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Berlin, November 2007

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Abstract

Innovation is at the basis of economic development and as such, it is instrumental for developing countries. We review the literature on innovation from the perspectives of four select branches of economics to build a conceptual framework of innovation applicable to developing countries. The conceptual framework includes insights from the surveyed literature and identifies areas of further research. Finally, we conclude with policy recommendations for innovation policies in developing countries highlighting the fact that intellectual property protection is not likely to be at the basis of innovation in these countries.

JEL-Classification: O31, B41, P20

Keywords: Innovation, Development, Absorptive Capacity

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1 Introduction

Innovation is at the basis of economic development and as such, it is instrumental for developing and least developed countries (LDCs). Important fora such as the Commission for Africa (2005) and the UN Millennium Project (2005) emphasize the role of innovation – both the investment in the creation, and the use of new knowledge – as a basis for economic transformation. However, the process of innovation is still a challenging subject of research in economics, and most efforts have concentrated on understanding the process in industrialized countries rather than in developing countries.

The innovation process in the developing country context is the main focus of our analysis. We review the literature on innovation in order to build a conceptual framework of innovation and identify areas of further research. Though the surveyed literature suggests that intellectual property rights (IPRs) play an important role with regard to innovation, we contend that this may not be the case for developing countries due to specific country characteristics.

Unlike previous studies on innovation in LDCs, we do not focus on the different relationships among the institutions of the “system”. Instead our approach takes in to account the national environment in which innovation takes place and hence looks more at the “ecology” of innovation. In order to clearly define the national environment, we turn to four select branches of economics that, in our opinion, are most relevant to firm level innovation.

The basis of our analysis is the chain-linked model which we first extend to include insights from the surveyed literature. This extended model is then applied to the developing country context to better understand the innovative process and environment or lack thereof in these countries. Finally, we conclude with policy recommendations for innovation in developing countries, among others to negotiate in multilateral and bilateral fora to ensure sufficient domestic policy space to allow innovation to take-off, and to support agricultural innovation, a critical industry to get development going.

The paper is structured as follows. In Section 2 we present a basic model of innovation, followed in Section 3 by a critical review of four branches of economic literature most relevant to firm level innovation.. In Section 4 we present and discuss our conceptual framework, and in Section 5, we describe developing countries and modify our conceptual framework to better represent their characteristics. Section 6 discusses the implications of our findings and we conclude in Section 7.

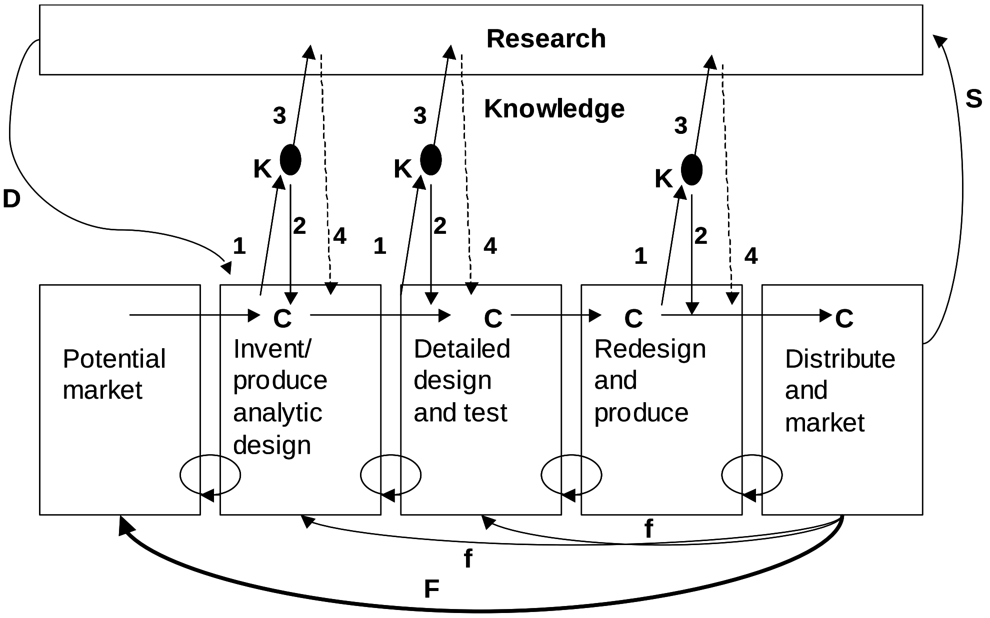
2 Innovation: Background

Innovation can be defined as all the scientific, technological, organizational, financial, and commercial activities necessary to create, implement, and market new or improved products or processes (OECD, 1997). In this review, we focus on the firm-level innovation process and concentrate on the scientific and technological activities supporting the performance of innovation.

Past models of innovation presented innovation as a linear phenomenon where each aspect was considered modular and unconnected to other parts of the innovation process. The theory identifies two traditional approaches to innovation; “Technology push” and “demand pull”. In the former approach, innovation is seen as exogenous and driven solely by scientific advances. The latter approach refers to innovation as a response to demands for new products and processes. However, it was found early on that these models did not survive empirical scrutiny (Mensch, 1979, Myer and Marquis, 1969). Mensch (1979) showed, using the example of computers in the UK during the sixties, that the lifecycle of products create a foundation for subsequent technological change. In other words he illustrated the fact that there are feedback effects in the process of innovation and linear representations of innovation processes do not capture these effects.

Due to the limitations of the traditional models, we make use of a well-known model of innovation, the chain-linked innovation model (Kline and Rosenberg, 1986) as the basis of our analysis. The chain-linked innovation model represents the technical activities occurring in the innovation process, the external forces of the market place, as well as the complex interactions and iterations between the various stages of the process (see figure 1). Though highly stylized i.e. the phases of the innovation process are not so clear-cut in reality, this model allows visualizing the different possible stages of the process, their determinants and how they are interrelated.

Figure 1: **Chain-linked Innovation Model**



Source: Kline and Rosenberg, 1986.

Uncertainty is a key concept: in fact, innovation is defined as an "exercise in the management and reduction of uncertainty" (Kline and Rosenberg, 1986, pp. 275-276). Uncertainty relates to two aspects: the technical performance of the innovation and the market response to its introduction. However, one can also define the process leading to the "discovery" of the invention as generating uncertainty, which decreases along the development, production and distribution phases.

The model identifies five major paths of innovation processes: the central chain of innovation (C) starts with the invention/ production of a design, based on market signals or technological advances (D)[1], which is then developed, produced and marketed. The process includes feedback loops (F, f) iterating the steps and controlling for perceived market signals and users' needs, and linkages between science and innovation (K), representing the recourse to various knowledge stocks accompanying the whole process. The innovator goes to the common pool of knowledge to try and solve a problem (1), comes back with this knowledge and continues along the innovation chain if the needed knowledge is available (2) or resorts to research (3) if it is not; the results of the research activities are then used in the innovation chain (4). Finally, innovation results feed back into the scientific arena (S).

In this model, “market-pull” and “technology push” aspects of innovation are interdependent. Perceived demand will only be met if the appropriate knowledge and technology are available, and an innovation will be realized only if there is a market for it.[1]

3 Economic Theories: Different Perspectives

This section reviews the four branches of economic literature we consider most relevant to firm level innovation; institutional, industrial, evolutionary and international trade economics. We consider firm level innovation to have internal and external components. The first three branches examine the characteristics of the national environment like legal institutions, IPRs, market structure, firm size, and specific country characteristics and their influence on domestic innovation. Alternatively international trade looks at the effect of external forces like foreign direct investment (FDI) and technology transfers and how they affect the national or local innovative environment. This section identifies areas where further research is needed, providing key insights to extend and improve upon the chain-linked model of innovation.

3.1 Institutional Economics

Externalities are an important characteristic of innovation. Property rights are defined to internalize externalities, and, in the case of innovation, they ensure that the rents from an invention are concentrated with the innovator, which provides more incentives for further innovation (Demsetz, 1967). Indeed, the result of innovation is not only a new product or process but also new information, which has public good characteristics. The use of it by more than one person does not require additional resources (non-rivalry) and does not exclude the use of it by another person (non-excludability). These two properties of information make the gains from innovation difficult to appropriate, which implies that R&D opportunities that would be socially profitable are not exploited because they are privately unprofitable. In order for innovation to be undertaken, incentives need to be given. Intellectual property rights (IPRs) are one possible government intervention to correct for this market failure. Other interventions

[1] An important category of innovations not covered by the model refers to the cases where innovation happens by chance. Though innovation by chance was at the origin of several important innovations (e.g. penicillin), it is not addressed in the model. Modeling a stochastic process is difficult, but this important source of innovation also needs to be mentioned.

can include tax breaks on the performance of R&D, public performance of R&D, contracts or contests, among others (Wright, 1983).[2]

However, with any property rights structure transaction costs are positive, which implies that rights are never perfectly specified and enforced (North, 1990), hence affecting the appropriability of returns. Furthermore, as Coase (1937; 1960) puts forward, when transactions are costly, institutions matter. Societies develop formal and informal institutions, such as culture and norms, to reduce the importance of transaction costs (Williamson, 2000). Formal institutions relevant to innovation are IPRs and the associated legal organizations needed for their enforcement, i.e., the legal system, are part of the institutional environment.

The environment in which these rights exist is decisive, since it determines the quality of the rights (the enforcement) and hence the extent to which they reduce transaction costs and correct for the public-good market failure. In a world of incomplete contracts and transaction costs, Pagano and Rossi (2004) model the existence of self-reinforcing interactions between property rights and technology, leading either to virtuous complementarities or to the perpetuation of inequalities. Agents (or countries) tend to acquire abilities because they have IPRs and tend to acquire IPRs because they have abilities and vice versa.

Transaction costs play an important role with respect to innovation. In the Mexican maize breeding industry, information, certification and enforcement costs were high enough to hamper the incentive effect of IPRs (Léger, 2005), and similar conclusions were reached for a firm-level panel after the strengthening of IP protection in Japan (Sakakibara and Branstetter, 2001).

Informal and formal institutions also influence the innovation process. Looking at R&D investments, Varsakelis (2001) found national culture to be a determinant of R&D intensity, using a panel of developing and industrialized countries. Comparing countries with similar culture and norms, Waguespack and others (2005) found the stability of political institutions, hence the institutional environment, to be an important factor explaining the propensity to patent. Private agricultural R&D investments in OECD countries also respond to the quality of the institutional environment, i.e., efficient bureaucracy, enforcement of contracts and IP protection (Alfranca and Huffman, 2003). In certain industries, research institutions also play an important role: Alfranca and Huffman (2003) find that private and public agricultural R&D expenditures are complementary and public research is often at the basis of further technological development, for example in the biotechnology industry.

The direct link between IP protection and innovation is empirically more fragile. In OECD countries (Alfranca and Huffman, 2003; Furman et al., 2002), IPRs reportedly play an important role in supporting innovation. Most studies using cross-section or panel data of developing and industrialized countries also find similar results (Kanwar and Evenson, 2003; Lederman and Maloney, 2003; Varsakelis, 2001). However, different results obtain when looking at developing countries. Expanding the Furman, Porter and Stern (2002) framework and applying it to five East Asian countries, Hu and Mathews (2005) do not find IPRs to be a significant factor explaining innovation. Similarly, comparing the determinants of innovation for LDCs and industrialized countries separately shows that, IPRs have a positive and significant impact on innovation in industrialized countries, but that the effect is negative or non-significant in LDCs (Higino Schneider, 2005). Given that public R&D represents a high proportion of total R&D expenditures in LDCs, it is normal that IPRs, a market-based tool, has a different impact in these economies.

Insights from the institutional economics literature points to the importance of internalizing externalities – through IPRs or other mechanisms – in order to ensure the appropriability of the returns to innovation. Transaction costs and the environment in which the firm operates are expected to affect the incentive effect of IPRs, and the empirical evidence available supports these hypotheses. Similarly, it is essential to take formal and informal institutions into account in studying innovation. The role of one such institution, IPRs, is however not clear theoretically, and the empirical evidence is mixed, especially for LDCs.

3.2 Industrial Economics

Solow’s (1957) identification of technological change as an important contributor to growth stimulated a body of literature on generation and transmission of new information from the firm level perspective. Arrow’s seminal work (1962a) presents an investigation of the allocation of resources for invention under uncertainty. A free enterprise (perfectly competitive) economy is expected to under-invest in invention and research because it is risky, because the product can be appropriated only to a limited extent,[3] and because of increasing returns in use. On the other hand, he finds that monopoly power acts as a strong disincentive to further innovation, compared to perfect competition. These considerations support the view that government intervention is needed for financing R&D and that the firm, that takes into account its private and not the social benefits, might not necessarily be the ideal fundamental unit of organization in invention.

R&D is a costly and risky undertaking; hence an industrial organization of large monopolistic firms can offer decisive advantages as larger firms are able to achieve scale economies, diversify, develop market reputation, etc. as shown by various empirical studies (see among others Cohen and Klepper, 1996; Scherer, 1965). Uncertainty is another important issue: ideas are scarce and their occurrence, relying on the firm's technological base, is difficult to predict (Scotchmer, 2005). Following this line of thought, large firms, with large R&D facilities, are more likely to innovate. The size of the firm is hence an important characteristic that must be considered to explain a firm's innovative performance. In Schumpeter's view (1942) large firms have a critical advantage with respect to innovation because they can finance their R&D programs internally and diversify. However, the efficiency gains due to size are found to disappear after a certain critical size (Schmookler, 1972). Looking at the innovative behavior of large firms, Williamson (1965) finds that the performance of a large firm depends on the structure of its industry: large firms in concentrated industries innovate less. Competitive pressure heightens the need for conducting R&D, especially for small and medium-sized firms (Kumar and Saqib, 1996). Hence, other authors (Boldrin and Levine, 2003; Hellwig and Irmen, 2001) argue that perfect competition could be the structure most conducive to innovation. This in turn contradicts Schumpeter's view that perfect competition cannot be compatible with innovation – in a perfectly competitive setting extraordinary profits due to innovation would immediately disappear through rivals' imitative activities. Kamien and Schwarz (1982) conclude that an intermediate structure – neither perfectly competitive nor monopolistic – is the most conducive to innovation.

An intermediate competitive structure, with firms similar in size and technological level, is also one in which firms can benefit most from technological spillovers (Tirole, 1988). As an industry becomes more competitive, the private loss associated with the public good character of R&D spillovers diminishes relative to the private benefit of being able to exploit competitor's spillovers (Cohen and Levinthal, 1989). The impact of spillovers and diffusion of information has a substantial impact on follow-on innovation (Brynjolfsson and Hitt, 2003), particularly in the area of information technologies.

Finally, there is an extensive literature on the design and impact of innovation policies, such as for example the optimal length and breadth of patents (see Encaoua et al., 2006 for a survey). Though theoretical models are still yielding contradictory results, these studies are instructive but however fall outside the scope of this study.

3.3 Evolutionary Economics

Evolutionary economics represents a departure from neoclassical theories and assumptions.[4] It is based on the Schumpeterian vision of the economic world as a succession of disequilibria, explicitly dynamic and evolutionary, however seeing invention as an endogenous process rather than an exogenous force acting on the economic system. As such, the environment in which the firm operates must also be taken into account, which is especially considered in the literature on systems of innovation (Edquist, 1997; Lundvall, 1992).

In evolutionary economics, the concept of diversity, relating to the different firm's characteristics and decisions and differences in the environment in which the firm evolves, is key to the explanation of inter-industry and inter-country differences. Taking into account the innovation system as a whole explains significant portion of inter-country differences in innovative performance (see Freeman, 2002; Furman et al., 2002; Hu and Mathews, 2005; Kim and Nelson, 2000; Nelson, 1993), which in turn or the inclusion of such factors in the analysis of innovation.

Continuity is another important concept and relates to the dependence of current performance on earlier decisions and actions (path dependence). Several examples of this phenomenon have been reported, the most famous being the QWERTY keyboard case (David, 1985), but other studies using historical data, for example on coal wagons in Britain (Scott, 2001) have confirmed the relevance of this concept.

In day-to-day activities, such continuity is expressed through the development of routines that reduce learning and other transaction costs. They however cause resistance to change, and hence can slow innovation or adoption in the medium and long run (Nelson and Winter, 2002). Through the execution of routines and other day-to-day activities, a learning process takes place (Arrow, 1962b): learning-by-doing and learning-by-using contribute to the development of tacit knowledge which is difficult to transmit and is often embodied in the firm or individuals. This knowledge is also instrumental for the absorption and use of inter-firm spillovers (Ruttan, 2001). This can be contrasted with information that can be codified and transferred (Dosi, 1988). We define these as knowledge and information, respectively, and will use these terms in the remaining sections.

Based on this distinction, one can also distinguish between two types of innovations: cumulative innovation motivated by the need for improvements that has been identified through routinized activities, and discrete, independent development that often indicates the beginning of a new technological paradigm (Dosi and Nelson, 1994; Klevorick et al., 1995). Knowledge and information are inputs in the occurrence of both types of innovations, to different extents. The main point is that from these differences arises the need for different policies, for example, IPRs might be beneficial to society for independent innovations, while they can inhibit technological progress when used to protect cumulative innovations.

Results from the firm-level innovation surveys (Klevorick et al., 1995; Levin et al., 1987) show that spillovers discourage R&D in industries with independent, discrete innovations such as chemicals and pharmaceuticals. This is confirmed by the results obtained in other studies (Mansfield, 1995a; Mansfield, 1995b), which find these two industries to be among the few where patents provide incentives for innovation. On the other hand, in industries characterized by cumulative innovation (e.g. electronics, software industries), spillovers of rival firms might raise the productivity of the firm's own R&D and IPRs can hence inhibit technological progress (Klevorick et al., 1995; Levin, 1988). Another survey (Cohen et al., 2000) finds that the propensity to patent has increased over time, which could hence create even more important barriers to innovation in cumulative industries.

The basic assumptions of evolutionary economics appear to reflect more adequately the processes and environment characterizing innovation. The stickiness of knowledge, and the costs related to its transfer are theoretically better represented when distinguishing between knowledge and information and taking them as related, but distinct items. Appropriability of returns to innovation, through IPRs or other appropriation mechanisms, explains a significant proportion of inter-industry differences in innovation, and the evidence shows that patents are not always so important – as long as other mechanisms exist. Finally, the importance of national institutions and characteristics for innovation is supported by case studies, where country characteristics explain a significant proportion of inter-country differences in innovation.

3.4 International Trade

Given the growing importance of trade liberalization and economic integration, interactions between trade and innovation have received increasing attention in the literature[5] (Grossman and Helpman, 1990; Grossman and Helpman, 1991; Grossman and Helpman, 1994). In most of these models, the principles of endogenous growth theory have been transposed to the two-country case, taking explicitly into account the differences in factor endowments and prices between the trading partners. Therefore, the determinants of innovation are similar to the ones already discussed in previous sections (e.g. endowments and factor prices, market structure and competition, demand pull factors) but the role of trade as a cross-country channel of information is emphasized.

On the one hand, intended information transfer takes place, through technology transfer and/or licensing. In such a case, IPRs are needed to define and protect the object of the transaction, and serve as a supplementary source of revenue for the patent-holder. The empirical evidence in this area shows that IPRs do play a role for technology transfer: in the absence of IP protection, American, Japanese and German firms were less likely to license advanced technologies to unaffiliated firms (Mansfield, 1995a; Mansfield, 1995b). Using a panel of developed and developing countries to investigate the impact of patent strength on technology transfer from the USA, Yang and Maskus (2001) find stronger patent laws to have a positive and significant effect on receipts of licensing fees and royalties from unaffiliated firms. Branstetter and others (2006), looking more specifically at the case of multinationals and their foreign affiliates in countries that undertook patent reforms, find that R&D spending by affiliates increases after the IP reform and that royalty payments from foreign affiliates to their parent firm increase. Though the quality of the data on licensing and royalty revenues is questionable – it is voluntarily reported by firms – the authors perform robustness tests providing evidence that differences in tax rates in different countries do not affect their results.

Alternatively, unintended transfers take place through spillovers, either from foreign direct investments (FDI) or trade flows. Total factor productivity in industrialized countries is found to be positively affected by incoming foreign R&D, more so for more open countries but less so for G7 countries, the most innovative ones (Coe and Helpman, 1995). Keller (2001) finds similar results, but underlines the importance of domestic R&D levels, i.e., absorptive capacity, which determines the extent to which firms can benefit from external spillovers. For North-South trade, total factor productivity increases with the importance of the foreign R&D

capital stock, the imports of machinery and equipment from industrialized countries, and the level of education of the domestic labor force (Coe et al., 1997; Connolly, 2003). A recent article (Higino Schneider, 2005) differentiates between industrialized and developing countries and finds market size and infrastructure to be the most important determinants of innovation for developing countries, while high-tech[6] imports, human capital and R&D expenditures are more important for innovation in developed countries.

Studies on FDI in industrialized countries generally find FDI to positively affect innovation and/or productivity in the host economy. Early evidence on Australia (Caves, 1974) finds a positive effect of employment in foreign-owned firms on average value-added per worker. More recent work offers mixed evidence on this point: several studies confirm the positive role of FDI inflows (Maskus, 2000) but other articles (Higino Schneider, 2005; Connolly, 2003; Lichtenberg and van Pottelsberghe, 1996) do not find significant impacts. For LDCs alone, incoming FDI flows do not have a significant effect on local innovation (Aitken and Harrison, 1999; Hanson, 2001; Higino Schneider, 2005). Recent evidence on China (Wang and Yu, 2007) shows that the benefits from MNC's spillovers to locally owned enterprises are higher when the foreign presence is lower and follow an inverse u-shaped pattern. Moderate levels of foreign presence are most beneficial to the performance of Chinese locally owned firms, and the level depends on the characteristics of the industry. The type of ownership might also be important: in Lithuania, intra-industry spillovers were found to be positive only for projects with mixed (local and foreign) ownership (Javorcik, 2004).

Finally, certain models assume the existence of a freely accessible global stock of information to which countries can turn to find appropriate solutions to their problems (Grossman and Helpman, 1991). Conversely, other models assume completely endogenous technological change, implying that a country's technological status is related only to its own innovations (Romer, 1990). Eaton and Kortum (1999) develop a model of endogenous innovation with international diffusion, using patenting abroad from the five "research economies" (USA, Japan, Germany, UK, and France) as a proxy for diffusion. Their results show that international diffusion of ideas is important: Countries adopt between 50% and 75% of ideas generated abroad, with the USA deriving most of its growth from its local innovation, and along with Japan generating most of the growth in other countries of the sample. Conversely, using patent citation data for 147 European and North American regions, Peri (2005) finds that only 20% of average knowledge is obtained from foreign regions, and that distance plays an im portant role. However, knowledge from technological leaders (the top 20 regions for total R&D) "travels" further. He also concludes that trade is not the only channel of knowledge flows: indeed, knowledge flows are much less localized than trade flows. Bottazzi and Peri (2007), using international patents in the USA and their citations, find that a positive shock to the most innovative country (USA) causes a boom in innovation in the short-run and sustained productivity growth in the long-run in other countries. In the long-run, international knowledge significantly contributes to domestic innovation. These three studies however include only industrialized countries in their analyses, and as was mentioned in the preceding sections, national characteristics affect the performance of innovation, and are likely to affect the benefits a country can obtain from international technology diffusion.

Overall, intended and unintended technology transfers significantly affect the performance of domestic innovation, but again, country characteristics have to be taken into account. Especially relevant is the level of domestic absorptive capacity, and more empirical evidence on experiences in LDCs could help refine the theory and support the development of more appropriate innovation and industrial policies in these countries.

4 Conceptual Framework

Based on the literature reviewed in the previous section, we extend the chain-linked innovation model to include the contributions from the different economic perspectives and provide a more appropriate model of innovation. Figure 2 presents this improved model.

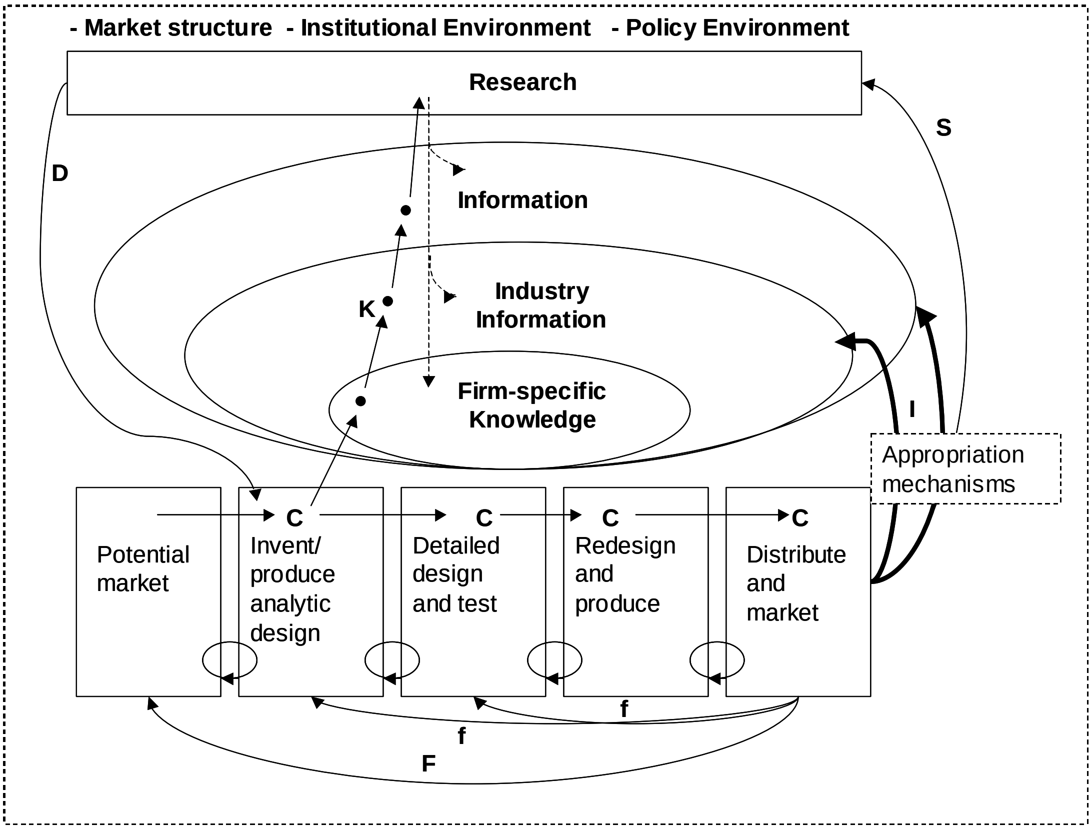
The basic model stays the same, but four additional aspects have been introduced:

- **the need to appropriate the returns from innovation.** Given the public good characteristics of new information, incentives need to be present for innovation to occur. Appropriation can occur with IPRs or other natural mechanisms.[7]
- **the distinction between knowledge and information**. Implicitly, the model assumes that the innovator has access to more than his own knowledge, however explicitly including intra-industry information implies spillovers among firms[8], from research (K) as well from the innovation itself (I). Conversely, this implies the presence of other firms in the industry. Furthermore, the feedback loops between the different steps also show that learning takes place within the firm, hence generating what evolutionary economists call firm-specific, or tacit, knowledge.

- **the environment in which the firm exists**. The structure of the market in which the firm operates affects the performance of innovation, and the policy and institutional environments also play important roles. The presence of other firms also implies the possibility of imitation, underlying the importance of appropriation mechanisms.
- **the characteristics of the firm**. The size of the firm, its resources, and its absorptive capacity determine the extent to which it can diversify its investments, invest in R&D, and absorb and process foreign information to respond to market signals. This is difficult to represent, but these features need to be considered as well.

In fact, such a model can be compared to the ones proposed in the literature on systems of innovation. However, this literature concentrates on the dynamics of the economy as a whole, where innovation plays an important role. Conversely, the innovation process is the focus of our analysis, but must be studied in its environment. As such, and since we do not focus on the different relationships among the institutions of the "system", our approach could be better described as a model of innovation taking into account the national environment in which it takes place, hence looking more at the "ecology" of innovation.

Figure 2: **Improved Innovation Model**



Note: The search and research process providing information spillovers (K) exists for the test and redesign steps as well.

International trade is justified by differences between countries: in comparative advantages, endowments, technology and other characteristics, which are taken into account in North-South models of trade. However, markets and interactions in developing countries are assumed identical to those of industrialized countries – or at least these aspects are not especially addressed. Additionally the use of IPRs as market based tool to ensure appropriation of intellectual property and create the right incentives to innovate has been highlighted by the surveyed literature as necessary for the innovative process. This might, however, not be an accurate description of the innovative process in countries where much of R&D is publicly conducted. The following section investigates these and other potential differences further in order to extend the improved innovation model to account for determinants of innovation, or lack thereof, in LDCs.

5 Developing Countries

Though varying in their stage of development, LDCs have several characteristics in common when considering innovation. Mashelkar (2005) classifies countries according to their individual innovative capability i.e., science and technology base, and economic strength (see figure 3).

Figure 3: **Classification of Developing Countries**

		Innovative Capabilities	
		Low	**High**
Economic	**High**	**II**	**I**
Strength	**Low**	**III**	**IV**

Source: Mashelkar, 2005

In quadrant 1, countries have substantial economic strength and innovative capabilities. Most industrialized countries fall into this quadrant. Quadrant II includes those countries that have limited innovative capacity but are economically sound (e.g., Middle-Eastern countries). The third quadrant comprises of low income countries with limited innovative capacity and economic development (least-developed countries). For the purpose of our analysis, we focus on the innovative capabilities and hence group these two quadrants together. In quadrant IV are those countries that, despite their lack of economic strength, show advances in their science and technological base (e.g., Southeast Asia, India, Brazil, China, Mexico).

Despite these differences, a certain consensus exists on the main features of the economic environment in LDCs in general. The institutional environment is characterized by the presence of high transaction costs, which often includes corruption (Collier, 1998), and by weak institutions.[9] These affect the functioning of the market and the transmission of the signals – e.g. demand for certain goods – to the innovators. Information failures are also predominant, and hinder the discovery of the economic cost structure of new processes and products, hence slowing down adoption. Similarly, coordination failures exist, where simultaneous, large-scale investments needed for projects to be profitable (or feasible) do not take place (Rodrik, 2004). Government intervention, taking form in the creation of new institutions, is generally appropriate to correct for market failures such as missing markets. However, in the case of

LDCs the institutions are often less efficient than in industrialized countries, which implies that the market failures cannot be corrected to the same extent (Stiglitz, 1989).

Markets (e.g., risk, financial and human capital) are often incomplete, weak or non-existent (Lall, 1995), which has important implications for the performance of innovative activities. The standards of education and innovative ability vary among countries, thus making some countries not only more capable of innovating but also facilitating absorption via technology spillovers and transfers (Aubert, 2005; Bell and Albu, 1999). An important concern in LDCs is the migration of skilled manpower to industrialized countries. For example, although skilled workers account for just 4% of all sub-Saharan labor force, they represent about 40% of its migrants (Özden and Schiff, 2005).

Given the low level of economic development and the unequal distribution of income, the effective domestic demand is usually small[10] (Foellmi and Zweimüller, 2006). The demand side is often neglected but the expansion of domestic demand is critical for economic growth, and for the performance of innovation addressing local needs (UNCTAD, 2006). Small countries can however innovate for export markets to overcome such limitations (such as e.g., Israel, Taiwan and Singapore).

Finally, agriculture is still a critical sector to get development going (Lipton, 2005). If the sector is linked to the rest of the economy, a virtuous circle of surplus from agricultural production stimulating entrepreneurship and investments in non-agricultural activities would have the potential to contribute to sustainable poverty reduction. However, agricultural production is constrained by limited resources – land, water – which implies that productivity increases are heavily dependent on yield increases – technological change – in this area (De Janvry et al., 2005).

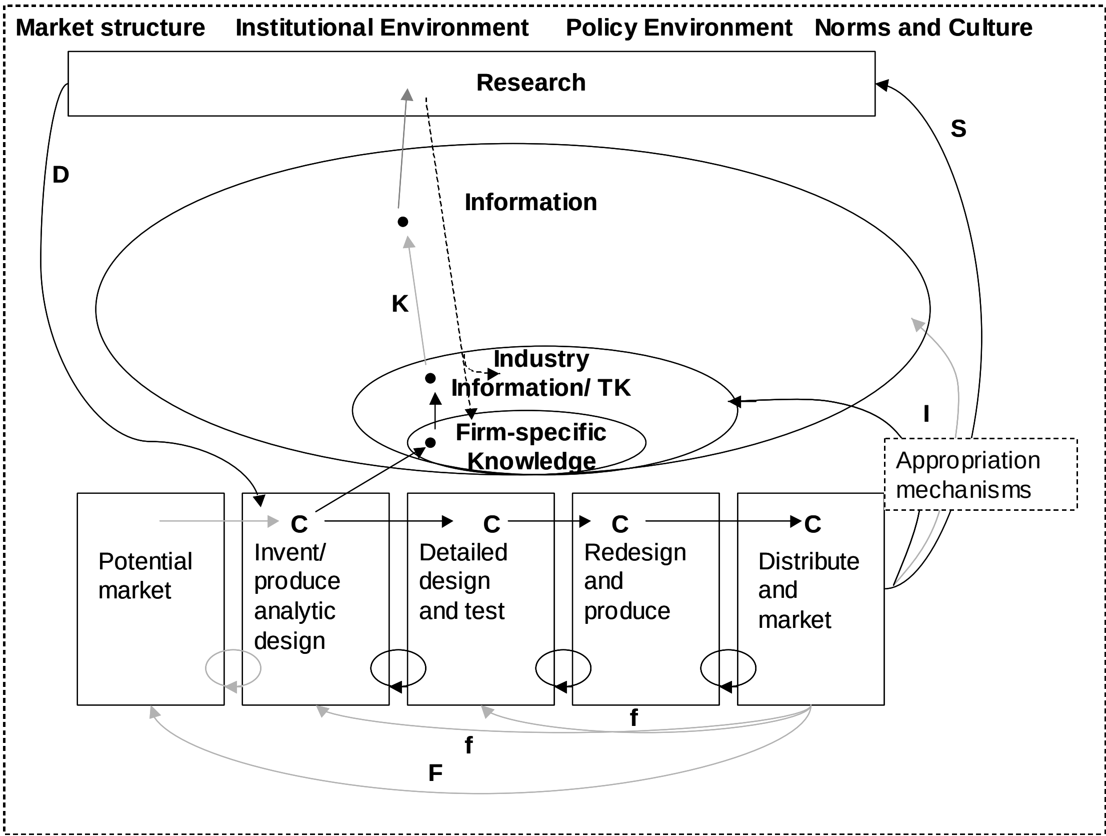
Given their relatively lower innovative capacities, LDCs are generally dependent on industrialized countries for the provision of new technology and knowledge. However, they are often rich in traditional knowledge (Aubert, 2005). Traditional knowledge is defined as a traditional technical know-how, or ecological, scientific or medical knowledge, encompassing the content or substance of traditional know-how, innovations, information, practices, skills and learning of systems such as traditional agricultural, environmental or medicinal knowledge (WIPO, 2005).

These characteristics justify the need to modify the model presented in the previous section to better represent the reality of developing countries (see figure 4). With respect to information and knowledge, the firm has little firm-specific knowledge to turn to for innovation. Similarly, the industry information is lower than in the original model, but the firm also has access to traditional knowledge. The search process is hampered when it comes to taking advantage of the information available since the firm often does not have the absorptive capacity (R&D base, tacit knowledge) needed to assimilate and apply it.

Innovations contribute to the stock of industry information, but often to a lower extent to the international pool, resulting in a more "local" nature of innovation. Similarly, the research taking place in the search process contributes mainly to the industry. However, given the characteristics of firms and their generally low level of absorptive capacity, intra-industry spillovers have a lower impact on a firm's innovative potential.

The market forces implicit in the chain-linked model have a more limited impact in the model for LDCs. While the previous aspects addressed were mainly relevant for countries at low levels of development, these are also relevant for more advanced, emerging economies (e.g. Brazil, India, China, Mexico). First, the size of the market for domestic innovation is often smaller, which provides fewer incentives for the performance of this activity. Alternatively, the feedback mechanisms from the market are not as effective given the institutional environment (i.e., high transaction costs, corruption, weak markets) prevailing in these countries. Finally, international and regional commitments (e.g. WTO or regional trade agreement memberships, World Bank/ IMF loans and associated obligations) oblige governments to follow priorities that are often not determined at the national level, and not directed at supporting innovation. This is what Hoekman (2004) calls a reduction in policy space.

Figure 4: **Chain-Linked Model of Innovation in Developing Countries**



Note: The search and research process providing information spillovers (K) exists for the test and redesign steps as well. Arrows in grey represent the malfunctioning links.

Our model extension also sheds light on other implicit assumptions (or omissions) of the chain-linked model. The quality and availability of inputs for the innovation process are not discussed, while in reality their absence or low quality are often important obstacles. Incomplete markets for risk, financial and human capital can often impede innovation, but these are assumed to be abundant in industrialized countries and hence not discussed.

6 Implications

6.1 Chain-linked innovation model

Our improvements to the chain-linked model can be grouped under four categories: i) the need for appropriation mechanisms; ii) the distinction between knowledge and information;

iii) the importance of taking account of the environment; and iv) the characteristics of the firm.

Given the public good characteristics of new information, incentives need to be present for private innovation to occur. IPRs are a possible intervention to address this problem, but other mechanisms (e.g., contests, contracts) also exist. These interventions have different implications in terms of social welfare, especially regarding their impacts on follow-up innovation. Scotchmer (2005) gives a good overview of the impacts of these different mechanisms. In particular, public performance or financing of R&D might represent an efficient alternative when incentives are non-existent, and raises less concerns regarding follow-up innovation.

Our distinction between knowledge and information sheds light on the processes of diffusion and absorption. On the one hand, a certain level of firm-based knowledge is developed through production and R&D activities, needed for absorbing information spillovers. On the other hand, this same knowledge is characterized by its stickiness, and hence can only be transferred with difficulty, which in turn complicates the transfer of information.

The environment in which the firm operates is crucial. The size of the market determines the incentives available for domestic innovation, and the appropriation mechanisms determine the extent to which the returns from innovation are internalized. These also determine the extent to which spillovers exist in the industry, while the structure of the market is often correlated to the absorptive capacity of the firms in the industry. In LDCs, traditional knowledge exists as a differentiated source of information that could provide a basis for original innovation and hence, a comparative advantage in these activities. Finally, the environment also entails such resources as the quality and availability of human capital, which directly affects the firms' capacity to conduct innovation, and is subject to different types of transaction costs that affect the extent to which the firm can perceive feedback from the market and hence react appropriately.

The last aspect is more difficult to integrate in a framework but needs to be taken into account, for it affects the capacity to innovate and points towards other omissions or implicit assumptions of the chain-linked model. The size of the firm is correlated with its ability to conduct R&D (and hence its absorptive capacity), to diversify its activities (and hence reduce risk) and to finance the innovation process. For small firms, the presence of risk and capital markets is hence vital, which is assumed as given in the chain-linked model and not discussed. However, in LDCs these markets can be absent or weak, which further complicates the performance of innovation.

6.2 Implications for developing countries

These aspects also have direct implications for local innovation in LDCs. Through multilateral, regional and bilateral agreements, stronger IP protection has been negotiated. The protection of IPRs should contribute to the promotion of technological innovation and to the transfer and dissemination of technology (WTO, 1995). For local innovation, IPRs represent a trade-off between improved innovation incentives and the restricted use of the protected innovation (Moschini, 2004). In a developing country setting, where transaction costs are high and technological capacities and effective demand are low, the patent system might not achieve the desired result.

In fact, the evidence available does not support the WTO's claims: innovation in LDCs is not necessarily related to the strength of IP protection (Higino Schneider, 2005; Hu and Mathews, 2005). Concerning technology transfer and dissemination, IPRs seem to support FDI and licensing in LDCs, but domestic firms do not always benefit from their presence (Aitken and Harrison, 1999; Hanson, 2001; Wang and Yu, 2007) as there are very little spillovers to local firms (minimal absorptive capacity) which could result in a crowding out effect.

Another aspect is related to the relevance of the technologies transferred. Since technological developments are induced by economic forces and local characteristics and endowments (Hayami and Ruttan, 1985), firms in industrialized countries often privilege the development of labor-saving technologies. These are often not adequate for developing countries, where, given the generally abundant supply of labor and relatively lower availability of capital, labor-intensive or capital-saving technological change is more appropriate. For certain technologies, e.g., plant varieties, agro-ecological conditions make transfers hazardous; hence most countries conduct public agricultural R&D, if not to innovate at least to adapt foreign innovations to local conditions.

Another related item is the importance of traditional knowledge, representing a potential source of comparative advantage in innovation. It is important to develop appropriate forms of protection defining the information to control its exploitation and eventually obtain appropriate compensation for its use. Still, success stories such as those of the Honey Bee Network in India[2] (Dutfield, 2006; Gupta, 2006) show that local innovation can yield interesting products and processes. The challenge is to increase the diffusion of traditional knowledge, both vertically and horizontally. Horizontally implies diffusing innovations from traditional communities to other, distant communities with similar characteristics for which they would be useful, basically by overcoming information costs. Vertical diffusion consists in abolishing the invisible barrier between scientific research and innovation and traditional knowledge, so that scientists can value and take advantage of the traditional knowledge as a basis for their research activities. Experiences so far have however not been very convincing.

The distinction between knowledge and information is closely intertwined with the technological level prevailing in a country and hence, its human capital. Absorptive capacity and the need to access and be able to use spillovers are key to the innovation process. Therefore, investments in education, to raise human capital levels, scientific capabilities and the capacity to absorb local or international spillovers, are central for a well functioning innovation policy, and more so where these resources are scarce.

It is also the government's responsibility to provide institutions, among others a functioning legal system, that provide a stable framework in which firms can operate and enforce their rights.[11] In the same line of thought, even though transaction costs are inevitable, reducing their importance, and that of corruption, would allow firms to better perceive market feedback and hence increase their efficiency in innovation. The development of bigger markets in LDCs is a long-term process, but an export-oriented strategy can provide greater incentives for local innovation, if governments refrain from taxing the exports of successful industries. Conversely, in cases for which effective demand is important but the capacity to pay is low, the public sector has a role to play in adapting foreign technologies or conducting R&D adapted to local needs and characteristics.

Finally, improving the quality of firms for innovation is a long-term process. However, government intervention such as investments in input markets and marketing infrastructures create public goods that, through solving for coordination and information failures, could significantly improve the climate for innovation. Given its importance for development, innovation

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[2] For further information regarding the Honey Bee Network in India, please refer to www.sristi.org, 18.09.2007

in the agricultural sector should be given particular attention. Indeed, innovation in this sector will be crucial to face increasing demand for food in a situation of limited resources. Furthermore, the agricultural sector is often at the basis of the development process (Thomas and Slater, 2006). Though several issues cannot be solved solely at the domestic level – e.g., price distortions on international markets, access to industrialized countries' markets – the public sector has a critical role to play in agricultural innovation. The returns from innovation are especially difficult to appropriate in this sector: poor farmers have very limited purchasing power for new technologies or products, and appropriating returns from innovation in, for example, plant breeding, is difficult since by buying the new variety, one can reproduce it. Furthermore, information costs are high in LDCs, especially where levels of human capital are low, therefore, pointing to the need for public financing (if not performance) of innovative activities, supported by extension services to support the diffusion and adoption processes.

Finally, one cannot generalize about LDCs, and evidence shows, as reviewed here, that local characteristics influence the performance of innovation. Therefore, each country should find its own strategy to provide an environment supportive of innovation and adapt policies to encourage it.

7 Conclusion

This article reviews the perspectives on innovation from four select branches of the economic literature to identify areas of further research and, more importantly, build a holistic conceptual framework of innovation including these various contributions. Empirical evidence shows that the innovation process could follow a different pattern in developing countries. We hence modify our conceptual framework to better represent the case of developing countries, and set the bases for future work in this area.

In general, more research is needed on the link between firm size and innovation, IPRs and innovation, as well as on market structure and innovation, where the theory and empirical evidence tend to be inconclusive. Another challenge in empirical work consists in distinguishing between knowledge and information, to find out more about their respective roles for innovation. But an important and necessary step is to substantiate the evidence in LDCs to further refine the theory on innovation, and inform policy-making in this area. Given the importance innovation could have for these countries' development, it should be set as a priority.

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Notes

1. This model considers that the link between science and innovation is not preponderantly at the beginning of typical innovations: confronted with a problem, scientists first call on known science and stored knowledge, and only when this mechanism fails to solve the problem will specific R&D activities be considered (Kline and Rosenberg, p. 291).

2. "Natural" appropriability mechanisms, such as for example secrecy, lead time and learning curve advantages, also exist. The principle is the same: to secure a monopoly position for the innovation in order to capture the returns from innovation, but the emphasis is put more on retarding or impeding imitation by other firms.

3. According to Arrow, information, because of its intangible nature, cannot be made thoroughly appropriable.

4. Bounded rationality is such a departure, with incomplete information and no foresight, where actors are not independent and not optimizing their utility but rather adopting a "satisficing" behaviour. See Nelson and Winter, 1982.

5. Most the work on innovation and trade focuses on the inverse relationship, that is, the role of technology as a determinant of trade patterns (e.g. Dornbusch, Fischer and Samuelson, 1977; Krugman, 1979; Wakelin, 1997).

6. The possible endogeneity of the high-tech imports regressor is neither addressed nor discussed, but could potentially bias the estimations results.

7. This is obviously related to the case of innovation by the private sector. The case of public-sector innovation will be discussed in section 6.

8. The industry also includes input providers and users, that also innovate or provide feedback on possible improvements.

9. In the presence of weak institutions, corruption and bribery might actually support innovation.

10. Obvious exceptions are large countries such as India, China and Brazil.

11. These conditions are however neither necessary nor sufficient for innovation to take place, as exemplified by the Chinese innovative performance.

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