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Technology, Development and Innovation Systems: An Introduction

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ABSTRACT *Today's thinking about growth associates economic and social development, institutions and technology. This short introduction presents some key concepts linking these elements and highlights the importance of the innovation systems approach as a framework of analysis for economic development. Also, the innovation systems approach is most often framed in evolutionary economics. The links between innovation systems (a middle range theory) and evolutionary concepts are presented summarily.*

I. Technology, Innovation and Development

Since Solow's (1956) seminal contribution, technology has been seen as the major factor explaining economic growth. However, the neoclassical growth models built upon his original paper placed technology, beyond capital and labour, as a factor exogenous to the economic landscape. Solow's technology 'residual', later renamed total factor productivity, was measured in many countries and appeared to explain well over 50 per cent of economic growth.

Yet, several decades before Solow, Joseph Schumpeter had asserted the endogenous character of technology (Rosenberg, 2000). Technology is not an external variable, but it is the result of the efforts deployed by private firms to improve their competitive position. Schumpeter's contribution has remained outside the economic mainstream, and supports the evolutionary perspective to economics and technical change. It was 30 years after Solow's initial paper that the endogeneity of technology was rediscovered in mainstream economics (Romer, 1986). By that time, the key role of technology in development had become one of the few elements of consensus among different currents in the discipline.

In the meantime, the increasing returns hypothesis pioneered by Sraffa in the 1920s was rescued from oblivion by the tireless work of a few outsiders, such as

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Kaldor in the 1970s and 1980s (Targetti and Thirlwall, 1989) and became a central feature of the economic landscape. Paul Krugman (1991) and W. Brian Arthur (1994) linked increasing returns to economic geography: for some reason, some cities attract investment and know-how; other companies follow and a virtuous circle of regional growth is put in motion. As more companies locate in the region, more knowledge is produced and diffused regionally, and it becomes less costly to conduct research and produce goods or services in the area. Historical accident plus agglomeration effects (increasing returns) explain the location of industry. Given increasing returns, as Arthur has emphasised (Arthur, 1994: 28), static analysis is no longer useful: many outcomes are possible, and it is important to follow the sequence by which events accumulate. Also, the increasing returns hypothesis was useful to understand high-technology industries. In these activities, the fixed costs of producing new knowledge by means of R&D would obtain larger returns if distributed on the largest possible output: increasing returns lead to economic concentration.

Soon the increasing returns hypothesis was accompanied by 'external increasing returns' (spillovers or externalities), originally proposed by Alfred Marshall in the 1880s and reintroduced by Arrow in the 1960s. The concept of externality was very successful. Maybe economic development could flow from developed to developing countries through international spillovers through trade, foreign direct investment, or imitation. Open economies would be in a better position to capture these spillovers (Coe and Helpman, 1995). But in the 1990s, some of the most astounding defaults in history were seen in those countries that unilaterally opened their economies to international trade and financial flows, namely Argentina and Russia, followed by several dozen smaller ones (Stiglitz, 2002). International externalities seemed to accrue not to open economies but to more 'managed' countries in South East Asia.

The role of policies to support and induce technological activities in developing countries, as well as the related spillovers, was too often neglected. It was taken for granted that spillovers would befall on developing countries without effort or investment. Sanjaya Lall's major contribution has been to emphasise the fact that developing countries required technology policies similar to those applied by industrial nations in order to capture such externalities (Lall, 1992).

II. Institutions and Development

In the last 15 years, institutions have come to play a key role in development economics.[1] Yet the institutions that different authors and currents are placing at the forefront as explanations of economic development are not the same. For some authors, institutions related to securing property rights are key (North, 1990), but also institutions ensuring the elimination of corruption (Acemoglu, 2003). According to others, market-preserving federal institutions are to be promoted (Weingast, 1995) as well as democracy and political stability (Waguespack et al., 2005). To obtain economic growth, institutions devoted to health care should be improved, as poor health has a negative impact on total factor productivity (Cole and Neumayer, 2006). Yet other authors demonstrated that higher education institutions needed to be reinforced in developing countries, as human capital has a positive impact on economic growth (Gyimah-Brempong et al., 2006).

The role of such important institutions as democratic and stable federal political regimes in economic development is unquestionable. Yet, in the nineteenth century, the catching up of several Continental European countries vis-à-vis Britain took place under less than democratic and stable political systems, and in the twentieth century rapid development in Japan, Korea, Taiwan and Singapore did not take place under federal regimes or highly democratic institutions. As Richard Nelson has recently argued, these represent a very heterogeneous bag of institutions, and their precise contribution to development is difficult to measure. He suggests, conversely, in line with the innovation system approach and with the key role of technology in economic development, that the more central institutions related to economic growth are those linked to technical change, technology diffusion, absorption and creation, such as universities, government R&D laboratories, and public incentives to R&D and innovation (Nelson, 2006).

III. The Evolutionary and Innovation Systems Approach and Development

The innovation system approach has gained ground over the last 20 years.[2] It provides a consistent conceptual framework for integrating key science, technology and innovation institutions into economic development. This current was started by the pioneering work of Christopher Freeman (1995, 2002), Bengt-Ake Lundvall (1992) and Richard Nelson (1993) on national systems of innovation (NSI). Lundvall offered two definitions of the NSI:

> The narrow definition would include organizations and institutions involved in searching and exploring – such a R&D departments, technological institutes and universities. The broad definition … includes all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring. (Lundvall, 1992: 12)

Universities, government laboratories and innovative firms are thus at the core of NSI. Yet, other elements are important and need to be taken into consideration, such as venture capital firms, regulatory agencies, stock exchanges, other enterprises, market structures and the like (Lundvall et al., 2002). Pre-tertiary educational institutions provide a case in point. As Lall (1999) has emphasised, the effectiveness of the university system is in part based on the quality of the primary and secondary education provided. Without basic education, developing countries usually fall into a 'low-skill equilibrium trap', unable to capture knowledge externalities and enter new industries.

Within a few years after these seminal papers, hundreds of authors were publishing on national systems of innovation on the five continents in top journals and university presses (Niosi et al., 1993; Mowery and Oxley, 1995; Reddy, 1997; Alcorta and Peres, 1998; Arocena and Sutz, 2001; Liu and White, 2001; Carlsson et al., 2002; Muchie et al., 2004). Similarly, governmental and international organisations have adopted the concept (OCDE, 1999, 2006). Innovation was found concentrated in two dozen countries. Their institutional structures were fairly different, based on divergent historical development paths, yet some authors proposed that all the different NSI could be grouped into a few models (Amable

et al., 1997). The public policy implications of this perspective are straightforward: governments interested in catching up and promoting development should nurture their core technical institutions as well as the inflow of technology, and pay attention to the creation of a domestic technical base. For international knowledge spillovers to occur, governments in developing countries would need to build institutions and policies to nurture learning and reduce the organisational inertia that affects private and public organisations alike. They should also pay attention to the co-evolution of technology and institutions, because over different stages of the construction of the NSI, different institutions, incentives and organisations may change their roles and missions. Finally, they should harmonise other organisations and institutions outside the core in order to create synergies and reduce obstacles to learning and adoption. In the words of Ruttan, 'the capacity to advance knowledge in science and technology is itself a result of a product of institutional innovation' (Ruttan, 2007: 250).

The evolutionary and institutional approach argues that governments often do not fully understand the role of institutions, incentives and organisations in economic development (Nelson, 2006). Also, in developing countries, social returns and private returns to political entrepreneurs often diverge (Ruttan, 2007: 257). As any other economic agents, governments have bounded rationality and proceed very much through imitation, trial and error, and subsequent fine-tuning of their policy initiatives. Developing countries may suffer from several 'systemic failures' including the lack of key institutions, policy and institutional inertia, inadequate system rules, and so on (Niosi, 2002). Under these conditions, developing countries may suffer from a 'low institutional trap' and remain locked in inferior institutional arrangements. The wealth of empirical and historical material that this current has accumulated over the years may offer some help in the comprehension of the role of core science, technology and innovation institutions and their systemic nature, in economic and social development.

In the building of a portfolio of science, technology and innovation policies, the sequence of adoption is not random. A few examples may illustrate the systemic and sequential character of this institutional accumulation.

- Primary and secondary education institutions both need to be reinforced before higher education (tertiary) is strengthened.
- Horizontal policies for innovation, such as tax credits for R&D (easier to apply to existing firms, and also less demanding in terms of monitoring) should come before more sophisticated policies such as vertical policies for specific sectors, and the promotion of venture capital for new technology firms.
- Grant loans or education credits for tertiary students should always come before grants because they mostly apply to larger populations of undergraduates.
- The supply of highly skilled people (through the reinforcement of education institutions and through grant loans and grants) should be made in parallel with the demand (through innovation policies giving incentives to firms for hiring this skilled personnel for R&D purposes).

In the early 1990s, the innovation systems theory extended to regional innovation systems (Cooke, 1992; Cooke et al., 1997; de la Mothe and Paquet, 1998; Parker and Tamaschke, 2005). Building similar definitions and hypotheses to those of the NSI

approach, regional innovation systems (RSI) were composed of a set of organisations and institutions that included, at their core, universities, government laboratories and innovative private and public firms. It was found that in every industrial or industrialising country, a few metropolitan regions assemble most of these dynamic institutions and organisations. The conclusions for developing countries are straightforward: they should pay attention to the dynamics of development at the regional (usually metropolitan) level. Again, the sequence is important:

- Biotechnology clusters are anchored on high-level research institutions. They will attract venture capital and spin off new biotechnology firms. Thus, they come before any other type of organisation or institution.
- Conversely, aerospace and information technology clusters are anchored to large private firms that create pools of skilled labour and spin off new technology based firms. Any region aiming at becoming a cluster in these industries should start by attracting the anchors.

The latest addition, at the end of the 1990s, was the concept of sectoral innovation systems (Breschi and Malerba, 1997; Malerba, 2004). The study of specific industries can be better understood when complemented by the inclusion of the supporting institutions and technological regimes. This hypothesis becomes particularly relevant for the study of economic development, as the economic structures of most countries, industrial or developing, are made up of a few innovative sectors. The innovation system approach can make an exceptional contribution to understanding the 'non convergence' phenomenon,[3] as well as the familiar but unexplained phenomenon of 'catching up, forging ahead and falling behind' (Abramovitz, 1986). Why did Argentina fall from the ninth place in GDP per capita in 1945 to the 50th place today? The SSI approach would suggest that its wealth was based on one sector, agriculture. When the country incorporated industrial activities with lower productivity, its GDP per capita stagnated. Similarly, the spectacular rise of GDP per capita in some of the South East Asian Tigers is linked to their successful efforts to create new sectors through industrial, science, technology and innovation policies (Lall, 2004).

Also, the innovation system approach and the evolutionary perspective in economics have moved closer together. And their contribution to economic development is far greater than simply pointing to the need to reinforce institutions. Saviotti and Pyka (2004) have underlined the fact that economic development is not simply a process of increasing productivity in existing sectors; on the contrary, they present it as a process of creating new sectors, adding variety to the economy and producing qualitative change. Their contribution is part of a long series of writings starting with those of the 'structuralist' school of Latin America (Prebisch, 1963). This school suggested that Latin America should promote its economic development through the creation of new and more dynamic sectors, and get out of the trap of natural resources, into advanced manufacturing. Basic resources displayed a cyclical nature in price and volume, many of them were non renewable (minerals and hydrocarbons), some are not easily renewable (forests and fish stocks) and in the long term (particularly foodstuffs) demand for them grows very slowly.

Unfortunately, in the 1950s and 1960s, the application of these ideas in Latin America was made through protectionist and import substitution models that fuelled trade deficits and inflation (Cardoso and Fishlow, 1992). South East Asian countries, instead, have added new sectors, with an export substitution pattern, forcing their new industries to compete in international markets and isolating them temporarily from domestic competition with low currency rates.

No other modern economist has contributed more to link evolutionary and structuralist economics to systems perspectives and development studies than Sanjaya Lall. In his vision, economic and policy agents are all governed by bounded rationality, and learning is a collective and cumulative process. In developing countries, entrepreneurs explore technologies, and policy makers implement, evaluate and refine incentives in multiple and continuous learning processes (Lall, 1998; Lall and Teubal, 1998). The business sector is not homogeneous; it includes innovators, imitators and laggards; government policy is basically aimed at increasing the number of innovators (Teubal, 2002). Government intervention includes selective and sophisticated incentives in the area of industrial and technology policy, picking industries that offer significant technological and other benefits, using exports to monitor progress and discipline the new entrants, investing massively in skill creation and support institutions, and being selective on foreign direct investment in order to maximise inward technological spillovers (Lall, 2004). Economic development is not an equilibrium-seeking process following a small departure from it; on the contrary, in a Schumpeterian perspective, economic development is an evolutionary process where change is the norm, and equilibrium usually represents passing stationary situations (Rosenberg, 2000).

In the evolutionary and system approach, the concept of 'absorptive capacity' has been borrowed from firm-level analyses in management theory (Cohen and Levinthal, 1990), to characterise the different regional and national capabilities observed in the assimilation of technologies and associated organisational practices (Dahlmann and Nelson, 1995). Regional and national innovation systems display different capabilities on the basis of their various institutional and social arrangements. One of the purposes of public policy is to increase the absorptive capability of developing countries in order to allow them to add new sectors through the incorporation of foreign technology and organisational knowledge.

IV. Presentation of the Papers

The papers included in this special issue are some of the best presentations to the First Globelics Workshop, which took place in Rio in November 2003. They deal with some of the theoretical questions briefly described above. All of them are directly related to the systems of innovation approach. The late Sanjaya Lall, together with Bengt-Ake Lundvall and Jorge Niosi, chose some 12 papers out of more than 60 for this special issue.

Mazzoleni's paper analyses the key role of universities within national systems of innovation during the catching up process. He argues that the fast growing countries of South East Asia display types of universities and university–industry relationships similar in several key aspects to those developed in Britain, France, Germany, Japan and the United States. These dimensions include massive public investment in

technical education, rapid increase in the number of students and graduates, as well as the migration of students to obtain degrees abroad. These foreign-degree holders are often hired as professors in the newly created institutions of higher education and government laboratories, thus supporting the inward transfer of technology and international knowledge spillovers nurturing the catching up process. Mazzoleni's argument fits nicely with some previously published papers (Gyimah-Brempong et al., 2006).

The next two papers, those of Chen and Chudnovsky, Lopez and Rossi, concern the role of multinational corporations in the creation of knowledge spillovers. Chudnovsky, Lopez and Rossi analyse knowledge spillovers created by transnational corporations and received by local firms in Argentina, after the significant inflows of foreign direct investment that accrued to that country in the 1990s. They found that, on average, Argentinean firms did not reap either positive or negative spillovers. Yet those domestic firms that received positive spillovers obtained those benefits through strong absorptive capabilities acquired in the previous industrialisation period. The authors conclude that policies aiming at reinforcing the NSI and promoting these capabilities are at the top of the policy agenda.

Chen analyses the Beijing high-technology cluster. He finds that the many foreign laboratories established in China's capital city in the last few years participated in a bi-directional process of knowledge creation and diffusion. These new R&D centres hire many foreign-graduate Chinese scientists and engineers, interact with local public R&D laboratories, and contribute to the formation of a local cluster. While Chudnovsky, Lopez and Rossi studied the more well established process of spillovers from MNC to local firms, Chen found a two-way externality process in Beijing: local organisations and personnel learning from foreign firms, and foreign corporate laboratories learning from public and private Chinese institutions.

These papers contribute to the never-ending process of theory building and, at the same time, they advance our knowledge of key issues in economic development. In the future, the innovation systems perspective may become the catalyst for a new way of thinking about institutions and economic growth. Professors Sanjaya Lall, Bengt-Ake Lundvall and myself chose the papers on the basis of over 100 communications presented at the First Globelics conference in Rio de Janeiro. Since the papers were selected Professor Lall passed away, as did Dr Daniel Chudnosky. Both were highly respected and prolific academics working on economic development issues. They are sorely missed by friends and colleagues.

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Notes

1. In January 2007, we undertook a short research in the Social Science Citation Index (SSCI) with the keywords 'institutions and economic development', and found 1,448 publications with 7,329 citations. From virtually 0 in 1989, the number of publications in this area reached 160 in 2005, with over 1,300 citations for that year alone.

2. Another search in the *Social Science Citation Index* in January 2007, using 'national innovation systems' as keyword yielded 359 publications in refereed journals, with 1,921 citations between 1994 and 2006; similarly, 229 publications appeared for 'regional innovation systems' with 1,282 citations. Finally, 33 publications with 187 citations were about the newest addition to the innovation system framework, 'sectoral systems of innovation'. Even allowing for some double counting, there are over 500 articles, as well as several hundred books on the topic.
3. 'Two hundred and fifty years ago, this gap between richest and poorest was perhaps 5 to 1, and the difference between Europe and, say, East or South East Asia (China or India) was around 1,5 to 1 or 2 to 1' (Landes, 1999: xx). Today, the difference between the richest countries (that is, words, Norway) and the poorest (that is, Burundi) is 650 to 1.

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