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Epistemic communities and informed policy making for promoting innovations: the case of Singapore

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A group of developing countries, primarily in Asia, have emerged as important generators of new technologies. Among them, Singapore has shown one of the fastest rates of growth in generating local innovations. This chapter explains that to accomplish this, Singapore first developed a critical mass of research scientists and engineers, and then put in place a set of research grants to encourage both local and foreign enterprises to increase their investment in R&D. Singapore's impressive performance can be attributed not only to the existence of an innovation policy and the quality of the instruments of intervention in the technology arena, but also to the existence of epistemic communities within the machinery of government itself. In other countries without such communities to aid government policy making, most policy instruments fail to achieve the desired results. In the absence of informal professional networks, innovation policy making tends to be ad hoc *and subject to political compulsion.*

1 Introduction

An 'epistemic community' has been defined as 'a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within the same domain or issue area'.[2] The existence of epistemic communities within otherwise bureaucratic bodies has enabled some developing countries to graduate from merely assembling goods to become the designers, manufacturers and exporters of high-technology products

This chapter discusses the role of epistemic communities in improving national innovation systems. Singapore was selected for two reasons. First, it has made dramatic improvements in its innovation system. Rather than replicating an elaborate bureaucracy in the form of a Ministry of Science and Technology, the country chose to create an epistemic community consisting of government officials, academics and international experts with domain-specific

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2 Haas (1992: 3).

knowledge. Second, Singapore has successfully made the transition from being a manufacturer and exporter of electronic products, to one that is regarded as an important player in the international life sciences industry.

This chapter is structured as follows. Section 2 presents some evidence of the emergence of high-technology innovators in the developing world. This is followed by a brief discussion of the role of epistemic communities and their contribution to informed policy making. Section 3 analyzes the content and effect of Singapore's innovation policies, the instruments developed to implement them, and the impacts on the country's performance. Finally, section 4 offers some conclusions about the process of innovation policy making.

2 *Epistemic communities and informed policy making*

Innovation policies consist of a set of instruments, financial or otherwise, and institutions that are intended to lead to the creation of technological improvements in both products and processes. Innovation policies are usually designed by ministries of science and technology (or their equivalents) that are responsible for supporting technological change within national economies.

The success or effectiveness of an innovation policy depends not just on its design, but also on how well it is implemented. There is little discussion of the processes through which innovation policies are actually designed. There are no widely accepted standards or processes specifically for innovation policy making. In most democratic countries policy issues are subject to debate and discussions among stakeholders or components of the innovation system. In some cases these discussions take place through a policy dialogue that moves 'from green papers to white papers'.[3] Given the increasing complexities of policy design, even the preparation of a green paper requires considerable discussion and help from experts. Some countries bring together groups of experts variously described as national advisory councils or science technology advisers, while others rely on external experts or consultants.

It has been suggested that countries with sufficient internal expertise (for instance within national ministries or other policy-making bodies) are in a better position to design and implement good policies than countries that do not have such expertise. This is because the availability of experts will enable the policy-making bodies to process information, especially the technical information that is required to develop policy instruments, more effectively. In other words, countries may encourage the formation of epistemic communities that take the form of informal networks of professionals with recognized expertise and competence in a particular field, as well as an authoritative claim to policy-relevant knowledge about that field or issue. In less politically motivated cases, epistemic communities have a greater hand in the various stages of the policy-making process, including the introduction of policy alternatives, the selection of policies, and the building of national and international coalitions in support of those policies.

[3] South Africa's 1996 innovation policy was designed through this mode of green paper to white paper (see Mani, 2002). However, when the recent innovation policy was announced (contained in the 2002 National R&D strategy) no such consultation took place.

All organizations engage in some form of 'satisfying' or procedural rationality in their consideration of policy alternatives; 'if rationality is bounded, epistemic communities may be responsible for circumscribing the boundaries and delimiting the options'.[4] Epistemic communities need to be distinguished from bureaucratic bodies. The latter operate largely to preserve their missions and budgets, whereas epistemic communities apply their knowledge to a policy undertaking, subject to their normative objectives. Thus, members of an epistemic community are not policy entrepreneurs, although they may use the bureaucratic leverage they are able to acquire through their key positions within bureaucracies. Their behaviour is different from that of the individuals usually analyzed in terms of their bureaucratic constraints. They are often active in international policy dialogues and in national policy-making processes.[5] Therefore, the existence of epistemic communities within otherwise bureaucratic bodies has allowed some developing countries to graduate within a short time from being mere assemblers to designers, manufacturers and exporters of high-technology products.

3 *The emergence of Singapore as a generator of high-technology innovations*

Developing countries are not normally seen as generators of new technologies, but generally merely assemble or apply imported technologies. While this is certainly usually the case, a handful of developing countries have emerged as generators of new technologies. Although measuring and interpreting the outcomes of innovation is difficult,[6] the number of US patents granted to inventors from specific countries is a good indicator of the quantity and quality of innovative outputs. This is because it is extremely difficult, time-consuming and expensive to secure a patent in the United States, especially for developing countries where the largest firms are likely to be as big as most small and medium enterprises in developed countries. Consequently, there is a fair amount of self-selection by firms and institutions in developing countries who patent their best innovations in the US (see figure 1). Over the period 1985–2001, about 11 countries were awarded an average of 30 patents per year in the US.[7] These were Taiwan, Korea, Hong Kong, Singapore, India, South Africa, Brazil, China, Mexico, Argentina and Malaysia.

Singapore began to develop activities in the life sciences during the 1980s with the creation of a molecular biology research centre. It also increased funding for biomedical research at hospitals and universities, and established an ambitious training programme for life sciences researchers. Over the past few years, the government has intensified both science funding and industry promotion activities with the creation of a new Biomedical Sciences Research Council (BMSRC), and several new funds for supporting innovation and commercialization in the biotechnology and life sciences industries. Even though indigenous industry activities remain limited, the government is actively promoting Singapore as the preferred location for biotechnology and pharmaceutical companies in Asia.[8]

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4 Hass (1992: 16).
5 Edwards (2001) uses the notion of epistemic communities to analyze issues such as authority, hierarchy, recruitment and conflict in open source software communities (http://opensource.mit.edu/papers/kasperedwards-ec.pdf).
6 Smith (2004).
7 Mani (2002).
8 Asian Technology Information Program (2002).

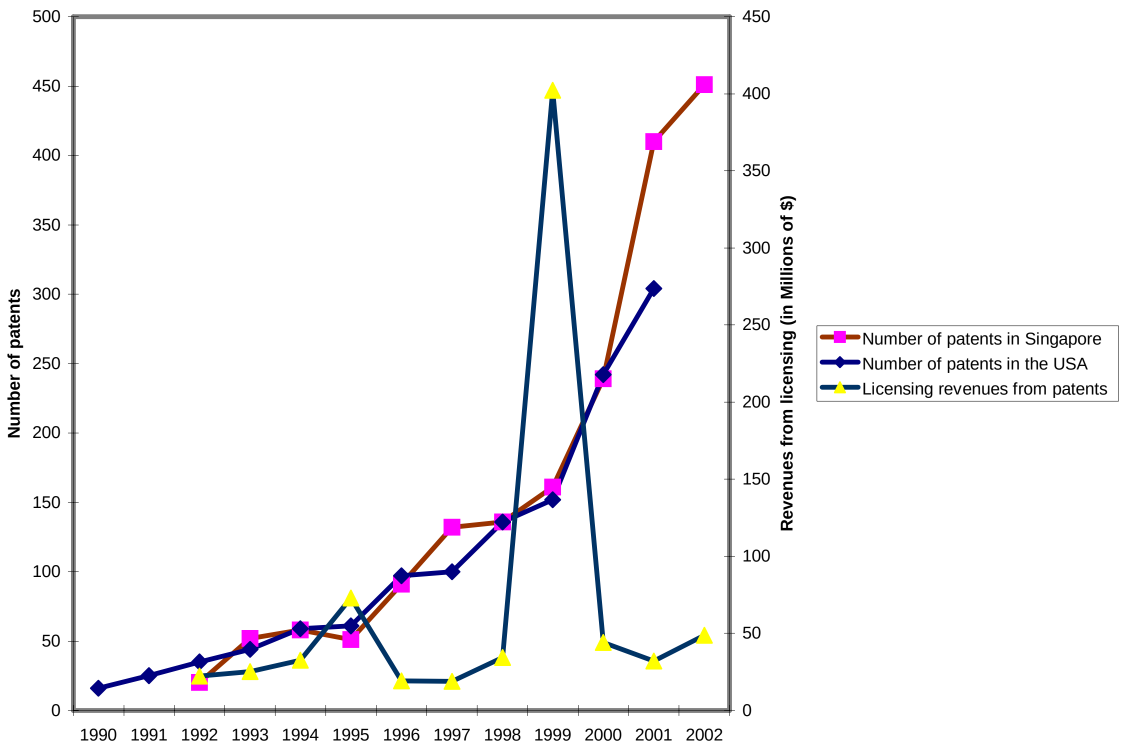

Figure 1. Patents granted to Singaporean inventors in Singapore and the USA, 1990–2001.
Sources: Agency for Science, Technology and Research (2003), USPTO (2003), World Bank (2003).

In the 1990s Singapore put in place a number of institutional and incentive systems designed to spur domestic technology-creating activities especially at the enterprise level. An examination of the performance of the domestic innovation system shows that the country has made significant progress in this direction, in both absolute and relative terms. The number of patents granted to Singaporean inventors has increased significantly – from less than 20 in the early 1990s to 300 in the USA and over 400 in Singapore in 2001. With high-tech products now accounting for more than 50% of manufactured exports, Singapore has the rare distinction of being a major competitor on world markets.

Singapore's innovation policies

The Singapore government introduced its innovation policies in two phases. During the first phase (1980–1991) the government played a passive role with respect to domestic technology development, and restricted its innovation policy to the development of small and medium enterprises and to engineering positive spillovers from foreign enterprises. During the second phase (since 1991) the government has been more explicit in its efforts to promote indigenous R&D by both foreign and domestic companies, and in establishing institutions such as the National Science and Technology Board (see table 1). This was also the time when Singapore's epistemic community was very pro-active.

Table 1. Singapore's innovation policy initiatives

1991	The National Science and Technology Board (NSTB) was established to develop the country into a centre of excellence in science and technology. The National Technology Plan set out the directions for promoting R&D in Singapore. A number of research institutes and centres were established.
1993	The Cluster Development Fund (CDF) was launched to catalyze the development of indigenous industries in high-growth clusters.
1995	The Innovation Development Scheme was launched.
1996	The Singapore Productivity and Standards Board (PSB), formed through the merger of NPB and SISIR, took over the role of SME development from the Economic Development Board (EDB). The National Science and Technology Plan (NSTP) and a US$4 billion R&D fund was launched to facilitate the development of S&T in Singapore. The Promising Local Enterprises (PLE) initiative was launched.
1997	The Committee on Singapore's Competitiveness was launched.
1998	Singapore One, the nationwide broadband multimedia infrastructure network, was launched.
1999	Industry 21, development blueprints for each manufacturing and exportable service clusters under the EDB, was launched. The Techno-entrepreneurship 21 Committee was established to develop and harness the potential of 'techno-entrepreneurs'. The Techno-entrepreneurship Investment Fund was launched to spur the development of the venture capital industry in Singapore.
2000	The NSTB was converted into the Agency for Science, Technology and Research (A*STAR).

Source: Economic Development Board.

The main institutional structure for S&T policy, the Singapore Science Council, was revamped in 1991 and renamed the National Science and Technology Board (NSTB) under the Ministry of Industry and Trade. Throughout the 1990s, the NSTB formulated and implemented all major policies with respect to innovation. In the recent past some of its tasks were transferred to another government agency, the Economic Development Board. Finally, in 2000 the NSTB was restructured and renamed the Agency for Science, Technology and Research (A*STAR), which comprises the Biomedical Research Council (BMRC), the Science and Engineering Research Council (SERC), Exploit Technologies Pte Ltd (ETPL), the A*STAR Graduate Academy (A*GA) and the Corporate Planning and Administration Division (CPAD).

Singapore's innovation policy instruments

Singapore has developed and applied a variety of policy instruments to promote indigenous science and technology research by both foreign and domestic companies. The first step was to increase the supply of technically trained human resources and to strengthen the technological infrastructure. In addition, the government has launched a variety of grant schemes and introduced fiscal incentives for companies to promote innovation. It has also encouraged the development of a venture capital industry to support technology start-ups, and has engineered positive spillovers from foreign direct investment (FDI).

1. *Increasing the supply of technically trained human resources*

Throughout the 1960s Singapore's emphasis was on a massive industrial training programme to upgrade the skills of its workers and to increase the supply of technicians and engineers who would eventually find employment in the numerous foreign companies that the state was in the process of encouraging. As the economy has developed, tertiary education has been expanded through two universities (the National University of Singapore and the Nanyang Technological University) and four polytechnics (Singapore, NgeeAnn, Temasek and Nanyang). Education has been a major item of public expenditure, accounting for about 22.4% of the government's recurrent expenditures,[9] since a substantial proportion of the cost of education is subsidized by the state. Over the decade 1989–1999 real expenditures on education increased by almost 20% per annum (see figure 2).

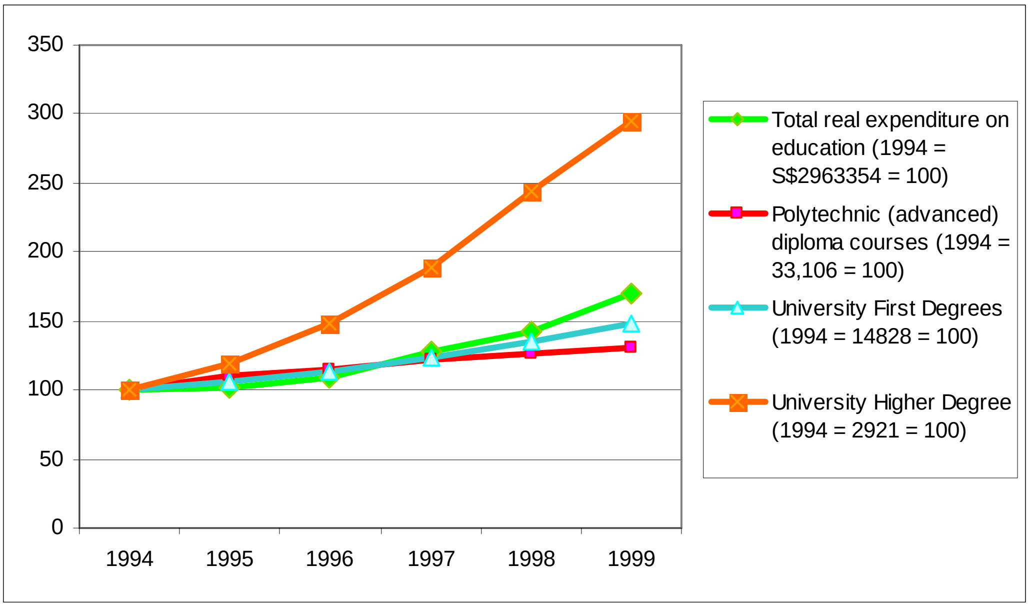

Figure 2. Expenditures on education, and enrolments at polytechnics and universities, 1994–1999.
Source: Department of Statistics (2000).

The education system in Singapore is biased in favour of science and technology subjects, and rightly so. Approximately 75% of enrolments at polytechnics and 62% at universities are in subjects such as engineering sciences, information technology, architecture and building technology, the health sciences and applied science and technology. Enrolments at both polytechnics and universities, in particular for higher-degree courses at universities, increased substantially over the period

In the field of science education, Singapore hopes to become the 'Boston of Southeast Asia' by developing the two universities to world-class standards. Substantial sums of money have been invested in improving their research facilities. The National University is in the process of setting up three specialized institutes linked to three areas in which Singapore has a comparative advantage – data storage, materials research and engineering, and medical informatics. The country is also supporting its graduates to undertake training abroad.

These policies on improving the quality of human resources have had two benefits: they have increased the supply of high-quality researchers, scientists and engineers, and have created a large pool of 'techno-entrepreneurs'.

9 Singapore Department of Statistics (2000).

2. *Strengthening the technological infrastructure*

A second policy instrument employed by the government of Singapore was the establishment of a number of research institutes and centres (RICs). Since 1991 the NSTB has established 13 RICs, each one concentrating on a specific area. These laboratories not only generate technologies themselves, but they also serve as a critical source of personnel for industry. The very existence of these institutes has encouraged local industry to collaborate with them in R&D projects. As noted above, R&D investments in these institutes have been increasing and now account for about 14% of the total.

It is interesting to note that Singapore established the RICs at a time when most other countries were rethinking the role of their own research institutes. The performance of these laboratories in Singapore has improved over time, although in terms of indicators such as the number of patents awarded and the revenue from them, no clear trends can yet be observed – it may be too early to assess them as a group. Among the 13 RICs, the most productive in terms of patents is the Institute of Microelectronics, which secured seven US patents in 1998-99. Some of these laboratories have linkages with both local and foreign firms through joint R&D projects.[10] These RIC–industry collaborations have resulted in the development of more than 70 new products and processes, some 20 of which have been commercialized, and have provided training for more than 580 researchers.[11]

3. *Incentive schemes: research grants*

Once it had achieved a critical mass of trained researchers, scientists and engineers, in 1991 Singapore began to employ a third policy instrument, the provision of grants for R&D. Today there are various grant schemes, including the Research Incentive Scheme for Companies (RISC), the Innovation Development Scheme (IDS), the Fund for Industrial Clusters (CDF), the Patent Application Fund Plus (PAF Plus) and the Technology for Enterprise Capability Upgrading Fund (T-UP).

Research Incentive Scheme for Companies (RISC)

The RISC encourages and assists companies and organizations to set up R&D centres and to develop in-house capabilities in strategic areas of technology in order to strengthen their competitiveness. Under the RISC programme a company can obtain a grant covering a maximum of 50% of its total research costs for a period of five years. There is no official maximum to the amount of grant. A company can receive RISC support only once, unless it changes course and decides to build up its research capacity in a different sector. In order to obtain a RISC grant, the company has to show a long-term research commitment, considerable research efforts and a perceptible growth in the number of researchers employed within the company. It is not known how many companies have benefited from this scheme.

Innovation Development Scheme (IDS)

The IDS is intended to encourage local and foreign companies to become more innovative. Under this scheme, companies are eligible to receive grants if their projects have not yet commenced at the time of application and involve product or process innovations that could lead to significant improvements in value added per employee, additional investments in new

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10 For example, the Institute of Molecular and Cell Biology collaborates or has collaborated with pharmaceutical and biotechnology companies such as Pfizer (USA), Amylin (USA), Lynx Therapeutics (USA), Genzyme (USA), Milipore (USA), Glaxo Research Group (UK), Boehringer Mannheim (Germany), Applied Genetics (USA), Pharmacia Biotech (USA), and Terragen Diversity (Canada), and with Asian companies such as Wiltech Agro, Gene Singapore, Gene Singapore China and MediPearl.

11 Singapore Ministry of Trade and Industry (1999: 74-75).

products or services, or the adoption of a new technology. The projects should also lead to significant contributions to the relevant industry or cluster. In the period 1995–1998, the IDS supported over 500 innovation projects (table 2). In 1996 alone, the scheme issued grants for 103 projects totalling US$80 million. For the period 1996–2001, these grants amounted to US$400 million.

Table 2. IDS grants by industry cluster (totals, 1995–1998)

Industry cluster	**No. of projects**
National Computer Board	154
Promising local enterprises	101
Electronics	73
Services	57
Engineering	56
Chemicals and life sciences	23
Other	49
Total	513

Source: Mani (2002).

Fund for Industrial Clusters (CDF)
The CDF is a special fund of US$650 million that was introduced in 1994 to support projects that carry too many risks for industrial companies to finance by themselves, and might thus not be realized. The fund is also used to create strategic alliances that will help secure investment projects in Singapore, to stimulate the growth of clusters of promising young industries, and to promote cooperation between Singapore and multinational companies. Since 1994 the CDF has spent US$325 million on 15 projects, in fields such as petrochemicals and other key industries. The government has announced its intention to increase the fund to US$1.3 billion.

Patent Application Fund Plus (PAF Plus)
PAF Plus is targeted at start-ups and helps defray the cost of patent applications, and thus encourages the diffusion of innovations. To be eligible to receive this grant, projects have two meet two conditions: the commercial benefits from inventions must accrue to Singapore and the project must not be receiving any other form of government assistance.

Technology for Enterprise Capability Upgrading Fund (T-UP)
T-UP is a grant fund that provides partial funding for research institutes to send research scientists and engineers on secondment to local enterprises for two years. It therefore helps local enterprises to develop their own in-house R&D capabilities. The scheme is open to all companies located in Singapore with at least 30% of their equity held by local investors.

4. *Fiscal incentives*
As the fourth policy instrument, the government offers five types of tax incentive for both foreign and domestic companies to promote local S&T research. These incentives include allowing companies to deduct some of the costs of in-house R&D from their income, to write off certain payments for R&D activities, and to offset the costs of acquiring patents. In addition, some royalty payments or technical assistance fees are payable to non-residents, including royalties, fees and contributions to R&D costs for the transfer of technology and know-how to Singapore. Thus, Singapore has created a comprehensive range of tax incentives

for companies not just to create technologies through in-house R&D, but also to acquire technologies created outside the firm.

5. *Venture capital*

The fifth policy instrument the government uses is the promotion of venture capital. Singapore is one of the first developing countries to establish a thriving venture capital industry. The evolution of this industry can be traced back to 1983 when the first venture capital fund was raised.[12] Over the years approximately 60% of the total venture capital disbursements in Singapore have gone to technology-based entrepreneurs in the computer, electronics, information technology, biotechnology and telecommunications sectors. The government has supported the industry through a host of tax incentives. As a result, between 1995 and 2001, the volume of venture capital funds more than doubled, from US$6.2 billion to US$13.7 billion. The number of Singapore-based companies backed by venture capital doubled from 310 in 1998 to 635 in 2001.[13]

6. *Spillovers from foreign direct investment (FDI)*

Singapore has put in place some very imaginative policies intended to engineer positive spillovers from FDI to local small and medium enterprises (SMEs). The rationale behind these policies is to strengthen the technological infrastructure of the local SMEs and thereby make them attractive suppliers of inputs and other services to foreign companies. Under this programme, known as the Local Industries Upgrading Programme (LIUP), the government encourages multinational corporations to ‘adopt’ a group of SMEs and transfer technology and skills to them. The programme normally pays the salary of a full-time procurement expert to work for specified periods with the adopted firms and help them upgrade their production and management capabilities to the required standards.

In 1999, the LIUP focused on the development of new capabilities and talents to support key clusters in strategic areas such as total and integrated maintenance management for the process industry. Many multinationals in the process industry have adopted the outsourcing business model to reduce their overheads, and they are moving towards awarding larger and integrated maintenance contracts to local engineering companies with the required expertise.

Under the LIUP scheme, more than 3700 workers have so far been trained and certified in 13 critical skill sets identified by the process industry. A further 30 multinationals and 11 large local enterprises, government-linked companies and government agencies are partnering some 670 vendors in LIUP. Although this is an industrial policy instrument, Singapore has used it effectively to strengthen its SME sector.

A second scheme in this direction is a collaboration initiative wherein the Economic Development Board encourages collaboration and strategic partnerships among industry players, acting as a ‘matchmaker’ where appropriate. Promising local SMEs can benefit from collaboration with multinationals or other local companies by being able to access new technologies, products or markets. Likewise, multinationals can benefit from partnerships

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[12] Wang (2004).

[13] Economic Development Board website (accessed 10 March 2004): www.sedb.com/etc/medialib/downloads/media_releases.Par.0010.File.tmp/Charts-Innovation%20&%20Enterprise.pdf.

with promising local enterprises that can provide competitive products, original designs or equipment manufacturing.[14]

Singapore's performance

Singapore's performance cannot be explained solely by the fact that it has better schemes for financing innovation. Rather, it can be attributed to its earlier policy on human resource development, which led to substantial improvements in both the number and the quality of researchers, scientists and engineers. In addition, the Singapore government introduced its innovation policy instruments in exactly the right sequence. It first developed a critical mass of human resources, and once this was achieved, it put in place a set of research grants to encourage both local and foreign enterprises to invest in R&D. This was of course also facilitated to a large extent by these firms' strong demand for innovation, since most of their products were sold on international rather than local markets.

To elaborate on this sequencing, the government's innovation policies took into account both instruments and institutions both for creating technologies locally and for enabling local firms to derive maximum benefits from technology imports through both FDI and licensing. Both of these policies were in turn contingent upon other policies aimed at, first, increasing the supply of scientists and engineers, and then improving quality of training.

This policy, in turn, resulted in government support to innovations through two mutually exclusive routes. First, the government created an army of 'techno-entrepreneurs', supported by state grants, favourable tax policies and venture capital, who then established technology-based SMEs. The most promising of these SMEs were identified and given additional financial support to become the large companies of tomorrow through a grant scheme known as the 'promising local enterprises' initiative.[15] Second, an increase in the availability of technically trained human resources led to a phenomenal increase in the density of scientists and engineers.

4 Conclusions

Informed policy-making leads to better and more relevant policies demanded by the users – firms and research establishments. Most countries interpret innovation policies in terms of a variety of financial instruments. Although the availability of finance is an important requirement for technology-generating activities, its maintenance leading to optimal outcomes depends very much on the availability of a critical mass of qualified scientists and engineers.

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[14] Economic Development Board (www.sedb.com/edbcorp/sg/en_uk/index/in_the_news/press_releases/2002/economic_development4.html).

[15] This grant scheme was introduced in 1995. There is a 'top 100 list' of 'promising local enterprises', selected by the EDB as possible Singaporean 'multinationals for the next century'. It strives to push each of these enterprises to a turnover of SGD100 million (US$60 million) by 2005. The list is intended to encourage innovation, and to help cultivate a new generation of entrepreneurs. The companies are then offered additional incentives. In 1999, 45 companies achieved sales revenues of more than US$100 million (up from US$31 million in 1998), and their average revenue was US$75 million (up from US$54 million). The scheme has also been successful in raising their productivity, which is now about 12 percentage points above the industry average

Policy instruments have to be logically sequenced. This is much more easily said than done, however. In most countries innovation policies are designed (often very half-heartedly) by bureaucrats who may not be personally involved in design of the policy instruments for their implementation. Some countries seek the services of external experts (foreign or local) in policy design. But unless it is internalized by the agency responsible for implementation, the exercise is unlikely to be successful and cannot be replicated in the country over time. This is because policy instruments need to reviewed and redesigned in accordance with changing government priorities and the stage of technological development of the country.

The existence of an epistemic community or network of policy specialists who meet outside formal bureaucratic channels to discuss specific issues, set agendas, and formulate policy alternatives can in fact lead to informed policy making. Singapore has apparently managed to establish such a community within the science and technology administrative apparatus itself.

In Singapore, the epistemic community involved in innovation policy making is composed of the National Science and Technology Board (NSTB) and its recent incarnation, the Agency for Science, Technology and Research (A*STAR), which works in close coordination with the Economic Development Board (EDB). The agency's Corporate Planning and Administration Division played a coordinating role in getting this community up and running. The country has also made use of international experts from time to time. This has led to logically sequenced innovation policies and instruments that have produced very desirable outcomes. Singapore is unique among developing countries in that it has responded effectively to the needs of its innovation system.

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