy, An International Comparative Analysis*

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Abstract

The paper undertakes a comprehensive analysis of the changing role of government with respect to domestic technology development in developing countries. First of all developing countries are can be categorised into two groups: those which possess the potential to create new technologies and those which do not. There are eleven countries in the former type and the present analysis is restricticted to five countries that belong to this category. The paper analyses in depth the fiscal and non-fiscal instruments which 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.

Key words: *Innovation policy, developing countries, R&D, patents, high technology exports, research grants, tax incentives, human resource development*

Introduction

Innovation policy is defined as a set of instruments and institutions which aid in the local generation of technology. This may also include adaptation of imported technologies to local conditions. Especially 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 like 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, and so forth. Most of these activities, though important, are not amenable to precise empirical quantification. Further, 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, though 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 (1962, 609-25) in one of his much-cited papers. His argument is that if R&D activities are entirely left to the private sector, it will soon lead to under-investments. This is based on the fact that private sector firms fail to recoup the full returns from their investments in R&D owing to their difficulty in appropriating the full returns from their own research efforts. This is despite the existence of institutional mechanisms such as patenting which bestows 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 returns, 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 US, Western Europe and Japan. In order to reverse this trend governments have been putting in place a whole host of especially 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.

While 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 which are usually imported from the developed ones through a variety of channels. Given this state of affairs, firms in developing countries are not expected to commit resources to R&D for just 're-inventing 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 to conduct some adaptive R&D 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, albeit, a small number of developing countries becoming creators of technologies in their own right. Against this background, the purpose of the study has been to survey the various policy instruments that some developed and developing countries are using to increase investments in R&D by their respective enterprise sectors. The study began 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[1]. The five cases bring out the supportive role of the state regarding the promotion of industrial R&D in enterprises.

The basic hypothesis that is being tested in the study is to see whether countries can stimulate investments in R&D in their enterprise sector by merely 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 while necessary is not sufficient enough. 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 employed R&D scientists and engineers in the organisations that comprise it, 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 much significance in the context of four discernible trends with respect to technology development that affects developing countries. They are:

1) the recent slowing down of investments in R&D across the world: There has been a statically significant slow down of investment in R&D by business enterprises, especially in the OECD countries, since the mid 1980s. The same period witnessed also a significant reduction in the government funding of business enterprise R&D investments;

2) the little evidence of internationalisation of R&D: Empirical studies by Patel and Pavitt (1995, 14-51)and Patel and Vega (1998, 145-155) showed that large proportion of the US patents granted to the largest companies in the world are still based on research conducted in their home countries

3) the growing imperfections in the market for new technologies: According to estimates made by Arora, Fosfuri and Gambardella (2001, 23-40), the market for disembodied technologies does show considerable year-to-year fluctuations and is actually shrinking in its size. Increasingly much of the technologies are getting transferred within large TNCs, namely between the parent firm and its affiliates; and

4) little 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 TNC. In countries like Singapore, where there is explicit evidence of such positive spillovers, these are the direct result of explicit

[1] Type 1 countries are those developing countries which 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 US. There are 11 such Type 1 developing countries. They are Argentina, Brazil, China, Hong Kong, India, Malaysia, Mexico, South Africa, South Korea and Taiwan. All other developing countries are termed as Type 2 countries.

public policies pursued by the government to engineer such spillovers to local companies.

Conceptual Framework

The conceptual framework underlying the study is the National Systems of Innovation (NSI) framework introduced into the literature by Freeman (1987) and subsequently extended and re-interpreted by Lundvall (1992) and Nelson (1983). Two different approaches to the study of the NSI are discernible (Table 1).

(Insert Table 1 here)

It must of course be stressed that Nelson's own definition of innovation is much more broad than merely equating it with input (R&D expenditure) or output (patents) measures. He defined 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" (Nelson, 1993,4)]. But all the 15 country studies in his comparative analysis defines the term in a formal sense

In our study, I employ a combination of the two approaches. But of course my emphasis is more on tracing the impact of national technology policies on the innovative activity of firms measured in the formal sense of the term. However, I do take into account interaction of firms with various elements in the system, for instance with the higher education sector or human resource development. Thus though my framework has more pronounced features of the so-called narrow approach of Nelson (1993) but at the same time it combines elements of the latter approach by Lundvall (1992).

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: 1) trends in over all research intensity; 2) the record with respect to patenting by inventors from these five countries; and 3) trends in the high-tech content of exports of manufactures. This is followed by a discussion of the structure of innovation policies in these countries, decomposing the innovation policy into its fiscal and non-fiscal components. However, no effort is made to link specific policy components with the outcomes. The paper is based on a primary survey of innovation policy instruments and outcomes collected from the ministries of science and technology of the selected countries.

Trends in overall research intensity

Research intensity has shown some dramatic increases only in the case of Singapore, the case of South Africa has tended to come down, while in the case of the other three countries it has virtually remained stagnant (Figure 1). In the case of Singapore, the overall research intensity has shown sharp increases especially in the period since 1991. I argue that this largely due to the result of various policies put into effect by the state to enhance the research consciousness of especially local level Small and Medium type of Enterprises (SMEs). 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 significant increases only in the case of Singapore. This can entirely be attributed to a conscious policy of the Singaporean state to increase not just enrolment at the tertiary level, but enrolment for science and engineering courses: approximately 75 per cent of enrolments in polytechnics and about 62 per cent of university enrolments are in Science and Technology (S&T)-related subjects.

(Insert Figure 1 here)

The situation is entirely the opposite in the other three countries. All of them have low densities and in the case of South Africa it has actually shown a declining trend.

(Insert Table 2 here)

Record with respect to patenting

Among the four countries, Singapore has the best patenting record in the US. Another important feature of Singapore's performance is the growing share of local companies. In this area, India too shows a similar trend. However much of the Indian patents in the US are obtained by government research institutes (GRIs) and this is due to an explicit policy followed by the network of GRIs which comes under the ownership of the Council for Scientific and Industrial Research (CSIR)[2]. 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, though this is not the case with the other two countries. The patenting record further shows that the innovation policy followed by Singapore, with emphasis on increasing the supply of research scientists and engineers, has been quite successful.

(Insert Table 3 here)

High-technology exports

Singapore has one of the highest high-tech export intensities in the world (Table 4). Malaysia too has a growing high-tech content. With such low research intensities and

[2] 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 ones (cumulatively) since 1994. Though 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 (2002, forthcoming) for the details.

(relatively speaking) poor patenting record, Malaysia's export performance in this area is largely contributed by 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.

(Insert Table 4 here)

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

Structure and content of innovation policy across the five countries

A detailed survey of their innovation policies[3] 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.

(Insert Table 5 here)

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.

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[4] . Fiscal incentives such as grants and tax incentives were put into operation only after a critical mass of this technically trained human resources 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 sequencing to follow for other countries in Type 2 if they want to progressively transform themselves into Type 1 countries.

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[3] Mani (2002, *forthcoming).*

[4] 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 programme, see Mani (2002, forthcoming), pp. 138-140.

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. In fact, quite the contrary. According to the standard indicators of the government's commitment towards human capital efforts, such as the proportion of total expenditure incurred on education, the country compares very favourably with Singapore and indeed even with Developed Countries such as Japan and the United States. However, in terms of another indicator such as enrolment ratios, those for the tertiary level in Malaysia are very low compared to Singapore, Japan and the United States. But, 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 knowledge of this problem in government circles, it is not clear what efforts are being mounted by the government 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 that on the demand for innovation side, 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. So 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.

(Insert Figure 2 here)

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, http://www.dst.gov.za/legislation_policies/white_papers/Science_Technology_White_Paper.pdf), 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 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 about 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 these three, the Innovation Fund was found to be the largest, whereas 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 small and medium enterprises), the demand for innovations appears to be very low in the South African context. What is called for at this stage is thus 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.

India

While 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. Even those that it has 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 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. So concerted effort is required in India not only to design and implement attractive fiscal incentives for innovation but also to increase the RSE.

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 actually composed largely 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 United States 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 terms of four areas: first, it placed restrictions on the import of foreign technology. But most of these restrictions were removed or diluted as part of the liberalisation strategy of the 1990s. Consequently the cost of purchasing disembodied technology registered some significant increases during the post-liberalisation phase. Second, 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 have been significant reductions 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. Third, the state has intervened to create an adequate supply of highly-trained scientific manpower. While there appear 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. Finally, 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 in Brazil.

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 will be effective only if the country has a sufficient supply of technically-trained scientific manpower which can perform R&D functions effectively. Countries that have put in place schemes to increase the supply of high quality scientific manpower have effective innovation policies as well. 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 they 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. All the five cases analysed in the study thus underscore the need for and importance of dovetailing policies on human resources development as an integral component of a nation's innovation policy and the government still has an important role to play in enabling the markets to function better.

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

Approaches	Scope
a. Narrow definition of the NSI - e.g. Nelson (1993)	The main emphasis of this framework is to analyse the impact of national technology policies on a firm's 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.

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

	Singapore	Malaysia	India	South Africa	Brazil
1978	8.4				
1981	10.6		7.09		
1984	18.4		7.57		
1987	25.3		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				

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

	Singapore	Malaysia	S Africa	India	Brazil
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)

Notes: * 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.

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

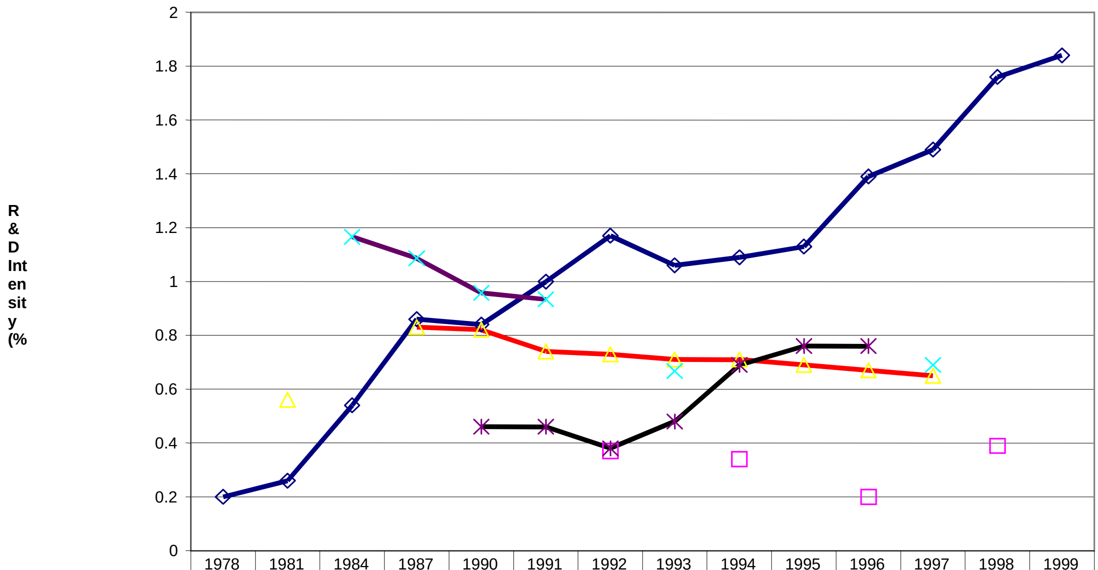
	Singapore	Malaysia	India	South Africa	Brazil
1989	37.23	38.39	4.27		6.34
1990	39.97	38.23	3.98		6.53
1991	40.11	38.24	4.71		5.24
1992	44.82	38.96	4.06	4.83	4.97
1993	46.42	41.13	4.27	4.73	3.98
1994	50.71	44.25	4.8	4.91	4.62
1995	54.16	46.13	5.83	5.77	4.91
1996	55.71	44.41	6.9	5.7	6.25
1997	57.04	49.02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

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

Country	Fiscal Instruments			Non-Fiscal Instruments
	Tax Incentives for R&D	Research Grants	Government-backed Venture capital	
Singapore	Double deduction on R&D expenses for both manufacturing and services	Research Incentive Schemes for Companies Innovation Development Scheme Funds for Industrial clusters	Techno-entrepreneurship Fund: the government launched a USD 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

		Promising Local Enterprises Scheme		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
India	A variety of direct and indirect tax incentives for R&D, but are poorly administered	Programme Aimed at Technological Self-reliance Fund for technology development and application	Government backed venture capital funds Reasonably well articulated public policies for the development of venture capital	Strengthening the technological infrastructure by reforming the GRIs

		Home grown Technology Programme Technology projects on mission mode		
Brazil	There are 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	Yes, the INOVAR project. It is in its initial stages.	Strengthening the technological infrastructure by reforming the GRIs



	1978	1981	1984	1987	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Singapore	0.2	0.26	0.54	0.86	0.84	1	1.17	1.06	1.09	1.13	1.39	1.49	1.76	1.84
Malaysia							0.37		0.34		0.2		0.39	
India		0.56		0.83	0.82	0.74	0.73	0.71	0.71	0.69	0.67	0.65		
South Africa			1.166	1.086	0.958	0.933		0.667				0.69		
Brazil					0.46	0.46	0.38	0.48	0.69	0.76	0.76			

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

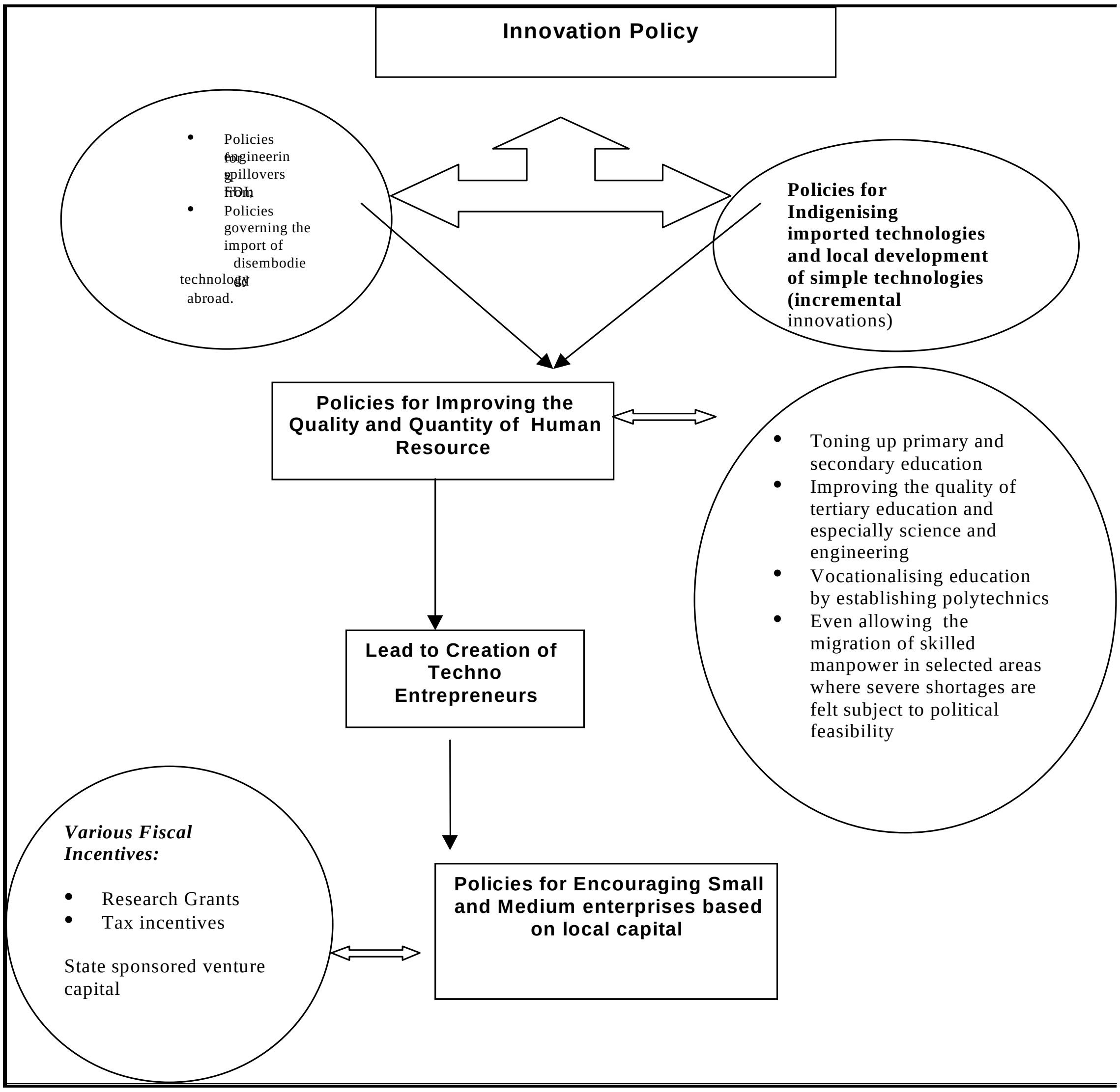


Figure 2: Sequencing of innovation policy in Singapore