Commercializing new technologies in India: a perspective on policy initiatives[1]^

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Abstract

Technology is a key resource of profound importance for the well being of a national economy as well as international competitiveness; it is also vital for corporate profitability and growth. Development and commercialization of new technologies has inherent uncertainties and associated risks. In a competitive world of scarce resources, new technologies fight for survival against developed technologies that promise immediate returns with comparatively little risk. Technologists and policy makers need to provide wider perspectives that encourage an entrepreneurial spirit that nurtures new technologies in an enabling environment through appropriate policy initiatives.

Keywords: Technology; Technology transfer; Technology commercialization; New technology; Innovation; Policy initiatives; Policy perspective; Policy

1. Literature survey of technology innovation

Rondo Cameron [1], in his study of the development of Europe 1800-1914, concluded that Germany, which was technologically backward during the 1830s compared to the United Kingdom, France, and Belgium, transformed itself into an industrialized country through technological innovation. Special institutions were

established, new technology risks were accepted, and the task of industrializing Germany through technology innovation was declared to be a national mission. National policy provided the required thrust as well as the perspective.

Similar development and growth through innovation application were repeated in Europe, America, and Japan during the late nineteenth and early twentieth century [2], again with policy support at the national level. Jantsch [3], Twiss [4], Martino [5] and others highlight the importance of technical change and its leverage through appropriate policies for industrial and economic growth of a nation. Steele [6] and Rubenstein [7] emphasize the importance of technology perspectives in national planning toward competitiveness. Further, Porter [8], in his analysis of competitive advantage concludes that technology is an important competitive factor in the value-adding business of a firm. Fagerberg [9], in his research on a technology approach to varying growth rates of 27 countries, provides strong evidence of the major contribution of the technological perspective of national policy to the growth of a nation as well as its firms.

Lundvall [10] emphasises that "the long-term competitiveness of firms, and of national economies, reflects their innovative capability, and, moreover, firms must engage in activities (facilitated by policy framework) which aim at innovation just in order to hold their ground." Similarly, Smith [11] points out "the success of any national or regional economy relies in part on its ability (channeled and nurtured by policy perspectives) to create firms which become the bearers' of new technologies." It was re-emphasised by Camagni and Rabelloth [12] in their study of the Italian textile industry that facilitation of technology change through an appropriate policy framework is crucial to revitalizing enterprises.

Thus, a large number of studies and research works have highlighted the importance of technology as related to policy initiatives to harness the benefits of technology for growth and competitiveness. Even World Bank studies on the recent experiences of several newly industrialized countries in Southeast Asia found that technologies, and more specifically a country's technological capabilities including the effectiveness of related policy frameworks, are among the most important elements in the process of economic and social development [13,14]. Studies of Indian industrial development [15-19] reveal that support and facilitation of policy have significant impacts on technological developments.

2. Strong support required for policy initiatives and facilitation

A new technology, by definition, is available either at laboratory scale or at the pilot plant level as compared to the commercial plant level availability of established technologies. Commercializing a new technology starts with upscaling and proving the technology, followed by upscaling process parameters, designing and fabricating plant and equipment, optimizing product to satisfy market needs, and developing markets.

Uncertainties and risks are involved during technology development and commercialization, and converting an invention to an innovation, prototyping it, and optimiz-

ing the product and process technologies involve many scientific and technical uncertainties. Upscaling a technology to pilot plant level and thereafter to commercial-level plants poses numerous technical challenges, and both market development and funding for new technologies are fraught with risk.

Scott and Szanyi [20], Twiss [21], Farrell and Saloner [22,23], Cooper [24]), among others, have highlighted the importance of uncertainties in new technologies. Ireland and Stoneman [25] and Coover [26] argue that diffusion and the success of a new technology are constrained unless these unknowns and their related risks are resolved. Douglas [27] calls them the "bugs of new technology" and Freeman [28,29] emphasizes that the economics of a new technology and the financial risks are a consequential outcome of technological and marketplace risks.

In addition to the uncertainties and risk raised by others, Steele [30] cautions about uncertainties in terms of (a) the readiness timeframe of a technology or product, (b) the product or technology performance vis-à-vis market anticipation, and (c) tradeoffs between cost and performance. Marquis [31], Allen [32], Smith Lee [33], Gold [34], and Silverberg [35] all highlight the challenges involved in developing new technologies and the uncertainties and risks associated with development and commercialization.

The benefits that accrue from a new technology generally outweigh the costs and the requisite investment, but many new technology-based ventures must compete with established technologies for funds. Most financial institutions have no separate mechanism for evaluating and assessing new technology projects, their intrinsic potential, and the likelihood of commercialization. Thus, most refrain from financing new technology commercialization ventures (NTCVs) for two reasons: first, the risks and uncertainties of the new technology, and second, financing NTCVs generally has no place in their business mandate.

Alexander Gerschenkron [36], in his well-researched study of the development and diffusion of new technologies during the industrial and technical revolutions in Europe, concludes that neglect of their technological role on the part of financial institutions can be explained by several factors, the most important of which is that financial institutions are viewed—and tend to view themselves—primarily as financial intermediaries. Kwack Chi Young [37] reports:

> While the finance function is the raison d'être of financial institutions, in the case of industrial development institutions, it is the industrial development function which is usually written in the basic charter of activities. The technological function, in contrast, is seldom, if ever mentioned, even in the charter of industrial development banks. Therefore, it is viewed not as a primary or even secondary objective of a bank, but essentially as a side-effect or indirect consequence of its activities of industrial development.

Another factor is that the causal relationships between the financial institutions' policies and decisions on one hand and their effects on the country's technological development on the other hand, are neither studied nor understood especially vis-à-vis new technologies. Developing countries in particular, given a paucity of funds,

find it difficult to strike a balance between upscaling and commercializing new technologies and subsequently fulfilling maintenance needs and sustaining regular activities.

It is generally because of this pervasive weakness of technology upscaling and commercialization systems in developing countries, inter-alia, that a "technology push" is constrained. Diffused and weak efforts seldom lead to successful technological development, and tempo and morale are not sufficient to support such intense activity. In an environment of limited technological activity, there is only an erratic connection between research and development institutions and industry. Exogenous input, in terms of policy measures and a facilitating and enabling environment, are essential for developing a new culture of technology commercialization.

3. Policy initiatives in other countries

Wilson [38] reports that in the 1960s France and Germany established special institutions the likes of which did not exist in any other country at that time. Jean Baptiste Colbert, chief of German Bank, said, "A banker is soldier for industrial development" and banks had a "mission to industrialise Germany". This indicates the major shift that took place in the attitudes, philosophies, and policies of financial institutions. In developed countries, banks have become major actors in the national science and technology system, and they play a crucial role in financing and supporting the development and commercialization of new technologies [39]. Several countries launched programmes to restructure their financial institutions to respond to changing needs when their industries were undergoing technological development. Amin [40], in a research study of Santa Croce, a small industrial town near Pisa, Italy which produces high-quality, cured bovine leather, states that the high-technology industrialisation of this small town, which had nothing until the last decade, became possible when three banks began consistently providing easy, risk-sharing finance for new technology units. He adds that the decision to make available risk-sharing and low-cost funds also enabled exploration for commercial applications.

In the US, many banks have taken on sufficient technical assistance and outside expertise to enable them to take a long-term view of ventures they finance and to encourage support for new ideas and innovations. The result has been the transformation of banks into banks cum technological institutions [41]. There was a deliberate attempt by banks and the government to bring the country into the process of technological development via a national purpose and commitment to industrial development. Subsidy programs were designed, companies formed that provide venture capital for startups, and innovative small companies were encouraged. Private investors in new technology ventures were offered 30% concessions against income tax [42]. The effect of the US government's supportive policy measures is the rapid development of venture capital funds (VCFs) into a major source of funds for NTCVs.

In Canada, the commercialization of new technologies has become a regular activity among R&D industry funding agencies as well as the government. Systems have stabilised, VCFs have matured and become a major source of finance for new

technology-based ventures. The government still encourages and supports VCFs through favorable fiscal policies. A study conducted by the Business Development Bank of Canada [43] found that research and development has made important contributions to the economic well-being of Canada, and it has been well supported by venture capital. The system has matured over years, and the government may eventually withdraw, saying "we have done our part", although the study concludes that while possible, such a step may be some years away. It further adds that government support and intervention are essential and must continue as innovations and their financing cannot be sustained on their own due to uncertainties and risks during the initial stages. Thus policy initiatives and facilitation of new technology commercialization are imperative.

Stock market activity continues to play an important role in providing startup investment resources for technology-based enterprises in the US and Canada. Indeed, this has become the second major source of finance, after venture capital investment, for commercializing new technologies.

Some highlights of other national efforts to support scientific and technological development are the following:

- Brazil's Banco Nacional de Desenvolvimento Economico established a national fund for scientific and technological development during the 1970s, and Banco do Brasil allotted 5% of its profit for development of technologies [44].
- The Development Finance Corporation of New Zealand established an Allied Technology Programme to raise the technology level of New Zealand enterprise [45].The Inter-American Development Bank started loans to encourage adoption of new agricultural technologies in Brazil and Bolivia [46].
- The Business Development Finance institution was established in Denmark in 1992 to provide risk-sharing, low-cost funds for upscaling and commercializing new technologies [47].
- The Ministry of International Trade and Industry in Japan, during the 1980s, began promoting technological R&D. The Korea Technology Development Corporation was established in 1981.

The financial sectors in other developing economies are also become re-oriented and focused on technological needs. For instance, Sri Lanka [48] and Malaysia [49], among others, have initiated programmes for restructuring their national financial institutions.

4. Policy initiatives in India

The importance of technology was spotlighted by its incorporation as a key factor in the first scientific Policy Resolution of India enacted in 1958. A large-scale development of technology was envisaged to support early and critical stages of industrialisation. The Technology Policy Statement (TPS) in 1983 spoke of technology in the broadest sense, including the agricultural and service sectors as well as the obvious

manufacturing sector, which stretches over a wide spectrum ranging from small-scale village and cottage industries (often based on traditional skills) to medium, heavy, and sophisticated industries [50]. The policy has a basic objective of developing indigenous technology and encouraging efficient absorption and adaptation of imported technologies that are appropriate to national priorities and resources. Its aims are to attain technological competence and self-reliance; to reduce vulnerability; identify obsolete technologies still in use and arrange for modernization of equipment and technology; and to develop technologies that are internationally competitive, particularly those with potential.

The TPS stated that, within technology development, special emphasis would focus on: Indigenous technology — strengthening and diversifying domestic technology bases in order to reduce imports and simultaneously expand exports to ensure international competitiveness. TPS emphasize the following requirements for developing indigenous technologies: (a) importance of technology development, (b) inventions, (c) enhancing traditional skills and capabilities, (d) ensuring timely availability, (e) upgrading to prevent obsolescence, (f) increasing the demand for indigenous technology, (g) preferential treatment, (h) fiscal incentives, (i) design engineering, (j) engineering consulting, and (k) establishing in-house R&D centres. Technology acquisition — Industrializing a country requires a heavy price to import science and technology in the form of plants and machinery, well-paid personnel, and technical consultants. The early and large-scale development of science and technology in India would greatly reduce the drain on capital during the early stages of industrialization. The TPS advocated a mix of indigenous and imported technology.

With a view to further strengthening the Indian economy and to assisting the nation to fulfill its role in the global economy with both confidence and urgency, a draft paper for a new technology policy was initialed in 1993. It aimed to inculcate a renewed sense of purpose for accelerated development and use of indigenous technology in the context of the 1991 industrial policy statement while keeping in view the need to adhere to international quality and to preserve the environment. It focused on issues such as: (a) technology and society, (b) technology and environment, (c) human skills, (d) thrust areas, (e) role of research, development and engineering (RDE), (f) resources for RDE, (g) linkages and (h) policy implementation, monitoring, and review. The draft technology policy was widely circulated during 1993-94. However, the final version of the policy statement has yet to appear.

The Research and Development Cess Act (1986) was promulgated to establish a fund for the import of technologies, to finance development of indigenous technologies, and to make imported technologies indigenous. Simultaneously, as a follow-up to the 1983 Technology Policy Statement, the Technology Information Forecasting & Assessment Council (TIFAC), an autonomous body fully owned by the government of India, was formed under the Department of Science and Technology during 1988. In addition to its other activities, TIFAC provides some financing and facilitates development and commercialization of technologies under the Home Grown Technology scheme. Venture capital funds and a few other schemes were also promoted during the 1980s to support similar activities. The Technology Development Board Act (1995) was another major policy initiative of the government in

this direction. Table 1 lists various special schemes and funding mechanisms that have been commissioned to finance new technology commercialization.

5. The research study

In spite of all the above policy initiatives, the desired impact has not been achieved by new technologies, albeit a modest beginning has been made. Over time, the majority of venture capital funds drifted away from their responsibility to finance new technologies, repositioning themselves instead in risk-free operation zones. The other mechanisms and special schemes specifically commissioned to promote commercialization of new technologies have not fully satisfied the clientele.

Our research study is holistic in nature and analyses the commercialization of new technologies in India from the perspective of major stakeholder groups, i.e., industrial firms, financial institutions, technology institutions, policy makers, and facilitators (sample size: 480 units). It is designed to bring to the forefront the areas of thrust, the issues involved, their importance and hierarchical positioning, and the expected challenges in terms of actions required to further this very important subject of nation building.

6. Findings

This paper presents our findings about funding mechanisms and policy initiatives for commercializing new technology in India.

Table 1
Special schemes and funding mechanisms for financing new technology improvements and commercialization ventures

PACER	Programme for Acceleration of Commercial Energy Research of ICICI
SPREAD	The Sponsored Research and Development Programme of ICICI
TF & DS and VCS	Technology Finance and Development Scheme, and Venture Capital Scheme of RCTC
VCF-IDBI	Venture Capital Fund-Industrial Development Bank of India
VCF-SIDBI	Venture Capital Fund - Small Industries Development Bank of India
APIDC-VCL	Andhra Pradesh Industrial Development Corporation-Venture Capital Limited
PATSER	Programme Aimed at Technological Self Reliance of DSIR
HGT	Home Grown Technology of TIFAC, DST
TDB	Technology Development Board of DST
Canbank-VCFL	Canara Bank Venture Capital Fund Limited
GVFL	Gujarat Venture Finance Limited

Key: ICICI = Industrial Credit and Investment Corporation of India; RCTC = Risk Capital and Technology Finance corporation Ltd; DSIR = Department of Scientific and Industrial Research; TIFAC = Technology Information, Forecasting & Assessment Council; DST = Department of Science & Technology.

6.1. Funding mechanisms

All financial institutions share the view that both quality and quantity of available financing facilities and services for NTCVs need significant improvement. As illustrated in Table 1, there are only eleven schemes and mechanisms that currently fund NTCVs. One of them (TDB) was commissioned in 1995 and has been operational only since 1997. Two ICICI schemes, namely PACER and SPREAD, have ceased operations since 1997, the terminal year of their approved duration. The level of operation of the remaining eight schemes has always been marginal. The average annual funds for support of NTCVs during the period 1990 to 1997 was Rs. 265 million; which improved during 1998-99 to about Rs. 435 million due to higher contributions from TDB. It is expected to increase to around Rs. 1000 million a year during the early 2000s, again, largely because of increased contributions from TDB.

The funds being made available for NTCVs, and the number of NTCVs supported (around 70 per year during the 1990s, increased to about 100 during the early 2000s) are rated insufficient by almost all the respondents. The improvements desired for each feature of existing mechanisms have been analysed in Table 2. The highlights of recommended changes are:

The number of special financial schemes for NTCVs should be more than doubled from the existing ~10 schemes; the number of NTCVs supported per year by each scheme should be tripled, and total funds available for NTCVs should be enhanced to more than Rs. 10,000 million per year.

Regarding loan monies, the majority of respondents recommended that the upper limit of returnable financial support should be increased substantially (Rs. 5 million for small-scale NTCVs, Rs. 50 million for medium-scale, and Rs. 500 million for large-scale). Further, it has been suggested that the upper limit of financial support as a percentage of the total cost of the project be increased from the current 50% to 75%. Participation in equity and provision of grants have also been suggested.

The processing time for proposals should be reduced, from an average of 6-12 months to 3-6 months. Moreover, the first installment should be disbursed within 3 to 6 weeks of project approval instead of the current 6 to 15 weeks.

A majority of respondents suggested that the interest rate during project gestation be kept between 0-6% and could be increased up to 15% during the repayment period, which should start after the project begins commercial production.

Other recommendations include: (a) royalty should be restricted to 2% of sales; (b) royalties to be paid over a period of 5 to 7 years; (c) repayment of financial support should be spread over 5 to 7 years after the gestation period; (d) a nominal processing fee (Rs.2,500 for small scale, Rs. 5,000 for medium scale and Rs, 10,000 for large scale) should be charged—all to improve the quality of proposals.

6.2. Facilitation initiatives

Actions that will facilitate development initiatives can be taken by four sectors of the country: (1) industrial firms, (2) R&D institutions, (3) financial institutions, and (4) the government itself.

Table 2
Response of financial institutions to the features of special mechanisms for financing NTCVs

Feature	Current level	Desired level
Number of schemes operational in the country	8-10	5-6 schemes, annual budget of Rs. 2000 million ea 10—15 schemes, annual budget of Rs. 100 million ea
Average number of proposals considered/year/per scheme or mechanism	≈=250	500 to 1000
Average number of proposals approved/year/per scheme	10-25	50 to 100
Processing time for proposal (mos)	=6-12	3 to 6
Time required to release first installment after approval of project (wks)	=6-15	3 to 6
Upper limit of financial support (Rs. million)	0.5-50	Small / Medium / Large
		As loan 5 / 50 / 500
		As equity 5 / 50 / 500
		As grant 1 / 10 / 100
Upper limit of financial support (% of total project cost)	25 to 50	66 to 75
Application processing charges (Rs. per proposal)	Nil to 50,000	Small Scale : Rs. 2500 Medium Scale: Rs. 5000 Large Scale : Rs. 10000
Interest rate during gestation period (per cent per annum)	0-18	0 to 6
Interest rate after gestation period (per cent per annum)	6-18	0 to 15
Royalty (% of sales)	0-5	0 to 2
Time period over which royalty is to be paid (no. of years)	0-10	5 to 7
Time period allowed for refund of financial support provided (no. of years after gestation period)	3-5	5 to 7
Hypothecation/mortgage of assets	applicable in some	Yes (100% respondent)
Bank guarantee	applicable in some	Yes (27%) No (73%)
Personal guarantees	applicable in some	Yes (45%) No (55%)
Placement of member on the board	applicable in some	Yes (36%) No (64%)
Setting up monitoring/review committee	applicable in some	Yes (100%)

Table 3
Recommended measures for industrial firms as ranked by financial institutions

Suggested measures	Weighted score
Have longer perspective of R&D activities as an investment for future	51
Promote sponsored research with Indian laboratories	41
For near-developed technologies: work with laboratories to set up demonstrations/pilot plants	33
Take corporate membership in R&D laboratories	22
Make R&D laboratories corporate members in the company	18

Note: The maximum possible score that one factor can earn is 55.

6.2.1. Actions to be taken by industrial firms

Financial institutions have suggested that there should be attitudinal changes in industrial firms. These recommendations are shown in Table 3. The recommended actions suggest an overall participative and collaborative working approach.

6.2.2. Actions to be taken by R&D institutions

The three most important actions by R&D institutions that would further facilitate commercialization of new technologies as shown in Table 4. The primary focus is on joint actions by research institutions and industrial firms. Such actions are expected to orient the R&D laboratories toward market needs.

6.2.3. Actions to be taken by financial institutions

The actions suggested by financial institutions to improve their own furtherance of commercialization of new technologies is shown in Table 5. It has also been suggested by some financial institutions that they should play a more meaningful role than simply being a funding agency. To this end, financial institutions should be the true partners to NTCVs by extending help and guidance even in the areas of marketing and management.

Table 4
Recommended measures for research institutions as ranked by financial institutions

Suggested measures	Weighted score
Collaborative projects among laboratories, industrial firms and academic institutions	78
Undertake more projects of industrial importance with a market-oriented approach	66
Concentrate on emerging and innovative areas	57
Properly document technology, design, and techno-economics of commercial plants	48
Do not stop at laboratory scale; take to demonstration plant level with industry participation	40
Seek technology transfer cases, work until established	36
Become a corporate member in companies	35
Become a corporate-sponsored agency (have corporate membership from industry)	29

Table 5

Recommended measures for financial institutions — ranking by financial institutions

Suggested measures	Weighted score
Share the risk with entrepreneurs	58
Charge no interest during gestation period	46
Provide required funds in time	33
Request no re-payment during gestation period	28
Lower re-payments in the initial stages of commercialisation	22
Arrange 5–8 year repayment period after the gestation period	20

Note : The maximum possible score that one factor can earn is 66.

6.2.4. Actions to be taken by the government

Financial institutions suggest that commercialization of new technologies warrants a declaration by the government that such activities are a priority so all facilitations and incentives available to a priority sector, including soft loans, would also be applicable to NTCVs. Other measures are shown in Table 6, Above all, incentives should be extended to existing laboratories to help them commercialize technologies as well as to those opening up government laboratories in need of to industrial firms.

7. **Concluding remarks**

The considerable research work by eminent scholars underscores the uncertainties and risks associated with new technologies and the need to provide a conducive environment that encourages wider perspectives through appropriate policy development and commercialization of new technologies.

Table 6
Recommended measures by government-ranking by financial institutions

Suggested measures	Weighted score
Declare "commercialization of new technologies" as a priority activity so that all facilitations and incentives are available to priority sectors, including soft loans	58
Government domain agencies to quickly patronise the products/services of new technologies, even at slightly higher cost during initial years	47
Provide sales tax, excise duty, and local tax exemptions for new technology products, plants, and machinery (including customs duty, if applicable) for 5 years from start date of production	38
Provide incentives to R&D institutes and firms to commercialise new technologies	31
Allow government laboratories to become corporate members of firms	25
Open up government laboratories to industrial corporate members	21

Note: The maximum possible score that one factor can earn is 66.

The research we conducted in India and the results presented here reaffirm that the supportive facilitation that is required for technology development and commercialization is virtually the same across all countries, although the means and their impact may vary. New technologies face uncertainty, risk, and the need for major startup capital and risk sharing.

With regard to the subject of financing, India's experience with venture capital funds has not been satisfactory compared to the relative success of the US and Canada. Similarly, the Indian banking industry is still in the process of developing mechanisms to provide capital for new technology commercialization ventures, and the pace of activity and the amount of funds being allocated are far from levels that will have a significant impact. Consequently, the kinds of successes experienced by Germany, France, America, and Japan during the late nineteenth and early twentieth centuries, are yet to be seen in India. The acquisition of techno-managerial skills by Indian banks also needs to happen at a speedier pace.

The Indian stock market, which are not yet mature, cannot be expected to be a major source of new technology financing. Special funds, financing mechanisms, and fiscal incentives, which have been successfully utilized in other Asian countries like Japan, Korea, Thailand, and Indonesia, now seem to be appropriate for India at this time. Various Indian stakeholder agencies recommend strengthening these mechanisms. Finally, a broader perspective of new technology development and commercialization needs to be assumed by every stakeholder agency.

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