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Developmental financial institutions as technology policy instruments: implications for innovation and entrepreneurship in emerging economies

Gerard George [a,*], Ganesh N. Prabhu [b]

[a] *Department of Management and Human Resources, Weinert Center for Entrepreneurship, University of Wisconsin–Madison, 975 University Avenue, Room 5252, Madison, WI 53706-1323, USA*

[b] *Indian Institute of Management at Bangalore, Bangalore, India*

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Abstract

Developmental financial institutions (DFIs) in emerging economies regularly assess new technology platforms to support their investments in new ventures, established firms, and technology institutions (TIs). Their financing decisions are guided by national priorities such as achieving technological self-reliance. By providing attractive financing options and related support, DFIs are well placed to consciously channel finance into designated priority technology areas. To better understand DFI roles, we conducted multiple interviews with participants affiliated with DFIs, firms and TIs in India. From data gathered from these interviews and secondary data on DFIs in emerging economies, we develop a preliminary framework to suggest that DFIs, when proactive in making technology assessments, form an important link between developing a firm's absorptive capacity and building a nation's innovative capacity. Also, DFI financing facilitates new venture creation in the context of underdeveloped capital markets prevalent in emerging economies. To illustrate these roles, we consider technology support programs of DFIs in India and their role in the information technology (IT) industry.

Keywords: Technology policy; Entrepreneurship; Innovation; Absorptive capacity; Emerging economies

1. Introduction

The concept of 'national innovation system' has received considerable attention in literature on technological change and economic development (Mowery, 1998). Nelson (1993) defines these systems as institutions whose interaction determines the innovative performance of national firms. The national innovation systems approach typically characterizes the relationship among institutions that support and foster knowledge creation and the firms that exploit this knowledge. This stream of work suggests that institutions within a country need to complement each other and work in tandem to maximize innovation. It is argued that technology policy, which creates efficient institutional mechanisms of integration between knowledge production and knowledge commercialization functions, is likely to enhance a country's ability to sustain an innovative technology system over time (Stern et al., 2001). The study of knowledge flows, between institutions and firms, within a country and how such flows can be influenced by government policy provides a useful

* Corresponding author.
E-mail address: ggeorge@bus.wisc.edu (G. George).

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analytical framework to study industrial development.

From a firm-level perspective, research on absorptive capacity emphasizes a firm's capabilities to manage knowledge towards commercial ends (Cohen and Levinthal, 1990). As firms develop their absorptive capacity, they improve their abilities to acquire, assimilate, transform and exploit knowledge, resulting in innovative technologies, processes and products (Zahra and George, 2002). Consequently, institutions that serve to develop a firm's absorptive capacity and harness it systematically towards a national technology development and commercialization agenda, would serve to bridge firm-level absorptive capacities to form a national innovative capacity, broadly defined as the country's ability to produce and commercialize a flow of innovative technology over time (Stern et al., 2001).

In this article, we address the relatedness of national innovative capacity and firm absorptive capacity by examining the bridging role of national-level[1] developmental financial institutions (DFIs). We suggest that DFIs can be effective institutions that serve to assess new technologies and finance their development, either in private firms or in technology institutions (TIs).[2] DFI financing also provides the 'soft infrastructure' to support entrepreneurship and business formation in economies with underdeveloped product and capital markets. By doing so, DFIs may act as market intermediaries in channeling finance to develop technologies consistent with a country's technology policy. Since targeted technology policies influence the development of national innovative capacity (Stern et al., 2001), the role of DFIs as bridging agents between a firm's absorptive capacity and a nation's innovative capacity merits a closer theoretical examination.

1.1. A description of DFIs

National level DFIs are quasi-governmental organizations that were formed with the purpose of developing and/or rejuvenating core industries within the country (Kane, 1975). The primary goal of DFIs is the economic development of emerging economies. Their birth can be attributed to government mandates or directives that sought to promote industrial development in core industries, such as steel, petrochemicals, and transportation. Though the government is a dominant stockholder, DFIs tend to behave as large institutional investors with independent managerial control (Bhatt, 1993). There are nearly 75 national-level DFIs in the Asia-Pacific region (ADFIAP, 2000), 70 in Africa, and about 90 in the Latin-America region (IMF, 2001), among others. Though infrastructure financing is a DFI's primary objective, a secondary or derivative outcome of DFI funding is technology development. In pursuing development of infrastructure and large-scale investment projects, DFIs are exposed to situations that necessitate decisions on the economic viability of certain new and emerging technologies. Consequently, DFI funding for certain types of nascent technologies allow it to influence the future commercialization or success of these technologies.

DFIs are also actively involved in developing programs and providing facilities that support technology development by firms and TIs within the country (Jequier and Hu, 1989). By financing technology development projects for industrial application, DFIs fill an important resource gap in emerging economies (Prabhu, 1996). Given the low investment capacity and a lack of financing options in many emerging economies (Khanna and Palepu, 1997), DFI finance can encourage R&D in areas where both firms and TIs, playing complementary roles (Rosenberg and Nelson, 1994), find it difficult to take the investment risk (Dahlman et al., 1987). If TIs rely primarily on research and consulting contracts from the industry, they may work in areas of concern to large and resource-rich firms that can afford such investments

[1] This article addresses DFIs that are national, in size, reach, and scope of services. These DFIs usually have technology development as a primary or secondary focus. Some DFIs in emerging economies even specialize in technology development—e.g. Risk Capital and Technology Finance Corporation of India. Other state-level DFIs may exist in these economies but do not have the same level of resource endowment or mandate to perform the roles discussed in this article.

[2] Technology institutions (TIs) are defined as non-profit organizations that are primarily responsible for the knowledge-production or knowledge-creation functions. Examples of TIs include research universities and non-profit research centers. See for example, Argyres and Liebeskind (1998) or Miner et al. (2001) arguments for the importance of TIs and its knowledge production function for economic development. Also, as a reviewer pointed out, in emerging economies quasi-private institutions are formed by the interaction between governmental agencies and the private sector with the specific intent of importing and disseminating new technologies. In other countries, unions and trade organizations may perform similar technology assimilation functions.

(Argyres and Liebeskind, 1998), while possibly neglecting priority areas with small-scale sector domination (Teece, 1986).

Some conceptual work on DFIs notes that these institutions act as catalysts of entrepreneurship in emerging economies by advocating restructuring and corporate governance of established organizations (George and Prabhu, 2000). Other studies argue that DFIs are effective market intermediaries in emerging economies (Bhatt, 1993). Given that emerging economies are characterized by under-developed capital, product, and labor markets (Khanna and Palepu, 1997), such intermediaries become important mechanisms to implement industrial policy (Shin, 1993). For example, Bhatt (1993) argues that DFIs can act as catalysts for industrial development if they possess (a) a nucleus of entrepreneurial talent which has both a strong developmental mission and sound ability to judge the worth of the project, the ability of the promoters to handle it well and its developmental potential, (b) the ability to monitor and correct the project during implementation, (c) the ability to play a dynamic promotional role by creating new markets for its products and services in providing technical and managerial guidance, making venture capital available and providing allied services and infrastructure. Though prescriptive literature exists on the role of DFIs in technology financing (e.g. Najmabadi and Lall, 1995), this topic has not been adequately explored in economics and management literatures. The value of this research stems from understanding the roles played by institutions in shaping national innovative capacity and economic development through new venture creation and growth. Though a considerable body of knowledge highlights the role of institutions in national innovation systems (e.g. Edquist, 1995; Mowery, 1998, Nelson, 1993), little is known on how development financing can influence technology choice, innovation, and entrepreneurship in emerging economies, which is the focus of this article.

1.2. Data collection and interpretation

This article draws from primary and secondary data collected on DFI financing for technology development projects. For primary data, we conducted in-depth semi-structured and open-ended interviews (Fetterman, 1989) of 40 key project participants in multiple functional areas and organizational levels in firms, TIs and DFIs for durations ranging from an hour to two and a half hours, leading to 167 pages of typewritten transcripts. Prior to interviews in firms and TIs, visits and contacts were made with several national level DFIs in India for collecting background information on their technology support programs to select the appropriate program to study in detail. Once the program was selected, further visits were made to the DFI to select appropriate projects that were supported within the program, to seek permission through the DFI from the firms and TIs to be covered, and to conduct interviews with all the DFI project coordinators regarding their program implementation experience across projects. Secondary data on programs offered by DFIs in India and other emerging economies were accessed through annual reports and web pages of DFIs and their regional associations. The 40 informants were affiliated with twelve DFI supported joint R&D projects involving six firms and seven TIs. These projects were partially funded by a major national level DFI in India under a specific technology-financing program. This program is similar in form, norms and structure to most other technology financing programs of that DFI as well as other DFIs in India, except that it specifically supported only TI–firm joint R&D projects, in an innovative effort to encourage such joint projects.

The six firms covered consisted of three small private firms and three publicly traded firms with an asset base ranging from INR 330 million (approximately US$ 8 million) to INR 500 million (approximately US$ 12 million). The seven TIs that these firms collaborated with, included two major technology educational institutions, two educational institutes affiliated with a major university, two national government laboratories and one small research society. The projects were selected to reflect a range of investment quantum (total investments by firms ranged from US$ 200,000 to US$ 3.5 million), a variety of technologies and industrial sectors (chemicals, bulk drugs, pharmaceuticals, fermentation products, foundry, machine tools, electronics and paper), and types of R&D involved (basic, commercial, incremental, radical and reverse engineering). Both single location (firm and TI located in one city) and multi-location (firm and TI located in different cities) cases were covered, as proximity is an important variable affecting project processes. Firms

working with multiple TIs and TIs working with multiple firms were covered. Ongoing projects were also included to facilitate real time observation of project developments (Fetterman, 1989; Strauss and Corbin, 1998). The questions traced the project process from inception to completion and also covered project outcomes. Two reviewers were used to draw the broad themes developed in this article. One of the reviewers did not attend the interviews, thereby reducing the possibility that the interviewers and reviewers interpreted the data with the same perspective of the interview participants (Denzin and Lincoln, 1999).

We categorized responses from these interviews into broad themes that would facilitate the development of an analytical framework. Secondary data were used to corroborate these broad patterns that the reviewers identified from the interview data (Strauss and Corbin, 1998). Considering that the interview data were restricted to Indian DFIs, we combined the themes that were gleaned from these interviews with theory development in economics literature on innovation systems. Subsequently, to develop a more inclusive picture of DFIs in emerging economies, we sought out secondary data on DFIs in other Asian and Latin American countries. By doing so, we provide a more complete picture of DFI involvement and its importance for innovative capacity development, in theory and in practice.

We arrived at three broad themes that influence DFI behavior and outcomes in economic development. First, the role of government policy is reflected in the mandate received by the DFI. This mandate defines the scope, specialization, and importance of the DFI as a government policy instrument. Second, DFI roles and support services differ across institutions, countries, and their respective resource endowments. The services that the DFI offers would influence the success of its outcomes in technology development. Which leads us to the third, and final, theme of outcomes achieved by DFIs either through increasing firm-level absorptive capacity and new product development or facilitating macro-economic and national innovative capacity development. In essence, we suggest that the DFI role in assessing and financing technology investments have the potential to shape national innovative capacity and influence new venture creation in industries and technologies that enjoy government policy support. Fig. 1 depicts this process and the linkages between the various components of the process.

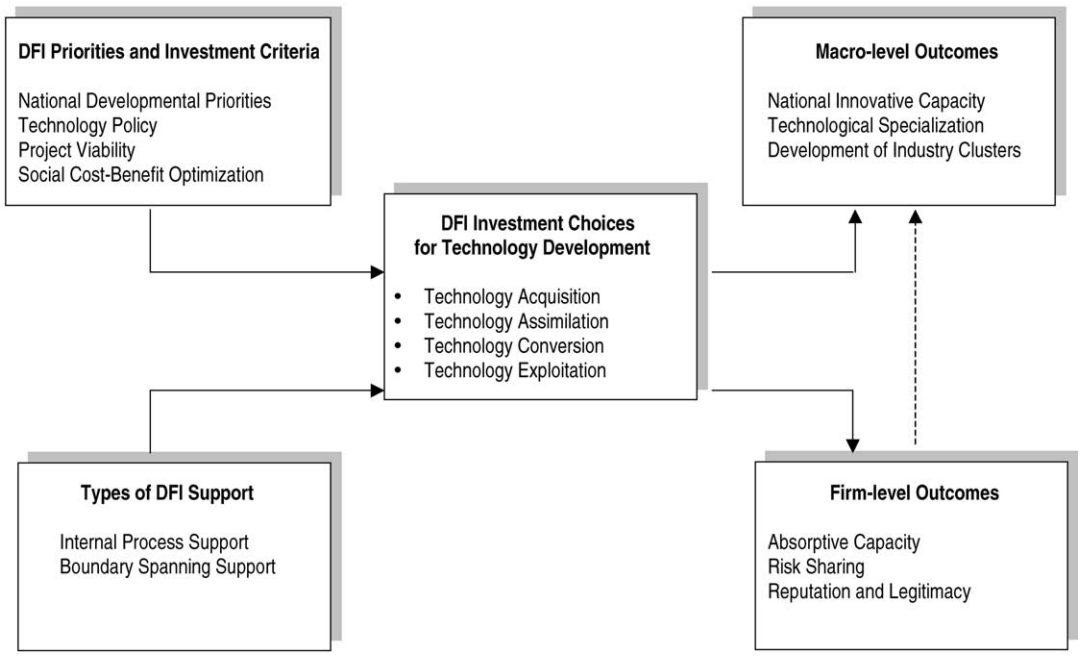

Fig. 1. DFI technology investment choices and outcomes in emerging economies.

1.3. Organization of this article

The remainder of this article systematically addresses each theme discussed above. First, we consider the implication of technology policy for DFI involvement in national innovative capacity development. Second, based on our interviews, we discuss the types of support offered by DFIs, their investment criteria and priorities. Then, we discuss possible firm and national economic outcomes of DFI involvement. To illustrate, we explain the role of DFIs in India in technology development. Based on secondary data, we cite the Indian information technology (IT) industry as an example of positive accruals to DFI activity. Finally, we discuss limitations of our data and approach and provide directions for future work in this area.

2. Technology policies and national innovative capacity

National innovative capacity is the ability of a country to produce and commercialize a flow of innovative technology over the long term (Stern et al., 2001). This capacity depends on the strength of a nation's common innovation infrastructure (such as TIs), the environment for innovation in its industrial clusters, and the strength of linkages between the two areas. The inter-relationship between TIs and the private sector in emerging economies is highlighted by a comment made by a scientist in an Indian firm:

> We have been in (this field) for 18 years. We have seen and interacted with these institute (TI) professors and students. Their publications are familiar to us. We attend their lectures and meet them in conferences. So we get to understand them better. We know the areas of expertise of these institutes, the work they have done and the expertise level of the professors. We approach them informally and talk to them about potential projects. We have a dialogue and gauge their interests. Then, we informally propose the project. If they are interested then we go ahead.

Similarly, researchers suggest that the university system, the most populous type of TI, can influence entrepreneurial behavior and economic development (e.g. George et al., 2002; Miner et al., 2001). For example, George and coworkers suggest that university linkages help new ventures develop their alliance portfolio and develop ties with other private sector firms. University ties reduce overhead costs associated with R&D investments and improves innovative activity (George et al., 2002). One informant in India provides a similar insight about the benefits firms derive from interaction with TIs:

> These large institutes (TIs) have the back up of costly analytical instruments, which we cannot afford. They have the expertise and resources to shorten the R&D cycle time. Their specialized equipment, instrumentation for basic work and specialized knowledge can cut development time. We cannot have or acquire this equipment, as it is not economically viable for us. From these six to seven projects, even if one or two click it is worth it as it gives us a substantial shortening of cycle time in product development.

National innovative capacity depends on an interrelated set of investments, policies, and resource commitments that underlie the production of innovative technologies (Porter, 1990). Key roles in this system are played by the knowledge production function derived from knowledge developed at TIs. Similarly, the knowledge exploitation function or the transformation of knowledge into commercial practice is enhanced when firms co-exist within industrial clusters (Baptista and Swann, 1998). The government's role is to create a common infrastructure that spurs innovation through policies that facilitate investments and appropriability in knowledge-based assets. For example, in a description of the US national innovation system, Mowery (1998) highlights the role played by universities, public and private R&D funding, and government policy on dissemination and protection of property rights. Similarly, in a discussion of the Argentinean innovation system, Correa (1998) notes that government policy that facilitates technology transfer is necessary to spur national innovation. Additionally, Stern et al. (2001) note that the role of government policy may extend to funding agencies for technology development. Though their focus was primarily on advanced economies, the importance of capital, in sponsoring and developing new technologies, assumes even greater prominence in the illiquid capital markets

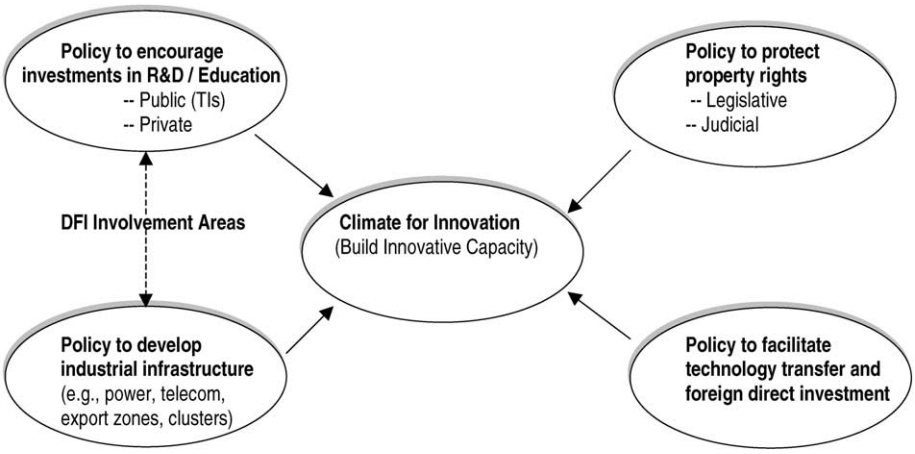

Fig. 2. An illustration of government policy and climate for innovation in emerging economies

of emerging economies. Fig. 2 represents a stylized model linking government policy to a positive climate for innovation and DFI roles in emerging economies.

2.1. DFI as integration mechanism

In the emerging economy context, DFIs have the potential to act as an integration mechanism between the knowledge production and knowledge exploitation functions that comprise national innovative capacity. The DFI, as our interview data confirm, is typically guided by government policy for funding specific technologies that have the potential for success due to existing knowledge stock (e.g. specialized engineers) or physical resources (e.g. metals and alloys, oil and natural gas). DFI financing can allow investment in exploratory technologies through investments in R&D or capital equipment in firms and TIs. The availability of technology financing through DFIs in emerging economies considerably reduces investment risk for firms with low internal resources. Though firms can rely on internal financing and internal technology development, their endowment through an external specialized source such as a DFI, backed by sophisticated technological assessment skills adds value even though it incurs a transaction cost in dealing with an external organization (Prabhu, 1996). In emerging economies, DFI financing can complement the limited venture capital financing available by supporting priority sector projects that may not be acceptable, due to technological and economic risks, under private venture capital financing norms (Lam, 1991). Therefore, DFIs play an important role in helping firms and TIs build their technological resources and increase utilization of available resources.

Our interview data suggest that DFI financing gave our informant firms an additional line of credit at low interest rates without hypothecation of assets, enabling them to enlarge their product development portfolio and initiate new projects earlier. They also benefited from risk sharing with the DFI, as it was flexible on the repayment schedule if the technology development project was delayed due to unforeseen technical problems and it was willing to write off the loan if the project failed technically. However, depending on the nature and perceived risk level of their projects, firms emphasized these benefits differently.

Though there are positive externalities associated with DFI involvement in the financing process, there are social costs as well. Part of DFI financing is funded through government budget appropriations, which possibly may have better alternate uses. Also, inefficiency of funding allocation and interest payment defaults may further serve to increase costs associated with government funding. Finally, DFIs as partly government-owned organizations are susceptible to bureaucratic structures and processes that could potentially increase transaction costs and the tax burden costs associated with organizing such institutions. Overall, we believe that the benefits

outweigh such costs to preclude DFIs as policy instruments. By targeting specialized technologies, on the one hand, and funding capital investments to specialize in such technologies, on the other hand, the DFI serves as an integration mechanism between the knowledge production and exploitation functions in emerging economies. The next section explains the types of DFI support and their role in technology development.

3. DFI services, priorities, and investment choices

3.1. Types of DFI support services

Our interview data suggest that the types of DFI support are influenced to a large extent by the government mandate for its creation. For example, DFIs are created to stimulate economic development in a variety of industries or industry sectors such as small-scale industries, tourism, or petrochemicals. For each specialization and to play different roles in technology financing activities, DFIs require a variety of skills, different from those of managing lending institutions such as commercial banks. One informant DFI highlights the types of services and the process by which DFIs may develop the human capital to make technological assessments:

> (This DFI) initiated a new program to support technology development in the Indian industry. They recruited several highly qualified engineers with several years of R&D and product development experience from the Indian industry to manage the program. Each engineer was chosen for their specialization in the areas that the DFI expected to receive a majority of the project proposals. These engineers became project managers representing (the DFI) and were trained extensively in finance and management both in India and elsewhere. The project managers made detailed technical investigations into every proposed project. They visited the R&D facilities of the firm and its technology partners and interviewed the scientists who were actually involved in the technical development to assess their expertise, contextual knowledge and interest in the project. To supplement the internal expertise of their project managers, (the DFI) appointed the best faculty from the top technical universities in India as part time consultants. An experienced technology board formally sanctioned projects during its quarterly meetings based on an assessment report and presentation of the DFI project manager and also monitored the sanctioned projects.

To ensure the survival and growth of the firms they fund, DFIs take an active role in the promotion and adoption of technologies by comprehensive evaluation and experimentation. When certain technologies are deemed appropriate, they are applied to subsequent projects in that area. This evaluation process requires the DFI to monitor developments at both the national and international level, finance experimental development of indigenous technology, and learn from both these areas to revise and improve technology financing decisions using appropriate evaluation criteria (Averch, 1991). Over time, the DFIs accumulate knowledge and translate it into better advice for clients as well as improve internal resource allocation and financing decisions (Jequier and Hu, 1989). For projects where the technology is new or untested, its personnel possess technical competence and ability to assess potential success both initially and to revise it over the duration of the project (Roberts and Weitzman, 1981). The DFI learns also from its projects over time and becomes a repository of technical and financial skills (Bhatt, 1993). DFIs also address the issue of internal expertise by establishing their own consulting subsidiaries. These consulting subsidiaries have a larger scale of operations in management services that enable them to build and maintain a range of technical expertise. With expertise accumulated over time, DFIs have transcended their purely financial roles by introducing programs that provide firms and TIs multiple and complementary types of support (Najmabadi and Lall, 1995).

Our interviews provided additional insight into the types of DFI services offered. An analysis of secondary data on DFIs in other economies revealed a similar range of services. Table 1 provides a brief listing of services offered by DFIs in emerging economies. We broadly classify this support into two categories: (1) facilitating a firm's internal processes; and (2) facilitating a firm's boundary spanning processes. Both categories of support are discussed in Section 3.1.1.

Table 1
Types of DFI support services

Support level	Types of support	Content	Illustration
Internal process support	Loan disbursement	Providing direct capital through equity investment, low-cost debt or seed capital	The Inter-America Development Bank (Latin America) provides financing for infrastructure projects in the region. Annual loan disbursement was US$ 5.3 billion in 2000
	Project management	Helping in project planning, scheduling and monitoring	Several DFIs provide such managerial assistance to ensure compliance with timeliness of privatization transition or project completion
	Market information	Creating awareness of business opportunities (domestic as well as international competition, exports, import substitution, etc.)	ICICI (DFI in India) along with its DFI partners, collects and disseminates information to Indian investors and firms on new business opportunities that will receive DFI support
	Infrastructure	Providing access to development zones with low cost/subsidized inputs. Providing managerial training or advisory services	The Provincial Development Bank of Bali (Indonesia) provides managerial support and training facilities to develop firm competence
Boundary spanning support	Network development	Providing access or opportunities for newly privatized firms to interact with similar organizations in similar markets through DFI network	International Bank for Reconstruction & Development facilitates network development by compiling list of developmental projects and bringing together suitable sponsors or alliances
	Loan syndications/consortium financing	Proposing and coordinating a consortium effort of multiple DFIs for financing of large infrastructure projects	The International Finance Corporation in 2000 provided direct loans of US$ 3.9 billion of which syndicated/consortium loans of US$ 1.5 billion
	Technology identification	Identifying emerging and untested technologies in home country and abroad for efficient process or product development	CSITIC (DFI in China) provides development finance for commercialization of research in high-technology projects; it helps identify new projects and technologies

3.1.1. Facilitating internal processes

DFIs were initially created to provide financial support to new ventures in industrial sectors critical to economic development (Diamond, 1957). They offer a comprehensive package of funding and services for enterprises investing in relatively high-risk environments (Pandey, 1990). They usually have a staff of bankers, investment analysts, and advisers operating from several geographically dispersed offices in their area of operation (Kane, 1975). Although the primary contribution of the DFI is financial support, in Table 1 we list other support activities as well. This support is usually provided on an informal basis and not as a condition for financing. The DFI may opt to provide different financing options such as equity and debt instruments, or a combination thereof, to infuse capital required to strengthen the firm's technology program (Pandey, 1990). DFI support activities may include educational support, technical consulting, informational support, planning assistance, managerial support, and financial advice among others (Prabhu, 1996). Their understanding of both technical and managerial issues, as well as their close monitoring of the project against technical and commercialization milestones, helps them make decisions that help the project succeed both technically and commercially. A CEO in our sample commented on the DFI monitoring process:

> With (the DFI) we have had an excellent relationship. There have been no disputes of any sort. We have discussed any problem (technical and managerial) we have had with them. We report to them formally on a quarterly basis. They call us on the phone whenever it is required. There was some delay in the project for getting the (specific components) from abroad which we have explained and they have found the explanation okay.

3.1.2. Facilitating boundary spanning processes

DFIs also provide some boundary spanning services. These services involve helping the firm develop its industry networks and access to other firms or TIs for building technological capabilities. Network development is an important secondary activity offered by DFIs. For example, commenting on a project a DFI had funded in his firm, the CEO said:

> Informally they did recommend some people to us when we were looking for (a new technology) possibility. It was general advice and not given as a formal participation in the project.

In facilitating boundary spanning processes, the DFI plays the roles of connector between various interested organizations as well as convenor of meetings and arbitrator of disputes between project participants (Prabhu, 1996). DFIs also provide other boundary spanning activities including consortium financing, technology sourcing and identification (Table 1).

Not all DFIs provide all the services listed in Table 1. Some DFIs have a narrow scope in terms of financing capabilities, while others offer a broad scope of services. Some DFIs restrict their expertise to a specific industry, e.g. travel industry. Some focus on a set of industries e.g. export–import development banks focus on industries where exports and imports are competitive. The range of services depends, primarily, on the government mandate during their creation. Some mandates are narrowly tailored to address specific types of industries such as small and medium-sized industries (e.g. Small Industries Development Bank of India), or economic sectors (e.g. National Bank for Agriculture and Rural Development in India), while others are broader in scope (e.g. Industrial Development Bank of India). Similarly, the resource endowment of these DFIs would dictate to a large extent the scope of services that they can offer. Though there are differences across DFIs and their government mandates, DFIs can potentially offer a range of services that allows them to finance, monitor, and advise the firm during the technology development and commercialization process.

3.2. DFI priorities and investment criteria

The technology financing decisions of DFIs in emerging economies are broadly guided by national technological priorities such as achieving technological self-reliance and addressing environmental concerns (Jequier and Hu, 1989). In many countries, DFIs are involved in both the formulation and execution of financing mechanisms to implement technology policy.[3] Therefore, at the initial identification and appraisal stage, the DFI procedures are

[3] An explanation of DFI roles in India, discussed later in this article, provides further examples of involvement in policy formulation and implementation.

typically comprehensive. DFIs typically assess technology issues to a greater depth than required by purely financial considerations.[4] Apart from commercial viability, their appraisal also addresses the project's impact on indigenous technological, social, and economic development over a fairly long-term horizon. Therefore, results of social cost–benefit analysis and environmental impact assessment are likely to play an important role in project selection, rather than serve only as minimum requirements for project implementation (Jequier and Hu, 1989). For example, statements by an Indian DFI executive about a project that they funded are indicative:

> It was a unique project. They (the firm) were trying new concepts in (that industry)—using group technology concepts to identify commonality and making batches to segregate their range and classify it. It has not been done by any (firm in that industry) worldwide. This appealed to us. No firm (in that industry) has tried mathematical and physical modeling as a way of improvement. The firm was a leader in the industry. This (industry) has export potential in the country. So we wanted to encourage a good project for demonstration effect for the country... There were management solutions attempted also. This was the first project where we were also looking at management solutions simultaneously. Their (development) lead times were very high—3 months. In other countries it is just 4 weeks. Cutting down lead-time was critical. The software (that was developed) was aimed at better resource planning so as to give clear commitments to the customer. Otherwise, it is difficult to negotiate with a foreign customer.

DFIs across the world also have a strong propensity to share and adopt effective appraisal and follow-up techniques and procedures (Bhatt, 1993). The VP Finance of a firm that was funded for a technology project by a DFI commented:

> (The DFI) basically wanted to be sure that we were really interested in research work in general and not specifically on some product. We could establish that well by showing them our investment in R&D so far. After that was established other things (for the loan sanction) followed smoothly.

A CEO whose firm was funded for a technology project said about the DFI:

> They are technically sound people and very sincere. Since they sensed that we were sincere, there were no hassles of any sort... There were some setbacks in the project due to failure of a major supplier abroad... Even with these setbacks they (DFIs) were cooperative and restructured the repayment plan for us.

DFIs form regional and global networks that foster information sharing. For instance, an Association of Development and Industrial Banks in Asia was established in 1995 to improve economic relationship and practical cooperation among leading institutions from China, India, Indonesia, Japan, Korea, Philippines, Singapore and Thailand. This association allows member institutions to exchange information and carry out joint studies of projects and technologies, enlarge personnel training and exchange programs, and promote new projects and financial products (ADIBA, 2001). Thus, innovations in DFI processes are likely to be rapidly diffused. DFIs by their very orientation are well placed to channel finance into technology development and commercialization in emerging economies.

3.3. DFI investment choices for technology development

Our interviews revealed that DFIs rely on several partners in making technological assessments for their

[4] For example, consider the details required by an Indian DFI from the firm in its preliminary proposal format for financing a technology development project jointly with a TI. The details cover a wide range and include the following: brief particulars of the firm, latest audited annual report, R&D done by the firm including major areas of R&D, brief description of the firm's R&D facilities, its current R&D budget, number of persons engaged in full time R&D activities, major R&D achievements of the firm, brief particulars of R&D projects sponsored in the past by the firm with TIs, project title, uses of project process, innovative content, name and designation of person in charge of R&D program in the firm, key persons in the TI who will be involved in the project, major steps involved in the R&D project, breakup of major activities to be undertaken by the firm and the TI, aim of the project in quantitative terms, economic justification for undertaking the project, cost–benefit analysis, brief particulars of work already carried out on the project, outlay on project at firm, outlay on project at TI, schedule of implementation of the R&D project, cost of commercialization of R&D project, time required for commercialization, and expected sale from the commercial venture.

investments. On broader funding policy issues and on specific technical matters they trade information with organizations like international DFIs,[5] other national DFIs, national planning agencies, public firms, TIs, non-governmental organizations, consulting firms, other financial institutions and private agencies. Some of these organizations can also work as funding partners and exercise a greater role in the assessment process, while possibly increasing intermediation efficiency (Blondel, 1995). While this implies that the DFI need not have all the required resources in-house, it also implies that its control on the process is constrained to some extent by its partners.

DFIs in emerging economies essentially face four types of technology investment choices. First, DFIs make choices on the investment in technology 'acquisition' or the import of foreign technology. This is the first step or the initial investment required for developing competence in a particular technology area (Mowery and Oxley, 1995). Developing countries may lack in particular technology areas that may make it necessary to import such technologies (Jacobsson, 1991). Second, DFIs may then provide support for the 'assimilation' of imported technology. This assimilation may be achieved through investments in the diffusion and adaptation of imported technology (Desai, 1985; Tyre and Orlikowski, 1994). Third, DFIs may take steps to leverage imported technology by 'converting' it for multiple uses, thereby providing opportunities to make changes and indigenize the imported technology and adapt it for local uses. Fourth, DFIs may provide financing for the 'exploitation' and commercialization of a particular technology by encouraging firms to make incremental or radical changes to the indigenously developed technology, or by fostering new and innovative technologies that emerge from imported technology (Prabhu, 1997). For example, statements made by an Indian DFI executive regarding a proposal for financing TI–firm joint R&D projects is indicative of the project selection process:

> They (the firms) gave a list of about 15 projects and we chose 10 of them to support. We chose those projects, which had innovative content, adequate justification and potential market. Where several projects required the same facilities for development and the project required establishment of those facilities, we chose a representative project for appraisal. If suitable, we financed all the projects that required those common facilities. . . In (one area) we selected all the projects while in (another area) we left out one product because it was a "me too" type of product. In (a third area) projects there were a few which were not considered, as they did not fit the (program) financing criteria. . . Success depends on both the firm and the TI—their expertise, facilities, interaction, market and technology "push"—there are no norms about success rates from our side. We are satisfied even if there is one success because there has been joint R&D and the interaction has been successful.

Even if the DFI develops a policy for allocating its available funds to each type of technology investment opportunity, it still faces a difficult assessment and choice problem as investment opportunities usually present themselves in random order (Teece, 1986). Therefore, prioritizing investment choices is obviously difficult and needs careful analysis (Smith and Nau, 1995). Hence, it is imperative for DFIs to chart out a technology investment plan and relate it to broad national technology priorities. Such charting of the DFI investment plans is likely to stimulate proposals by firms and TIs for investing in these priority areas. The National Science Foundation in the US that calls for funding proposals on specific frontier technologies, thereby acting as a catalyst for R&D, plays a similar role as do DFIs in emerging economies.

4. Outcomes of DFI involvement

4.1. Firm-level outcomes

Interviews with Indian managers suggest that DFI technology development initiatives benefit their firm by minimizing opportunity loss due to lack of resources. As interest in new technology venture investments by venture capital firms decline due to

[5] International DFIs include International Finance Corporation or the European Bank for Reconstruction & Development. There are other regional DFIs and development funds as well, such as the South Asian Development Fund (for South Asian economies) and the Inter-American Development Bank (for Latin American countries).

increasing technological risks, DFIs may have to increasingly fill this gap to enable the emergence of priority technology ventures. DFIs give firms indirect access to other funds, as the DFIs' support signal the project quality and lend credibility to its promoters (Lam, 1991). Some venture capital firms finance projects only from the prototype stage onwards. In such cases, DFIs may have to take the role of investing at earlier stages of product development in promising ventures that are important for national development (George and Prabhu, 2000). Statements made by an Indian DFI executive in our sample regarding a technology-financing proposal are indicative:

> (The firm) had earlier taken financing under (the DFI's) export development fund. Our export development fund experience with them was good. So we gave an initial okay after discussion... The project was a logical extension of what their consultant for the export development fund project had advised. The export development fund process led to the firm's thought process along a new way and this got linked to them seeking and using (the new DFI technology financing program) to develop their new product.

An important outcome of DFI investment is the development of a firm's absorptive capacity (Cohen and Levinthal, 1990). Absorptive capacity has been defined as an organization's capability to manage knowledge towards innovative ends. These capabilities involve the abilities to acquire, assimilate, convert, and exploit knowledge (Zahra and George, 2002). The DFI's investment choices, guided by national technological priorities, enable the development of the firm's capabilities in acquiring, assimilating, converting and exploiting technology to achieve innovative outputs such as new products and new processes. Interaction with DFIs is likely to provide firms greater access to industry networks and research consortia, enhanced support for new and untested technologies, and act as a signal of the firm's legitimacy. Such legitimacy may help attract foreign strategic alliances, private investors, improve firm image and the valuation of publicly traded equity. Statements made by an Indian DFI executive regarding a project they funded for a firm developing a new type of machine indigenously, are indicative of the process of developing absorptive capacity and its importance in the DFI's consideration:

> The firm had a good brand image. There was no competition in their product. It was an ambitious project for them. They were technically sound but not growing. The project was clearly linked to their need—their future growth depended on it. They could not leave it. Their need was specific—such a machine was not easily available. Nobody in the country could deliver it. They were looking at a larger turnover through this machine and we could help them grow. Complementary skills could come into the firm through the introduction of computer numerical control (CNC) technology and (related) electronics. Also, good feedback on the shop floor was possible. (The promoter) was a committed person with a good background. He had a single project focus of attention—he was not dividing time on several projects so he could concentrate fully on this project. The (TI) professors are leading people in the field and were interested in the project. The professors gave new insights and a new level of technology development came up from the project for the firm.

4.2. Macro-level outcomes

DFIs influence the national innovative capacity by the cumulative effect of making a large number of micro-assessments of technology funding. In emerging economies, the central concern of technological development has not been on developing entirely new products and processes (Dahlman et al., 1987; Jacobsson, 1991). Rather, the focus has been on the development of technological capabilities and their translation into better technological choice assessments as well as their application in making incremental improvements in existing technology (Jequier and Hu, 1989). Given the difficult foreign exchange reserves situation in most emerging economies, this activity often has to take advantage of local resources rather than rely on imports at high cost. Currency devaluation also increases the cost of maintenance and the repair and replacement of components for imported technologies and equipment.

The DFI needs to finance and support projects that effectively combine both local and imported technology such that local technology and expertise is enhanced. When national policy or the DFI's internal policy dictates that effective local technology should

be preferred over imported technology, the implications of choices made under this constraint has developmental implications that go well beyond individual funding proposals by firms. Where such policy preferences are known, proposals are likely to be tailor-made by firms and TIs to comply with such requirements, thereby influencing technology specialization within the country. For example, a DFI executive in India discussed a broad range of issues the DFI typically covered in making an initial assessment of technology projects that they financed:

> We try to understand the requirements—raw material and machinery—its availability and price. Does the new product (development) require new machinery or does it use the existing set up? We then look into the performance parameters that will be used (e.g. efficiency, specifications and time for completion) to define the technical fit of the project. We estimate the chances of the product working commercially in the desired conditions. Knowing the industry is important. We should know what is important in that industry—e.g. in chemicals the yields, byproducts and energy consumption is important; in electronics standardization, compactness and cost reduction is important; in pharmaceuticals regulatory factors are important. Once technical details are clear then we examine the direction of development and ask for data on how it will be done. What is being attempted and what is its impact on the end product? The cost may go up but is the quality better? Will the consumer pay more for reliability? Based on all these the customized format (for detailed assessment) is prepared (for the funding decision).

Given that DFIs are a major source of finance in emerging economies, their investment choices can have a far-reaching impact. By consistently considering national technological priorities in making significant investments, DFIs in emerging economies play a key role in creating a national innovative capacity in areas that are of national importance (Lall, 1992). DFIs making targeted investments have significant multiplier effects on technological development within the country and as a consequence on social and economic development. These effects on technological development can take place at various stages of the technological project life cycle, i.e. initial identification, assessment, appraisal, selection, implementation and evaluation. However, the DFI may choose to concentrate its resources and interest on one or a few of these stages; and only the larger DFIs are likely to play a role in all these stages. Therefore, the cumulative impact of DFI investment choices influences the development of national innovative capacity, in turn, influencing the rate of new product development and innovation within the country (Liu and White, 1997).

Second, a consistent pattern of DFI investments in priority technologies could possibly enhance the formation of industry clusters and lead to lower inter-firm transaction and marketing costs. Unlike some developed countries like Italy where industry clusters emerged naturally (Malerba and Marengo, 1995), other countries have attempted to stimulate the emergence of industry clusters through policy initiatives (Sharp and Pavitt, 1993; Saxenian, 1994). Typically, such initiatives involve government-sponsored organizations for marketing the products produced by the cluster. Also, development of industry clusters requires the building of common infrastructure facilities such as effluent treatment plants and testing equipment for raw materials and finished goods. DFIs stimulate the development of industry clusters by building such common infrastructure and by promoting programs that support firms performing specific functions in the value chain of these clusters.

Thus far, we have provided a broad overview of DFI involvement in technology financing. We suggest that active DFI involvement in technology financing and support services is likely to build absorptive capacity in firms and TIs and influence the development of national innovative capacity in emerging economies. Thus, governments can effectively use DFIs as technology policy instruments to influence technology development in priority areas. In the next section, we use secondary data to illustrate our model by explaining the roles played by DFIs and their programs in India.

5. Role of DFIs in technology development in India: an example

5.1. Technology development by Indian industry

Indian firms have used multiple modes to meet the technology needs of their manufacturing and

service activities (Kaplinsky, 1997) of which technology transfer from advanced economies was common (Alam and Langrish, 1984; Beri, 1993) in the pre-liberalization period prior to 1991. It was also a cheaper option before the rapid devaluation of the Indian currency in recent years. However imported technologies need to be adapted to local climatic conditions and raw material availability, as they are developed in conditions different from that in India (Sikdar, 1997). Such adaptations may involve scaling down the production processes to suit typically smaller Indian markets, modifications of process technology to suit locally available raw materials, addition or modification of product attributes to suit local conditions, and adaptation to use local components and inputs due to government policy of indigenization (Desai, 1985; Chaudhuri, 1986).

Also, technologies that have a higher tacit component that cannot be transferred can restrict optimum exploitation of the imported technology. Advanced economies may also be hesitant to share technology due to the weak intellectual property protection regime in India. Also, Indian firms have found the replacement of imported components expensive and time consuming, especially when the equipment is nearing obsolescence (Sikdar and Prabhu, 1999). Therefore, Indian firms tend to have access primarily to outdated technology that may be inadequate to face the competitive environment in domestic and foreign markets (Jacobsson, 1991). Further such imported technologies are accessible to other Indian competitors and therefore do not give the buyer any competitive advantage (Krishnan and Prabhu, 1999). If the Indian firm seeks to import the latest technology, it often requires giving equity stake to the foreign firm, which may not be a favorable proposition due to considerable differences in bargaining power between the typically smaller Indian firm and its larger foreign partner (Sikdar and Prabhu, 1999).

Another mode of technology sourcing by Indian firms is through in-house R&D. In-house R&D in India has, apart from the development of new products or processes, also covered adaptation of existing products or processes (Jacobsson, 1991). In-house R&D based technology, being proprietary, is not easily imitated by other firms, and may provide the firm with a first-mover advantage. Moreover, being indigenous, such technology is inherently adapted to local conditions with simultaneous learning and development of tacit knowledge within the firm (Gambardella, 1992). This facilitates the assimilation and application of technology more easily, compared to imported technology. However, in-house R&D requires relatively large and often unaffordable investments in capital equipment, technical skills, infrastructure and improvement of the firm's knowledge base (Sikdar, 1997). Indian firms have however leveraged their internal R&D by utilizing resources available with TIs through technology transfers, R&D contracts and joint R&D projects (Prabhu, 1997).

5.2. TIs in India

India has a large number of TIs catering to specialized areas of technology development. These TIs include national laboratories under various central and state ministries, universities and other technology educational institutions, laboratories set up by industry associations, and research foundations that conduct industrial research (Chaudhuri and Dixit, 1994). Universities and other technology educational institutions including premier institutions like the Indian Institutes of Technology and the Indian Institute of Science conduct both basic and applied R&D with only one of their multiple and often diverse objectives being to develop technology for the industry. Research foundations may have objectives ranging from working for specific sectors to working on wider interdisciplinary developmental issues. While the government research laboratories under the Council for Scientific and Industrial Research exist primarily for industrial research (Krishnan, 1999), other government research laboratories also contribute to industrial research. R&D labs in nationally important and sensitive fields like space, defense and atomic energy are fully supported by the government and are directly controlled by it. These labs transfer some of the technologies that they develop as byproducts to the industry through various modes (Brown et al., 1991).

5.3. Financing for technology development in India

DFIs are a major source of finance for the Indian industry and national DFIs have played an active role in technology development. They have initiated a number of schemes in which they give conditional

grants or subsidized loans for technology development and new venture creation activities. Limited venture capital for new technology based ventures came into existence after the Indian government issued guidelines for the formation of venture capital firms in 1988. Venture capital was initiated by a DFI, the Industrial Credit and Investment Corporation of India (ICICI), which set up the Technology Development and Investment Corporation of India as a subsidiary (Najmabadi and Lall, 1995). Subsequently, other venture firms have emerged in India but project scale and risk considerations limit their investments in high-risk new technologies. In-house R&D is encouraged in private firms by the government providing a 100% tax credit for R&D expenses. While firms have financed R&D contracts with TIs on their own, the Indian government provides subsidized funds for TI–firm R&D contracts to make them attractive. The government also gives firms a higher tax credit (125%) for R&D expenses paid to TIs for contracted R&D.

DFIs have provided impetus to TI–firm interaction by developing programs and providing facilities to encourage such interaction. These programs, a component of their technology development efforts, seek to complement the firm's internal R&D activities with joint R&D projects that leverage the extensive facilities available with the government research laboratories and other independent TIs in the country. These programs are important as they can help combine resources from existing institutions, increase utilization efficiency, and facilitate the emergence of new products.

Over the years, a well-knit structure of financial institutions has evolved in India comprising of 11 national DFIs and 46 state DFIs. These institutions provide a variety of financial products and services to suit the varied needs of firms. Among the 11 national institutions, 5 are development banks, 3 are specialized financial institutions, e.g. Risk Capital and Technology Finance Corporation Ltd., and 3 are investment institutions that are involved in secondary capital markets, extending assistance to firms through loans and underwriting/direct subscription to equities. Data on their historical growth levels and their increasing importance to the Indian economy are provided in Table 2. Since 1980, the cumulative sanctioned loans of these institutions amounted to INR 4448.7 billion (approximately US$ 105 billion) (IDBI, 1998).

Table 2
Assistance sanctioned and disbursed by financial institutions in India (excludes commercial banks)[a,b]

Year	Sanctions	Growth rate (%)	Disbursements	Growth rate (%)
1980–81	29.3		18.5	
1981–82	32.8	12.0	23.5	27.3
1982–83	33.6	2.5	24.7	4.9
1983–84	41.7	24.1	31.4	27.1
1984–85	55.5	33.2	36.2	15.3
1985–86	65.3	17.7	49.4	36.6
1986–87	81.2	24.3	57.1	15.6
1987–88	95.5	17.7	70.6	23.7
1988–89	112.9	18.1	77.0	9.1
1989–90	144.6	28.1	96.4	25.2
1990–91	192.0	32.8	128.1	32.9
1991–92	223.2	16.2	162.7	27.0
1992–93	331.9	48.8	231.5	42.3
1993–94	409.9	23.5	266.2	15.0
1994–95	592.8	44.6	335.7	26.1
1995–96	641.6	8.2	386.5	15.1
1996–97	546.4	(−)14.8	426.6	10.4
1997–98	815.9	49.3	538.3	26.2
Cumulative up to end-March 1998	4448.7		3055.2	

[a] Source: IDBI Report on Development Banking in India (1998), IDBI, Mumbai, India in 1998, US$ 1 ∼ INR 42.
[b] Figures in INR billion.

The Industrial Development Bank of India (IDBI), the largest development bank in India, provided infrastructure finance of about US$ 2 billion in 2000–2001 with telecom and power generation receiving a major share. IDBI plays a major role in technology development in priority industries. For example, IDBI is the nodal agency for the Technology Upgradation Fund Scheme for the textile industry disbursing funds to the tune of about US $ 500 million. Its venture capital scheme has disbursed about US$ 25 million, and it supports Technical Consultancy Organizations throughout the country (IDBI, 2001). IDBI is also the financial agent for the World Bank for the Ozone Trust Fund, the Chlorofluorocarbon Product Sector Gradual Phase-out Project and the Greenhouse Gas Pollution Prevention Project. It is the implementing agency for the USAID's Energy Management Consultation and Training Project (IDBI, 2001).

To illustrate, some initiatives of three other major national DFIs—the Small Industries Development Bank of India (SIDBI), the Industrial Finance Corporation of India (IFCI) and ICICI are presented in Table 3. For example, ICICI has developed and implemented specific programs as part of the US$ 200 million Industrial Technology Development Project funded by the World Bank. Under this initiative, the Sponsored Research and Development program (US$ 15 million) provides soft loans for TI–firm joint product development projects. The Technology Institution Program (US$ 40 million) provides financial assistance to TIs for upgrading their facilities and enhancing their expertise to serve the technology needs of the industry more effectively. The objectives of the Industrial Technology Development Project are "to provide functional support for technology imports, to strengthen the science and technology infrastructure and make it relevant to industry and to promote innovation financing" (Najmabadi and Lall, 1995, p. 90).

5.4. Government policy, DFI involvement and the Indian IT industry

In 1998, the Government of India set up a national task force to study the development of the IT industry with a goal of increasing the prominence of IT services in the economy (up from 1% of GDP in 1998).

Table 3
DFIs in India: a sampling of programs[a]

Support	SIDBI	ICICI	IFCI
Infrastructure support	Common facilities, testing	ACE, TEST, TIP	Science and technology parks
Technical knowledge support	Quality programs	ACE, PACT, SPREAD, TDICI, TEST,	Technology consulting, project profiles
Informational support	Awareness workshops TI–firm interaction	ACE, PACER, PACT, SPREAD, TDICI, TEST	Market surveys; opportunity identification
Purchasing support	On some programs	On some programs	Technology source identification
Marketing support	Quality programs modernization programs	ACE, TEST	Market surveys
Planning support	On some programs	On all programs	On some programs
Financial support	Loans to small scale industry, venture capital, environmental funding	ACE, PACER, PACT, SPREAD, TDICI, TEST, TIP, loans to exporters	Project loans
Managerial support	Modernization packages	PACER, PACT, SPREAD, TDICI	Diagnostics, turnaround assistance
Educational support	Skill upgradation, entrepreneurship development programs	TEST, TIP	Support to entrepreneurship development programs

[a] ACE, Agricultural Commercialization and Enterprise program provides finance for private post-farm agricultural processing and marketing businesses; PACER, Program for Acceleration of Commercial Energy Research supports energy sector research through multi-organizational consortia of manufacturers, users and research institutions; PACT, Program for Advancement of Commercial Technology supports technology development through Indo–USA joint ventures; SPREAD, Sponsored Research and Development program supports TI–firm joint product development; TDICI, Technology Development Investment Corporation of India, an ICICI subsidiary, provides venture capital; TEST, Trade in Environmental Services and Technologies program caters to environmental technology investments through Indo–USA joint ventures; TIP, Technology Institutions Program; Source: Program brochures and annual reports. Some programs listed are pilot projects and may no longer exist.

The stated policy goal was to achieve US$ 50 billion in software and US$ 10 billion in hardware exports by the year 2008, placing IT among the largest contributors to GDP growth over the next decade. The importance of IT was also stressed by the creation of a cabinet-level ministerial position and investments in infrastructure to develop telecom and ancillary industries. In the following years, the legislative branch endorsed these initiatives by passing wide-ranging legislation on convergence in IT and telecom, and Internet commerce transactions. Also, the government issued the New Telecom Policy permitting private firms into telecom and cellular services and opened up the long-distance telephony to free market competition.

The government also committed to providing capital resources to ventures that enter the IT sector. DFIs were involved both in the policy formulation as well as diffusion of capital support to these firms. For example, the chief executive of ICICI became part of the national task force on telecom and IT convergence implementation. Also, DFIs were encouraged to raise funds specifically earmarked for IT spending. For instance, the National Venture Fund for Software and IT industry, a venture fund of approximately US$ 225 million was set up by SIDBI in 2000, with capital that was partially allocated through budgetary appropriations (SIDBI, 2001). DFIs also created their own subsidiaries to encourage investment and provide managerial and consulting services to the IT industry. For example, ICICI formed its subsidiary ICICI Infotech Services Ltd., which, in turn, had eight other subsidiaries that targeted specific markets and technologies, like Internet infrastructure and Internet commerce initiatives. IDBI's subsidiary, IDBI Intech Ltd., is registered with the Software Technology Parks of India to exploit opportunities in software ventures (IDBI, 2001). Similarly, other DFIs have set up such subsidiaries to galvanize this market.

In Fig. 3, we illustrate the role of government policy and how DFI involvement could create an environment for innovation and technology development in the Indian IT industry. Some data suggest that the Indian IT

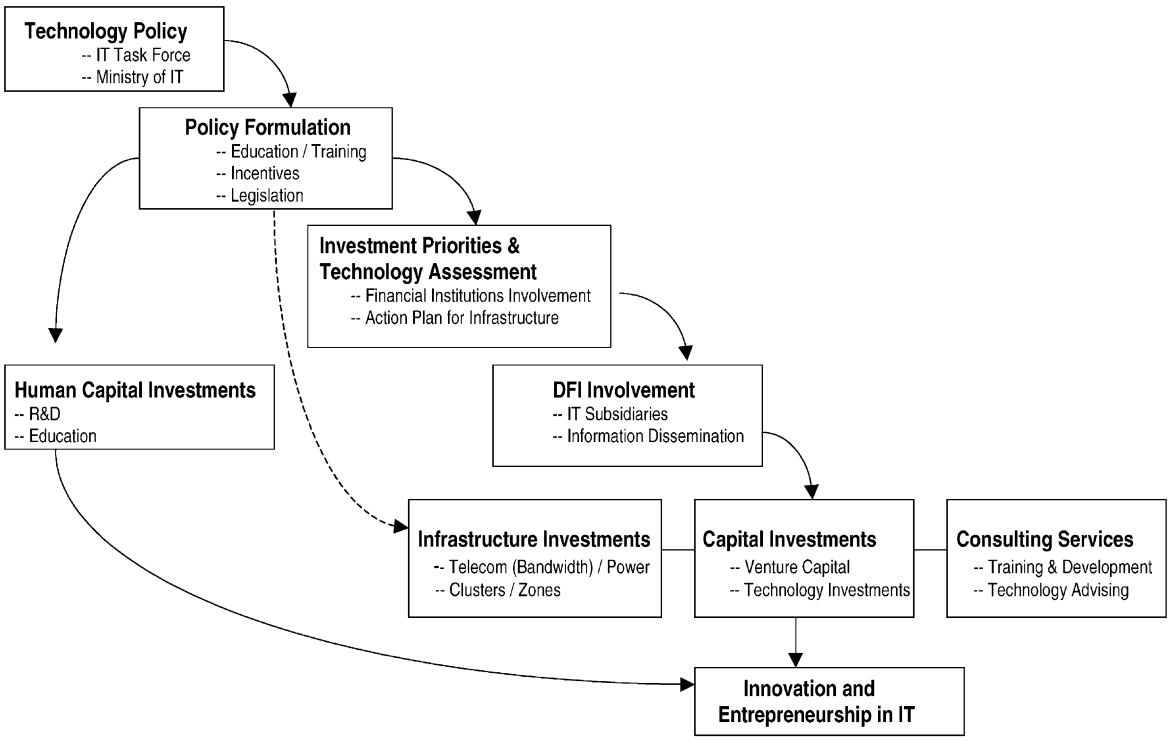

Fig. 3. Government policy and DFI involvement in Indian IT industry.

industry grew at 50% per year over the past five years (IEO, 1999). Software exports accounted for 2.5% of India's total exports in 1999 (Ministry of Commerce, 2000). Informal and formal networks of IT firms and IT educational institutions have evolved in clusters around cities such as Bangalore, Pune, Hyderabad, and New Delhi. These clusters have had a profound effect on venture creation and industrial growth in the IT industry. In a study of the Indian IT services industry by Arora et al. (2001), they note that Indian firms are moving up the value chain in the IT industry by acquiring deeper knowledge of business domains and management capability. Though these authors question the sustainability of cost advantage of Indian IT over time, they deduce that the effect on the Indian economy is profound, insofar as it generates new ventures and entrepreneurial talent in technology intensive industries. Similarly, a study of software product development projects in India (Krishnan and Prabhu, in press) indicates that some Indian software firms have moved beyond selling IT services to develop products usually by converting customized software built through service contracts into generic products. To summarize, DFIs have the potential to be key players in technology development within the country. By working closely with the government, TIs and firms, national DFIs can influence technology policy and ensure that development of technological capabilities is achieved by participating in policy implementation.

6. Limitations and future research directions

This article combines qualitative data obtained from interviews with a theory building exercise to provide an analytical framework to understand DFI roles and their implications for economic development. Clearly, there are limitations to such an exercise. First, the interview data pertain to Indian DFIs; though our survey of published material would indicate little difference among emerging economy DFIs across countries, our data does not cover the DFI or firm population in these countries. Second, DFIs differ in size, scope, resources, and specifically, government mandates. We provide a broader and inclusive role for DFIs in national innovative capacity development in emerging economies based on the Indian experience. Other governments may provide their DFIs with greater or restrictive degrees of freedom that may change the dynamics and importance of DFI roles in these economies. Future research can address differences in government mandates and their differential impact on DFI developmental roles. Third, we develop outcomes of DFI involvement based both on previous literature and interview data, yet, we do not corroborate any claims made by firm managers and DFI administrators with secondary data on the firm's innovative outputs or performance improvements. The next step is to connect both the DFI claims and firm-level tangible outcomes, critically examining the degree of success and importance of DFIs in emerging economies. Finally, there are considerable differences among economic contexts between advanced, emerging, and less-developed economies that may influence the importance and role of DFIs, a topic that needs informed policy support for economic development.

7. Conclusions

Emerging economies are under pressure to develop their own technology and decrease reliance on imported technology. The advanced economies are likely to be wary of sharing technology with emerging economies that could soon become its competitors. As technology imports from the advanced economies become difficult, firms in emerging economies that lack internal technology development resources are exploring indigenous technology development facilities and inter-firm networks for new and cheaper technologies (Hausler et al., 1994). DFIs can play an increasingly important role in encouraging such trends towards indigenous technology development in emerging economies.

It is suggested that governments in emerging economies actively use their DFIs as technology policy instruments to encourage investment in priority technology areas. DFIs need to develop higher levels of expertise in understanding macro-level technology priorities to enable them to contribute to developing national innovative capacity. Emerging economies have promoted technology development through a variety of policy instruments, the most common being subsidies and tax credits. Though such 'passive' forms of promotion can work in technological areas that have high interest levels within the nation's

industrial community (Brahm, 1995), it may not be possible with technological areas where the interest is low. In this scenario, the more 'active' role played by national governments through DFIs can add value, in ways similar to venture capitalists, that can potentially be superior to other modes for encouraging priority sector technology development.

In this article, it was our goal to highlight the importance of DFIs as technology policy instruments. The Indian example provides a success story of technology development initiatives. Though Indian DFIs have a broad range of programs and seem to possess enhanced skills in technology assessment and consulting, they are comparable to other DFIs in other emerging economies (e.g. Singapore, China, Korea) and represent the potential role that DFIs can play. DFIs can be an important integration mechanism between the knowledge production and commercialization functions within a national innovation system. By doing so, they reflect government policy in creating a positive climate for innovation and entrepreneurship in emerging economies.

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