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The challenge of alignment and barriers for the design and implementation of science, technology and innovation policies for innovation systems in developing countries

Cristina Chaminade (cchaminade@gmail.com)
CIRCLE, Lund University

Ramón Padilla Pérez (ramon.padilla@cepal.org)
United Nations Economic Commission for Latin America and the Caribbean

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Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN
http://www.circle.lu.se/publications

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Cristina Chaminade and Ramón Padilla Pérez

Abstract

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JEL codes: O25, O38, O33

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Cristina Chaminade

Circle, Lund University, Sweden

cchaminade@gmail.com

Ramón Padilla Pérez

United Nations Economic Commission for Latin America and the Caribbean

ramon.padilla@cepal.org

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1. Introduction

In the last few years, a growing number of developing countries have officially adopted the innovation system (IS) approach to formulate their science, technology and innovation (STI) policies (Padilla-Pérez, 2013; ECLAC/OCDE, 2012). This is the case even for the group of the so-called 'less-successful developing countries' like Ghana, Honduras, Mauritania, and Nicaragua (UNCTAD, 2010, 2011a, b, 2012).

In general, policies targeting the innovation system as a whole seem to be more appropriate for developing countries that pure science or technology policies since they encompass not only science and technology, but all public actions influencing competence building and learning like education and training, social policies underpinning social capital, functioning of labor markets of the organization of firms, to put some examples (Lundvall etal, 2009; 6). But they are also more challenging. In order to be effective, STI policies from an innovation system perspective (innovation system policies now onwards) require an explicit alignment of policies with the specific development challenges that the country is facing (Chaminade et al., 2009). The problem is that more often than not, the STI policies deployed in developing countries reflect more a process of imitation of objectives and instruments than actually a strategy to address the specific problems that the country has. It is also often the case, that there is a lack of alignment between objectives, instruments and specific problems (Chaminade et al, 2012). Moreover, STI policies frequently are neither at the centre of the economic development agenda nor aligned with a national development strategy (Padilla-Pérez and Gaudin, 2014; Padilla-Pérez, 2013). Making reference to Kingdon (2010) ideas, STI has not been set as a central pillar of the economic development agenda.

As an example, STI policies in Latin America followed a demand-led approach in the 1980s, 1990s and 2000s, focusing on tackling market failures and considering economic liberalisation and trade openness as the main sources of technological learning. Public agencies responsible for STI policies had reduced political power to mobilise and manage resources, and to coordinate the activities of all other public agencies. Their national plans of science and technology were not a central and integrated component of a broader national strategy of economic development. Moreover, trade liberalization and foreign direct investment (FDI) attraction were not accompanied by active STI policies to strengthen local capabilities (Padilla-Perez and Martinez-Piva, 2009).

So, in developing countries, policies have traditionally relied on market based development strategies aiming at creating static efficiencies instead of dynamic capabilities. In the very few cases where there has been an innovation policy, it has frequently followed the linear model (research and development, R&D, subsidies and not innovation system based policies) (Chaminade et al., 2009). The existing literature has paid lip service to the analysis of the adoption of the IS approach for science, technology and innovation polices in developing countries and to the specific barriers of its implementation. This chapter aims at fulfilling this gap. Although more theoretical in nature, the book chapter brings examples of STI policy design and implementation in Asian and Latin American countries to illustrate the arguments deployed in the paper.[1].

This chapter is structured as follows. First we conceptualize STI policies as policies targeting the innovation system. In section 3, we introduce the main differences of innovation systems in developing countries, and barriers for designing and implementing STI policies are examined. Section 4 is devoted to the issue of vertical and horizontal alignment in STI policies in developing countries. In particular, we discuss the problems of alignment of STI policies with the national economic development agenda, the alignment of innovation system policy with ST policies, the alignment of objectives and instruments with systemic problems as well as a proposed method for the identification of systemic problems in systems of innovation in developing countries.

2. Conceptual framework: STI policies as innovation system policies

Since the emergence of the system of innovation concept in the 1980s and 1990's (Freeman, 1987; Lundvall,1992; Nelson, 1993, and Edquist, 1997), it has

[1] This book chapter is based on recent works by the authors which discuss the importance of innovation system policies for developing countries Chaminade et al., (2009) and the barriers that

attracted rapidly the interest of policy makers and international policy think-tanks such as the Organisation for Economic Cooperation and Development (OECD) and the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), and gradually has been adopted as the focus of STI policies in both developed and developing countries. However, their effective implementation has been limited and only a handful of countries has been able to upgrade their innovation capabilities throughout time. One of the possible explanations for this, is the difficulties of aligning STI objectives, policies and instruments with the context specific problems that countries face.

STI policies from a systemic perspective are defined here as actions by public organizations that influence the functioning of the innovation system and aim at solving problems in the systems of innovation (Borrás et al, 2009). And these problems are fundamentally different in a developing context as the composition and functioning of the system of innovation also differs from that of a developed country (Lundvall et al, 2006, 2009).

One could argue that science policies, technology policies and innovation policies target different elements of the system (Lundvall and Borrás, 2004). In this respect, they should not be seen as mutually exclusive but, on the contrary, as necessarily complementary. Lundvall and Borrás (2004) describe the ideal types of science, technology and innovation policy to illustrate the different focus of each of them. According to the authors, science policies aim at ensuring that there are sufficient resources for science. The main actors targeted are those conforming the "research subsystem", that is, universities, research institutions, technological institutes and R&D laboratories. The main instruments are usually financial incentives (in the form of direct subsidies, R&D grants, etc) to reduce the high costs of research. Technology policies, on the other hand, refer to policies that focus on specific technologies and sectors, which are considered strategic for the country. They target similar actors in the innovation system, but pay more attention to the links between university and industry and to applied more than to basic research. Finally, Lundvall and Borrás (2004) define innovation policies as a more holistic type of policy, which pays particular attention to the linkages in the system of innovation while putting more emphasis on the institutions and organizations than pure science and technology policies do. Innovation policies are often considered to focus on the outcome, that is on new products and services and, as such, they are criticized for an excessive focus in the firm as the main actor transforming ideas into new products and services.

While in theoretical terms is useful to identify the main features of science policies as compared with technology policies and innovation policies, in practice, the boundaries between the three are not so clear cut. They all target the system of innovation and, as such, they need to be combined in order to achieve the desired effects in terms of increasing technological capabilities and well-functioning innovation systems.

We understand innovation systems in a broad sense, that is as "an open, evolving and complex system that encompasses relationships within and between organizations, *institutions and socio-economic structures* which determine the rate and direction of innovation and *competence-building* emanating from processes of *science-based and experience-based learning*" (Lundvall et al, 2009, italics by the authors).

This definition has important consequences in terms of how we conceptualize STI policies in developing countries. First, this definition puts high emphasis on competence building, thus pointing out to the importance of building absorptive capacity, and on absorbing technology rather than only creating it. Second, as it embraces both processes of science-based and experience-based learning, from our perspective, innovation policies cannot be disentangled from science and technology policies, as they are both sides of the same coin. Third, there is an explicit focus on institutions and socio-economic structures. The extensive literature on systems of innovation has largely emphasized the role of institutions in shaping capability building and interactive learning. Formal and informal institutions such as rules, norms, routines, or informal social patterns of behaviour shape the interactions of the different organizations in the system of innovation (Nooteboom, 2000; North, 1990). And those institutions are highly context-specific. Socio-economic structures are highly path-dependent and country-specific.

However, with meagre exceptions (Lundvall et al, 2009; Chaminade et al, 2012) the literature on STI policies under the system of innovation perspective is rather abstract and does not address the context specific character of interactive learning in systems of innovation (Metcalfe, 1995). Furthermore, it has generally neglected the socio-economic and political context in which the system of innovation is embedded. This has had negative consequences in terms of the implementation of the innovation system approach in the design of STI policies in developing countries.

3. Designing and implementing STI policies in developing countries

3.1. Barriers for the implementation of STI policies in developing countries[2]

There is an increasing recognition among policy makers in developing countries of the crucial role of science, technology and innovation for inclusive and sustainable economic growth. Yet developing countries commonly face significant barriers to design and implement STI policies. Empirical studies highlight the following barriers (Padilla-Pérez and Gaudin, 2014; Chaminade et al., 2012, and Nurse, 2007, among others):

First, the increasing recognition of STI as a central driver of economic growth has been rarely accompanied by a significant increase of financial resources. Public financial support for STI activities is scant and even nonexistent in some developing countries. Therefore, governments in those countries usually have a limited budget to implement national plans of STI (Lall and Pietrobelli, 2005; World Bank, 2010). In addition, public bodies in charge of STI policies (national councils, secretariats, vice-ministries and ministries) do not have enough leverage to push their own agendas across all ministries. Usually, national STI plans are not fully implemented due to deficient funds when executing programmes and policies. Exiguous finance normally goes hand in hand with slender staffs. Actually, lean finance just mirrors a major political obstacle: STI policies have not yet attained the status of pillars of economic and social policies. Low public sector revenues are a significant barrier to increase public investment in STI, since governments in developing countries face overwhelming demands to tackle basic needs such as health care, shelter, education and security.

Second, both long-term planning and continuous implementation of STI policies are absent (Wamae, 2006; Nurse, 2007; Altenburg, 2009; World Bank, 2010). The implementation of these policies suffers frequent institutional changes, sometimes to strengthen them in the political agenda, other times to undermine them. Their place

[2] This subsection is based on Padilla-Pérez and Gaudin (2014).

within the economic agenda commonly depends on the priorities and strategies followed by each government. National councils or vice-ministries of science and technology often fall under different ministries, such as economy, industry and trade, or education. Likewise, STI programmes and policies do not always survive the entrance of new governments. Their place in the economic agenda frequently depends on the priorities and strategies being followed by each government. Tangible results of STI activities usually take a longer time than political periods do. Therefore, it is likely that incoming governments that execute STI policies will hardly see concrete outcomes by the end of their administrations.

Third, there are neither financial resources nor the institutional culture to monitor and evaluate programmes and policies (Hadjimanolis and Dickson, 2001; Lall and Pietrobelli, 2005; Aubert, 2010; World Bank, 2010). Such deficiencies appear as barriers to strengthening the impact of STI-policies. Public programmes are underfunded and do not allot resources to conduct evaluations. Sometimes STI indicators are not collected periodically and systematically, a flaw which hinders policy evaluation exercises.

Fourth, governments must deal with a reduced commitment from all the components of the national innovation system with STI activities. R&D investment by the private sector is scant and in general private enterprises do not demand more active public support in this area (Lall and Pietrobelli, 2005; Altenburg, 2009). Universities are mainly focused on teaching or carrying out basic-science research, but are linked weakly to private enterprises (Brundenius et al, 2009).

Fifth, although the degree of institutional development varies among developing countries, most of them have built a basic set of institutions such as public bodies to promote STI activities and to protect intellectual property rights and promote competition, as well as national plans for science, technology and innovation. However, public funds and the commitment to implement plans and enforce intellectual property rights and competition usually are reduced (Aubert, 2010; Chen and Puttitanun, 2005; Nurse, 2007; Altenburg, 2009).

Sixth, co-ordination among public organisations in designing and implementing STI policies is weak (Hadjimanolis and Dickson, 2001; Aubert, 2010; Lall and Pietrobelli, 2005; Nurse, 2007). Sometimes they even compete among themselves for access to public funds. Ministries and other public agencies tend to elaborate their own strategies, which frequently are not fully integrated and coordinated. This is a barrier to improving the impact of STI policies and fostering an efficient use of scant public resources.

Seventh, the education system at all levels does not generate enough human resources in terms of both quality and quantity (Aubert, 2010; Segarra-Blasco et al., 2008; World Bank, 2010). STI activities demand highly-qualified human resources, particularly in engineering and hard sciences. Universities are oriented to social sciences and administrative programmes, and offer few postgraduate programmes. Primary and secondary education does not obey a clear-cut strategy to strengthen the role of maths and basic science. Creativity and innovation are barely included in taught programmes.

Eighth, financial systems in developing countries are not akin to support innovation. New entrepreneurs and existing firms hardly find access to the formal financial sector to finance innovation activities (Segarra-Blasco et al., 2008; Gorodnichenko and Schnitzer, 2011). And a vicious circle takes place: on the one hand, the risk-averse financial sector avoids offering long-term credit for risky innovation projects due to scant incentives to finance a little or non-profitable segment (in comparison with more profitable segments such as mortgages and consumption). On the other, credit demand in this area is minimal because those firms engaged in innovation activities are few. Small and medium-sized enterprises also find it arduous to offer financial guarantees that would give them access to long-term credit otherwise.

Ninth, policy makers must implement STI policies in a socio-economic environment frequently characterized by poverty, health issues, severe income disparities and insecurity. Limited access to health services, education and housing undermines the impact of STI policies. In addition, income and wealth inequality have a negative impact on trust between individuals and organisations, which is a key factor to fostering interactions.

3.2. STI policies in developing countries- a stage based approach

In the context previously outlined, it is clear that STI policies need to be very selective. A critical challenge is to decide where to invest the limited resources so as to have the larger impact, giving the socio-economic and political context of a particular developing country. From a theoretical perspective, policy makers should intervene in the system of innovation when there is a problem or a "failure of the system" (Woolthuis et al, 2005; Chaminade and Edquist, 2006, 2010).

The difficulty is that in developing countries, more often than not, innovation systems are plagued with systemic failures or problems. Despite the high degree of heterogeneity in developing countries, one could argue that their innovation systems often share some common traits (Lundvall et al, 2009; Intarakumnerd and Chaminade, 2007): they tend to be characterized by a low degree of institutional thickness (institutional problems) and thus weak interactive learning (Amin and Thrift, 1995; D'costa, 2006) (network problems). Local knowledge resources are very limited (capability problems) which often forces indigenous firms to rely much more on Trans National Corporations (TNCs), and other foreign sources, as providers of knowledge and capital (Pietrobelli and Rabellotti, 2006, 2009; Marin and Arza, 2009; Padilla et al, 2009, and Barnard et al., 2009). Good educational and research institutions are often scarce, their administrative capacity limited, their competences usually meagre and with very limited research capacity (capability and learning problems). Finally, a large number of countries do not even have the basic infrastructure in place to enable communication, knowledge sharing, research and innovation (electricity, internet, roads) (infrastructure problems). Ince each innovation system is unique, not all problems are present in all innovation systems and even when they are, they tend to differ in their nature or intensity.

Hence, as we have argued elsewhere, Innovation Systems (ISs) in developing countries are better conceptualized in an evolutionary perspective (Chaminade and Vang, 2008a; Chaminade et al, 2009). They should be understood as emerging innovation systems where some of its building blocks are in place but where the interactions among its elements are still in formation and thus appear fragmented. Furthermore, adopting an evolutionary perspective could allow policy makers to better identify which are the priorities in the system of innovation at a given moment in time.

Coming back to our previous discussions on rationales, the question is not whether the elements and relationships within the system are weak but what elements are critical for the emergence and development of an innovation system into a fully-fledged innovation system. In what follows, we discuss the main problems of the system of innovation in different stages of development of the system, from emerging systems of innovation to fully fledged systems. It is important to highlight that these are **ideal types** which try to describe the common features of a group of developing countries but each country has its own characteristics and idiosyncrasies and, as a consequence, STI policies need to be necessarily country specific and based on the detail analysis of their innovation systems. Furthemore, any scheme of this sort can be misleading if it is interpreted in a linear way, as a sequencial model with one unique ideal development path. Far from that, adopting an evolutionary perspective implies that each innovation system is unique and there is not one single ideal type of innovation systems that all countries need to strive for nor one single path of development.

Following the World Bank (2010) we distinguish between three main ideal types of innovation systems in developing countries, attending at the general level of technological capabilities:

- Emergent innovation system, characterised by low levels of technological capabilities
- Fragmented innovation system or dual innovation system, characterized by medium levels of technological capabilities and some pockets of innovation.
- Mature innovation systems, portraying high levels of technological capabilities and competitiveness at international level.

Table 1. Contextualizing STI policies to developing countries according to the level of technological capabilities.

	Low technological capabilities	**Medium Technological Capabilities**	**High technological capabilities**
Main objective or function of the innovation system	Technology adoption Emergent or nascent innovation system	Technology adaptation and technology creation Fragmented innovation system; dual innovation system	Technology creation Mature innovation system
Examples of countries	Subsaharan Africa Tanzania, Mauritania Honduras, Nicaragua	Large Latin American countries (Argentina, Mexico, Brazil), post-soviet countries, South	Asian Tigers

		Africa	
Most common characteristics in the system of innovation	Large informal sector. Majority of small firms with low or no technological capabilities; Poor business and governance environment; Limited access to basic infrastructure like electricity, internet, finance Lack of skilled workers	Pockets of dynamism with large proportion of the population in poverty and other forms of exclusion Critical mass of qualified engineers and technical staff. Inter-organizational links are weak. Born-globals are fairly common as a compensation mechanism	Critical mass of S&T and managerial capabilities Good business climate
Strategic STI policies	Focus on capability building Focus on taping and adapting global knowledge to local needs Microfinance, distant learning, export zones. Micro-level reforms (small scale programs or projects or partial reforms of financial system, export regulation) Cross-border innovation systems (small bordering countries)	Focus on links - Cluster and value chain policies since there are some technical capabilities. Coordination of policies – framework programs and coordination of policy actors	Focus on emergence of new technological fields with international competitors
Key actors	Diaspora members, which are acquainted with the local conditions but not dependent on national interests (e.g. Ghana, Chile, Taiwan).	R&D performed by public sector Isolated pockets of dynamism (certain TNCs, certain regions, a few sectors)	Business sector leads R&D financing and execution
Capability problems	Attracting foreign technology and expertise BUT building simultaneously absorptive capacity in the country. Need to focus on engineering and design capabilities. Vocational training is also paramount.	Need to focus on soft skills (leadership, management, problem solving) Need to strengthen the role of private sector in STI activities	Need to focus on new technological fields and research capabilities
Linkages problems	Links to MNEs are usually very important. Local cluster initiatives (e.g. cooperatives). Intermediate organizations such as NGOs or measuring and testing centers can play a crucial role in translating the knowledge of MNEs to the local actors.	Links to local customers are usually very important in large countries. Promotion of clusters and value chains are paramount (e.g. Bangalore upgrading). Building bridged between pockets of dynamism and rest of the system. University-industry training and research linkages are also important.	S&T links as well as links to technology sophisticated users are important
Institutional problems	Creating an adequate business environment: Social inclusion, transparency, corruption,	Regional cohesion, Reliable IPR regimes	

Source: authors based on World Bank (2010) and Chaminade et al (2009)

3.2.1 Emergent innovation systems

Emergent innovation systems are systems of innovation in early stages of formation, where some of the components are present (universities, firms, intermediate organizations) but they often suffer from low technological capabilities, weak linkages with other organizations within the system and a socio-economic environment characterized by a high degree of informality, limited access to basic infrastructures, poor business climate, uncertain institutional framework and very limited endowment of qualified human capital. Countries with emerging or nascent innovation systems are highly dependent on technology developed abroad.

A **critical objective** for STI policies for emerging innovation systems is to facilitate the adoption of technology developed abroad and the development of research and technological capabilities. Both critical capabilities and linkages needed at this stage of development are highly related to adopting technology and building competences.

Critical capabilities, at this stage of development, design and engineering capabilities are more likely needed to adopt the foreign technology to the local requirements. In this sense, universities play a fundamental role in the provision of qualified human capital, which is often scarce. But vocational training is also of paramount importance, since it is likely to improve the absorptive capacity of small and medium size enterprises. Often developing countries in these stages of development are highly dependent on agriculture and other natural resources. Upgrading the capabilities of farmers is likely to facilitate the introduction of new technologies or process improvements in this very important sector of the economy (Lundvall et al, 2009).

Critical linkages in nascent innovation systems are those that facilitate the dissemination of existing technologies to the indigenous firms. One of those critical linkages is that with TNCs. However, firms in emergent or nascent innovation systems are often specialized in lower value-adding activities, which implies in most cases hierarchical or quasi-hierarchical relationships with the TNCs (Schmitz, 2006, Pietrobelli and Rabellotti, 2009) and lower levels of spillovers. Again, building local capabilities is a prior condition for building linkages with multinational companies conducive to interactive learning and capability upgrading (Pietrobelli and Rabellotti, 2009). Linkages with TNCs are not the only critical linkage. Facilitating linkages between universities and local firms can also lead to capability upgrading. In emergent or nascent innovation systems, intermediate organizations such as technological centers, testing and measuring facilities or non-governmental organizations can help translating the advance knowledge of the TNC to the local economy. Box 1 illustrates the role played by an non-governmental organization (NGO) facilitating the transfer of technological knowledge from the university to a group of small firms in the informal economy in Tanzania. Similar examples of intermediate organizations –like NGOs or technology and testing facilities fostering capability building and technology transfer to firms (mostly informal economy) in El Salvador and Tanzania can be found in Szogs (2010) and Chaminade et al. (2011). By the same token, chapter ? of this book, by Eduardo Robles Belmont and Dominique Vinck, shows the importance of an NGO in the development of micro and nanotechnologies in Mexico.

Box 1. Facilitating the creation of university-industry linkages in emerging innovation systems. The role of bridging organizations in Tanzania.

Tanzania is classified as a least developed country. The national economy is primarily based on the agricultural sector. The Tanzanian agriculture constitutes subsistence farming with mainly smallholders cultivating up to 85% of the arable land. The national innovation system, is characterized by its fragmented structure and only sporadic links among the different organizations (Mwamila and Diyamett, 2006). In general, even the more advanced firms do not have their own R&D departments, and only weak linkages with government R&D organizations and universities (Diyamett, 2005; Wangwe et al 2003). Indigenous small and medium-sized enterprises (SMEs) are struggling with a lack of awareness regarding relevant sources for new and appropriate technology and with limited internal capacities to implement innovations (Mahemba, C.M.M. and De Bruijn, E.J. 2003). Intermediate organizations play here an extremely crucial task in linking relevant actors in the national innovation system to each other, and with international sources of knowledge and resources, as well as, facilitating learning processes that could lead to greater innovation. In this context, the University of Dar Es Salaam (UDES) is one of the most important sources of technical knowledge in the country. However, its linkages with the local industry are extremely weak (Szogs, 2008).

This case illustrates the role of an NGO -Tanzania Gastby Club- (TGT) linking the College of Engineering and Technology (CoET) at UDES with small and medium size companies in the informal economy with the objective of transferring technology and upgrading technological capabilities. The specific objectives of the CoET - TGT collaboration were "i) to further expose the engineering students to the issues and problems that SMEs were facing; ii) to provide assistance to a selected group of undergraduate students who were encouraged to develop their final year projects in issues relevant to the identified SMEs; iii) to facilitate the development of business plans for specific SMEs using expertise available at the University; and iv) to carry out research and development of new prototypes for SMEs' (TGT & CoET, 2006).

To attain these objectives, a number of strategies were proposed: a survey of the nature and scope of operations, employment characteristics and income generation of targeted SME sectors; assignments of students to specific SMEs or associations of SMEs in the course of their studies; development of practical and innovative prototype projects which will be further developed in collaboration either with an individual SME or a cluster of SMEs working in the same sector; linking CoET staff to specific SMEs or clusters of SMEs, in order to assist in the development of their business plans and the identification of specific bottlenecks in the development of a sub sector, which can be addressed through targeted Research and Development (R&D)" (TGT & CoET, 2006).

The collaboration contributed to the upgrading of skills, the creation of networks as well as to the development of product and process innovation. Of the different projects, two deserve special attention due to their achievements: the clarification of juice/wine using Pectrinace Enzymes which was adopted by M/s Solar Innovations and another project on the quality of Soymilk as influenced by the Blanching conditions, which was adopted by two companies –Abantu Food Products and M/s Soja Halisi Foods. This student project allowed the firms to reduce of the loss of flour from a milling machine from 20% to only 2%, improving qualities of wine, soya food, solar dried fruits, developing specialized technologies and machinery for some entrepreneurs, etc. Students' consultancy to the specific agricultural units in the country was a contribution into the creation of a link between the research and its application

Source: Chaminade et al (2011)

Governments in developing countries, but particularly in emergent innovation systems suffer from acute financial problems. **Effective policies** could consist in micro-level reforms such as small scale programs or projects involving some key actors in the system of innovation (see the example of university-industry linkages in Tanzania), micro-credits, partial reforms of the financial system or other aspects of the business environment, etc. (World Bank, 2010). The key aspect here is starting with small-scale projects and prioritize capability building through education, on-the-job training, and vocational training and university training of engineers. Without a certain level of capabilities, all other STI focused policies are likely have very limited results (see more examples in the section on horizontal policy coordination). In this respect, international organizations such as the UNCTAD or World Bank, base their STI policy reviews in the identification of one or two critical industries which have a certain potential to leverage technological capabilities like health, agriculture and agroindustry in the Dominican Republic (UNCTAD, 2012), agroprocessing in El Salvador (UNCTAD, 2011a), traditional herbal and medicine sector in Ghana (UNCTAD, 2011b) or oil and mining in Mauritania (UNCTAD, 2010).

As some successful examples show (World Bank, 2010), diaspora members can play a fundamental role in introducing small changes that may turn into role models in the economy. Diaspora members are well acquainted with the local conditions while they are not subject to national interests. They are, in that sense, in a privileged position to start new activities, bridging the local context and the international arena. Examples are the creation of the Ashesi university in Ghana or the initial stages in the development of the software cluster in Bangalore, India (Saxenian, 2006; Kapur, 2002)

3.2.2 Fragmented or dual innovation system

A large proportion of developing countries, usually the large ones have fragmented and dual innovation systems characterized by two speeds, with some clusters or industries that are highly innovative and capable of technology creation side by side with under-developed clusters, regions and industries with very low technological capabilities and capable, at most, at technology adaptation. We call this fragmented or dual innovation systems. Argentina, Mexico, Brazil, India or China and some post-soviet countries are some of the examples of fragmented or dual innovation systems.

Fragmented innovation systems often portray a critical mass of qualified engineers, scientists and technical staff. They host some world-class universities, ranked high by international standards. They are capable of attracting technology-related FDI to particular sectors or regions. Some of the indigenous firms are born-globals firms that have evolved into large emerging multinationals or large business groups (Gammeltoft, 2008; Santiso, 2008). Often, the internationalization strategy is a compensation mechanism for the lack of a supportive and well-functioning innovation system, with strong organizations and institutions (Stal and Cuervo Cazurra, 2011). These emerging multinationals may play a role as gatekeepers transferring technology from abroad to the local context (Barnard, 2006, 2010,2011). These innovation hubs tend to be highly concentrated in certain regions and clusters (Crescenzi et al., 2012). Very well known examples the software cluster in Bangalore in India (Basant and Chandra, 2007; Chaminade and Vang, 2008a; Parthasarathy and Aoyama, 2006; Saxenian, 2001), the salmon cluster in Chile (UNCTAD, 2006), the auto cluster and software clusters in Brazil (Arora and Gambardella, 2005), electronics in Mexico (see Box 2) or the telecommunications in China (Altenburg et al., 2008) which are considered knowledge hubs in global value chains, attracting R&D related investments. Emerging multinationals are also playing an increasingly important role in new emerging technological fields like regenerative medicine (Mcmahon and Thorsteinsdóttir, 2013) or clean-tech (Binz et al., 2013), to name a few. In this case, the lack of very strong institutional frameworks has turned an advantage, providing a more flexible context for the emergence of new technological fields.

Box 2. The role of public policies to develop technological capabilities. The case of the electronics industry in two states of Mexico.

Mexico is one of the largest exporters of electronic goods and components in the world. Large transnational enterprises such as Sony, Samsung, HP, Flextronics and Sanmina have set up plants in Mexico to manufacture and assemble intermediate and final goods and export them to a wide array of countries.

An empirical study conducted by one of the authors in two states of Mexico, Jalisco and Baja California, showed that the former had developed stronger local technological capabilities in terms of firm-level product and process innovation, supply of highly-qualified and specialised human resources and research centres focused on the electronics industry, among other factors.

The local government in Jalisco has played a key role in the development of regional technological capabilities. Some examples of local STI policies are:

- Dissemination of technology. Universities, research centres and private organisations that were interested in organising fairs, exhibitions, seminars, publications, etc. obtained support and funding from the local council for science and technology.
- Supporting human resources formation. The local government funded university and technical education, and has a public office dedicated to coordinating higher education in the state.
- Funding research and development activities. The local council for science and technology administered bids for public funds (local and federal resources) to carry out R&D.
- Supporting high-tech start-ups. The local government provided assistance to local start-ups that designed electronic components and embedded software.
- Promotion of university–industry links. The local council for science and technology launched a programme to promote university–industry links in Jalisco. The first step was to develop a manual that included an assessment of current needs, best practice and specific activities to strengthen interactions. The second step was to promote interactions through funding and assistance. Most of the activities involved technical assistance provided by universities to firms.

In contrast, weak and poorly coordinated STI policies in Baja California are a central factor to explain less advanced technological capabilities in this state.

Source: Padilla-Pérez (2006).

These pockets of innovation are embedded in otherwise innovation systems in formation, which share many of the characteristics of nascent innovation systems: large degree of informality, social and economic inequalities and high levels of corruption, a large share of firms with low technological capabilities, linkages with universities are ill developed, etc. (Brundenius et al., 2009). This makes STI policies very challenging, since general policies targeting capability building or the attraction of technology related FDI need to be combined with policies targeted to the specific needs of the most advanced sectors and regions. Policy makers in these countries often suffer from policy fatigue (World Bank, 2010). Both technology adaptation and technology creation are the **objective of STI policies** in fragmented innovation systems. Coordination of policies is paramount in all innovation systems, but particularly in these fragmented or dual innovation systems.

Effective STI policies in these systems may be cluster and value chain policies, since there is a certain level of technological and scientific capabilities. One of the **capability problems** that these innovation systems face is limited soft skills (leadership, management, problem solving) to complement the already existing technical skills. In terms of **linkages,** one of the most important challenge for STI policies is to establish linkages between the pockets of dynamism and the rest of the system. Relevant linkages are university-industry training and research linkages, clusters and value chains and linkages with international and local users. In fact, user-producer interaction with local users has proved to be a very effective source of innovations[3] (Prahalad, 2005). Furthermore, south-south cooperation between users and producers is more likely to lead to new to the industry innovation than north-north (Harirchi and Chaminade, Forthcoming), probably due to the similar level of technological capabilities of both users and producers which facilitates interactive learning.

[3] Well known examples are the low cost electro cardiogram developed by General electric initially to cater the rural population in India (Immelt et al., 2009), the nano-car developed by Tata (Ray & Ray, 2011) or the nano-computer.

3.3.3 Mature innovation systems[4]

Emerging and fragmented innovation system may gradually evolve into mature innovation systems. Mature innovation systems are usually found in developed countries or embedded in otherwise fragmented innovation systems, as discussed before. Former developing countries that have well-functioning innovation systems are the Asian tigers: Hong-Kong, Singapore, South–Korea and Taiwan. Strictly speaking, these countries can no longer be considered as developing countries but they were developing countries not so long ago and thus, their experience in upgrading capabilities and developing their innovation systems into fully-fledged innovation systems is very valuable here.

Mature innovation systems are usually characterised by macro-economic and institutional stability. Formal and informal institutions are well developed (rules, regulations, policies) which provide favourable framework conditions for innovation. In general, both science and technology capabilities as well as more on-the job competences are well developed. In comparison with the other two ideal types of system, the key actors are business companies and research is not only driven by public organizations and funding. The main challenge for these systems of innovation is renewal, finding new growth paths and sustaining their technological competitiveness over time. In mature innovation systems organizations interactions are intense and take diverse forms, from sourcing of technology through market mechanisms to research collaboration through formal and informal networks. While in emerging and fragmented innovation systems the international linkages are predominant in innovation, in mature systems we can observe a more intense use of regional and national linkages which simply reflects the higher level of technological competences of the organizations in the country and region (Chaminade and Plechero, 2014)

Box 3. The example of Asian tigers – variety of leverages in the transition from emergent to mature innovation systems

The four Asian tigers are a very good example of the variety of paths that can be used to upgrade technological capabilities and move from an emergent innovation system to a mature innovation system. What these four countries have in common is

[4] It is important to note that mature does not mean that there are no systemic problems that require policy attention, but the nature of the problem is different.

their small size and fast growth rates, but each of them has focused on a different driver to leverage the innovation system performance.

The Taiwan case illustrates how the government can play a leading role in the performance of an innovation system dominated by small and medium size enterprises (Balaguer et al., 2008), while Korea offers a good example of a large-firm-driven national innovation systems (NIS) (Lim, 2008). Singapore is a good paradigm of the role played by foreign direct investment and multinationals in the development of the NIS (Wong and Singh, 2008). The government applied selective incentives to nurture particular industries and activities that were considered to be of high added value. Finally, Hong-Kong points out the importance of linkages with larger markets, such as China and is a good illustration of a NIS specialized in the coordination of production networks (Sharif and Baark, 2008).

Taiwan STI policies aimed at developing specialization in areas were complementarity with China existed through attracting international leading multinationals to set their R&D centers in Taiwan as well as diaspora members. Special attention was paid to strengthening the linkages between SMEs and the university, in all sectors (Balaguer et al, 2008). An interesting case is the linkages established in the flower cluster which included the development of new species of orchid for the international market through the cooperation of farmers, market cooperatives, researchers and the government (Chaminade and Vang, 2008b).

In Korea there was traditionally a clear separation between STI policies and economic and industrial policies. As a consequence, policies for competence building, stimulation of R&D activities, financial system, labor relationships etc, were not coordinated and the impact in the development of the system of innovation was limited. This changed in 2004 when the government established as a strategic priority to shift to a knowledge base economy. STI policies became a national priority. The Korean innovation system is, in a sense, still a fragmented innovation system where the very competitive large firms (chaebols) coexist with a population of small firms with low technological capabilities and weak linkages with the rest of the innovation system (Lim, 2008).

Singapore success partly lays on a successful coordination of STI policies with the wider industrial, trade and competition policy and a high reliance on foreign direct investment. To facilitate the absorption of technology by the local industry, the government initially put special emphasis to the development of operational and adaptive capabilities, rather than R&D which allowed the local firms to gradually upgrade their technological capabilities. Due to the small size of their market, linkages with international customers are crucial for the development of innovations.

Hong-Kong introduced STI policies much later than the other Asian tigers. They respond more to a model of technology policy rather than systemic innovation policy. The government chose nine focus areas, among those logistics, textiles, consumer electronics, automotive parts, Chinese medicine and integrated circuit design with a double strategy of creating new technology and facilitating the access of mainland China to global production networks (Wong and Singh, 2008).

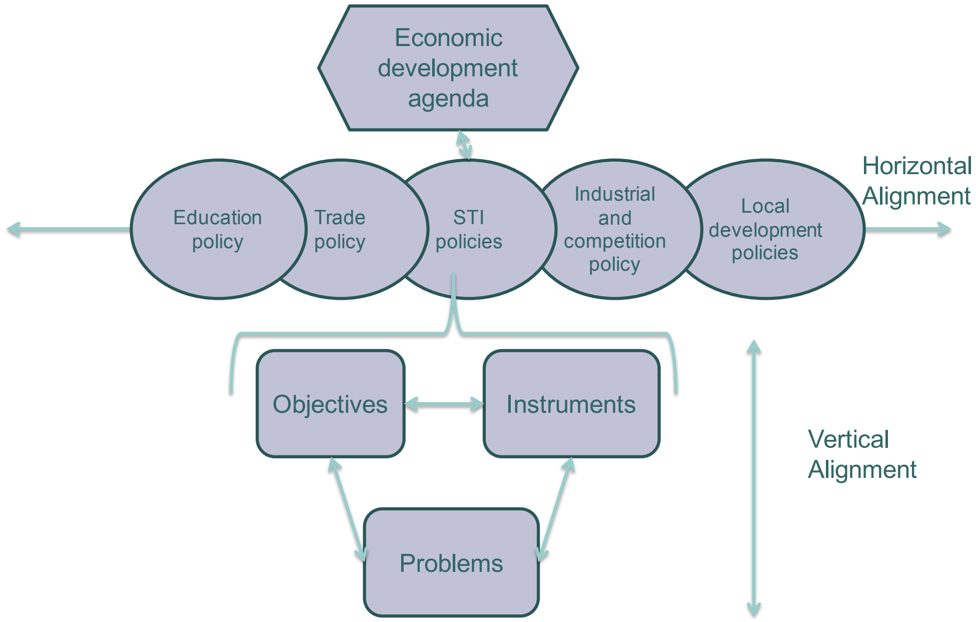
Source: Edquist and Hommen (2008).

It is important to highlight that these are only general types of innovation systems. Each system of innovation has particular characteristics and, as a consequence, **STI policies need to be based on a specific analysis of the innovation system** and need to be the result of experimentation with different instruments and approaches. What works in a specific country may completely fail in another. STI policies should be designed and implement ad-hoc, taking into account the specificities of the country.

It is easy to deduct from the previous discussion that innovation policies in developing countries need to be based on a throughout analysis of the specific problems in the system, need to contribute to the economic development agenda and need to be coordinated with other policies in place. This, as we will discuss later, is far from a reality in most of the developing countries that we have worked with.

4. The challenge of designing STI policies for innovation systems in developing countries: an issue of alignment

Designing and implementing STI policies for innovation systems in developing countries is fundamentally an issue of alignment. On the one hand, because policy objectives and instruments need to be tailored to the specific characteristics and needs of the particular innovation system, including the socio-economic and political environment in which the system is embedded. We call this vertical alignment. On the other hand, because different policies need to be coordinated to achieve the desired objectives in terms of capability building and innovation. We call this horizontal alignment. Figure 1 depicts both forms of alignment.



4.1 Vertical alignment- fine-tuning policies to specific problems of the system[5]

The first form of alignment is that between objectives, instruments and specific problems of the system. Following a systems of innovation (SI) approach implies the adoption of new rationales that might collide with former rationales. The result is often that policy makers might adopt the system of innovation approach in their discourse while still using "market failure" arguments for allocating resources for innovation (Chaminade and Edquist, 2010; Intarakumnerd and Chaminade, 2007). As a result, the most widespread instruments for STI policy are those aiming at reducing the cost of R&D to encourage the exploitation of technological opportunities maintaining the same level of capabilities (Metcalfe and Georghiou, 1997). Designing STI policies targeting the innovation system require adopting a systemic perspective, tackling the system as a whole and not specific components and paying special attention to competence building and the linkages that facilitate interactive learning, both science technology and innovation (STI) and DUI (Doing, Using, Interacting) forms of interactive learning (Jensen et al, 2007). The STI mode of learning is strongly linked to research, experimentation and codification knowledge. The DUI mode of learning, in contrast, emphasizes on-the job learning, learning by doing and by interacting with other actors, particularly users. Both are paramount for innovation (Jensen et al, 2007).

[5] This section is substantially based on Chaminade el al (2012).

The literature review on systemic problems suggests that there are mainly five systemic problems: infrastructure problems, capability problems, network problems, institutional problems, and transition and lock-in problems (Woolthuis et al., 2005). However, this same literature is rather theoretical and abstract, not providing any guidelines on how these systemic problems can be identified.

A first attempt in the direction of empirically identifying systemic problems was recently made by one of the authors in collaboration with researchers in Thailand (Chaminade et al., 2012). The point of departure was firm-based data collected through the Thai innovation survey. The Thai innovation survey follows the definitions and methodologies used by OECD (OECD, 1997, 2002). In that respect, the survey is similar to other innovation surveys in Asia (i.e., Singapore, Malaysia, Japan, Taiwan and Korea) and Latin America (Brazil, Mexico, Argentina, among others). But it also has some distinctive questions on the quality of the business environment which helps in the identification of some institutional problems.

Due to the cross-sectional nature of the data, it is not possible to identify if there are transition or lock-in problems. The analysis, which is described in detail in Chaminade et al. (2012)[6], allowed to identify four problems in the innovation systems related to institutions, S&T infrastructure, networks and a forth one which was not considered in the existing literature on systemic problems which was labelled "support services". Capabilities didn't emerge as a critical problem in the Thai innovation system.

Once that the specific problems have been identified, it is possible to design STI policies that targeted those specific problems. An analysis of the STI policies in Thailand revealed a lack of alignment between policies and problems. Most of the problems identified in the system of innovation were at most partially tackled with the existing policy portfolio of instruments. At the same time, a number of policies were aimed at augmenting the S&T capabilities, when that was not considered a problem anymore in the innovation system by the surveyed firms. Box 4 illustrates the problems of vertical alignment for the Thai case.

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[6] Using hierarchical factor analysis on a selection of questions in the survey, systemic problems suggested by prior studies are grouped into four components: institution, network, science and technology infrastructure and other support services. These system components were then linked to a qualitativedescription of the real situation in Thailand in the discussion of whether there is a mismatch between Thai innovation policy instruments and the systemic problems captured.

Box 4. Vertical alignment of policies in Thailand

Like the four Asian Tigers (Korea, Taiwan, Singapore and Hong Kong) Thailand has gradually moved from an agriculture-based economic structure to one in which the industrial (manufacturing in particular) and service sectors have distinctive significance, while attempting to modify the export structure. However, unlike the Asian NIEs, Thailand has a low performance in terms of research and innovation.

One of the reasons for the relatively low innovative performance of Thailand – compared to the Asian NIEs – is the lack of adequate policies that target the specific weaknesses of its innovation system (Arnold et al., 2000; Bell, 2002; Intarakumnerd et al., 2002; Intarakumnerd, 2005). For decades, the emphasis was on developing S&T capabilities in the public sector, ignoring almost completely the firms.

This narrow scope of S&T was very much based on the linear model of innovation that put research at the core of the innovation process. Private firms were almost absent from the policy (Bell, 2002) and regarded at most as “users” of S&T knowledge mainly produced by government agencies and universities (Arnold, *et. al*. 2000).

In 2001, there was a major shift in the orientation of STI policy. The ten-year Science and Technology Strategic Plan for 2004 to 2013 placed the concepts of a national innovation system and industrial clusters at its heart (NSTDA, 2004).

Nonetheless, as Intarakumnerd and Chaminade (2007) point out, the innovation policy instruments that were actually put in place reflected more the old STI policy paradigm, since they placed considerable emphasis on research-based activities and much less on innovation in a broader sense, involving capability building and DUI as well as STI forms of interactive learning. The main difference between the new plan and the pre-Thaskin plans is that the latter explicitly targets firms.

The empirical analysis of the innovation survey data (Chaminade et al, 2012) revealed that for non-research based firms, the main systemic problems relate to the institutional conditions for innovation (including capabilities, hard and soft institutions, networking and support services). However, the current instruments are barely tackling the identified problems.

Source: (Chaminade et al., 2012; Intarakumnerd, 2007)

Vertical alignment implies tailoring STI policies to specific needs and characteristics of the innovation system. This implies taking into consideration the stage of development of the system, as discussed in section 3, but also start from the specific analysis of the problems in the system of innovation. For that, developing countries need to develop a proper system of STI indicators that capture the systemic aspects. While some countries have made an effort in that direction and have (more or less) regular R&D and innovation surveys, others lack even the most basic information like R&D investments or number of researchers (UNCTAD, 2010)[7].

Designing effective STI policies when there is a lack of information of the system is problematic and more efforts should be made in the design of innovation surveys that capture the complexity of innovation in developing countries and that, for example, collects information on innovation in agriculture or innovation in the informal sector.

4.2 Horizontal alignment

This section aims at discussing the challenges faced by developing countries when coordinating STI policies among different ministries and other public organisations, and among diverse government levels. It also discusses the need to coordinate STI with national development agendas.

First, although there is an increasing recognition among developing countries of the crucial role of STI for long-term economic and social development, quite often national development agendas do not include STI as a central pillar, that is STI is neither embraced by nor coordinated with other development areas. For instance, although all Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama) have elaborated national development plans which include STI policies, only in Costa Rica STI is a key component of the plan and specific strategic lines are comprised (Padilla-Pérez and Gaudin, 2014).

Adopting an innovation system approach to STI policies implies to bring together a variety of policies that have traditionally been separated (education policy, industrial policy, trade policy, etc.). In this sense, innovation policy can be seen as a policy system itself, integrating traditionally individual and independent policies into a new systemic policy with new rationales, new instruments and new governance bodies (Intarakumnerd, 2007). However, coordination among public organisations for designing and implementing STI policies in developing countries is frequently poor. There is even some competition among them for gaining access to public funds and international aid. National councils or ministries for STI, ministries of economy and

[7] It is important to bear in mind that innovation surveys are potentially a good source of information, but it is a limited one, since it only targets firms.

education, as well as ministries that conduct and coordinate STI in specific areas (energy, health, etc.), have their own agendas and budgets. New types of public organizations such as cross-sector and interdisciplinary councils on innovation (Borras and Lundvall, 2004) or new and stronger mandates for existing organisations are needed.

As a result of this poor coordination and integration, STI policies are frequently fragmented. Science and technology councils support mainly research on universities and public research centres and offer scholarships for postgraduate studies; ministries of education focus on technical and university-degree education, and ministries of economy provide technical assistance and financing for firm-level innovations. These policies are not coordinated and it is common to end up with diverse programmes pursuing similar objectives and targeting the same population. A detailed study of public policies to support SMEs in Latin America, including diverse programmes for strengthening their technological capabilities, found that there is poor coordination among national public agencies (for instance, Ministry of Economy, Competitiveness Councils or Institutes, Ministries or Councils for Science and Technology, etc.). This results on lack of synergies and inefficient use of public funds, hindering the impact of such programmes (Ferraro and Stumpo eds., 2010).

Second, large countries and countries with different government levels face the challenge to design mechanisms to either centralise or decentralise STI policies. On the one hand, centralising STI policies (federal o national government) may result in economies of scale and internalisation of positive externalities. On the other, centralised policies , that is policies designed and implemented by federal or national governments, may often reduce the ability to meet local needs, respect diverse regional (sub-national) preferences and adapt to local circumstances (Padilla-Pérez, 2013).

Developing countries, characterised by large income and technological-capability gaps among their sub-national regions, face an enormous challenge to foster capability building in technologically backward regions and reduce heterogeneity.

The case of Mexico illustrates this challenge. Mexico is a federation with three government levels: federal, state and municipal. State governments collect a limited amount of taxes and most of their revenues come from direct transfers from the federal government, including funds to support STI activities. Federal funds are matched by state financial resources (through a bidding scheme), therefore the states which possess higher capabilities and resources frequently receive more funding for STI activities. This process widens technology gaps between states (Stezano and Padilla-Pérez, 2013).

Third, the economic model and theoretical assumptions behind policy making shape significantly the scope and approach of STI policies. For instance, STI policies in Latin America have been characterised by a persistent linearity for the last six decades. During the import substitution phase (from the 1950s to the 1980s) a linear supply model of technology policy prevailed. The public sector played a major role in identifying priorities and direct conducting science and technology activities. Science and technology policies were mainly oriented to the creation of basic infrastructure and to the promotion of human capital formation, based on government priorities (Cimoli et al., 2005). Reduced attention was paid to innovation policies.

The theoretical background of the supply model derived from the assumption that knowledge was a public good, and that government and public agencies were natural knowledge providers. Knowledge was supposed to naturally flow and circulate among economic agents once it had been inserted in the economic system by public institutions (Cimoli et al., 2005).

In contrast, STI policies in the 1990s and 2000s were dominated by a linear demand model. It emphasized the role of markets incentives and of demand side in priority setting. The rationale for STI policies was based on correcting market failures. For instance, R&D subsidies did not discriminate among sectors or activities, and were aimed at addressing failures resulting from externalities and public goods. The assumption behind these policies was that knowledge and innovation were the same as information accessibility. The reliance in market mechanisms resulted in neutral and horizontal policies planned to minimize state interference with market behaviour (Cimoli et al., 2005).

This misalignment of objectives, assumptions and instruments is illustrated by the relationship (or lack of) between international trade and foreign direct investment, on the one hand, and technical change on the other, in Latin America in the past three decades.

One of the common policies pursued by some developing countries in the past three decades has been to open the economy to international trade, in order to facilitate the access to foreign technology and increase local competition. Following a neoclassical, demand-led approach, opening up an economy to international trade creates the demand conditions necessary, and in the most extreme forms of the theory also sufficient, to develop local technological capabilities (Balassa, 1991; World Bank, 1991; Krueger, 1993). This is based on the alleged positive effects that opening up to international trade has on technological capabilities through exports of goods, imports of intermediate and capital goods and foreign direct investment (FDI). The main assumption is that technology is a free and fully codified good that can be easily diffused and absorbed among countries. According to this approach, exports of goods give access to new and bigger markets, generating economic incentives for increasing innovative efforts. Additionally, foreign buyers are an important source of new technologies, and exposure to international markets keeps exporters informed of new products (Padilla-Pérez and Martínez-Piva, 2009).

In terms of imports, local firms, in order to compete successfully in the domestic and international markets, demand foreign capital goods and intermediate components, which are a source of technical change. Foreign direct investment has also important positive effects on local capabilities through technology spillovers, which are understood as the positive unintended effects from transnational enterprises (TNEs) to the host economy arising from forward and backward linkages, migration of trained workers, informal collaboration agreements, and dissemination of information on foreign markets (Grossman and Helpman, 1991; Blomström and Kokko, 1998).

However, these alleged effects are seldom achieved without active policies aiming at building absorptive capacity in firms, universities and other organizations of the system, as Box 5 illustrates for Latin American countries. Without investments in absorptive capacity, trade and investment policies aiming at introducing competition and facilitating foreign investment and the access to technologies developed abroad are likely to fail to leverage local technological capabilities (Padilla-Pérez and Martínez-Piva, 2009).

Box 5. Technological upgrading through trade liberalization. The Latin American example

Championed by the so-called Washington Consensus, Latin American countries, in general, implemented far-reaching economic reforms in the 1980s and 1990s. They conducted unilateral trade liberalization processes through international trade tariff reduction; signed bilateral and multilateral free trade agreements, including those under the World Trade Organization (WTO) (the Multilateral Agreements on Trade in Goods, GATT; the General Agreement on Trade in Services, GATS; the Agreement on Trade Related Aspects of Intellectual Property Rights, TRIPS, and the Agreement on Trade-Related Investment Measures, TRIM); lifted restrictions to FDI and simplified import barriers (permits and quotas).

After three decades of economic reforms the results have been satisfactory in terms of export growth, but quite modest in terms of technological capability building. As shown in table 2, Latin American countries performed well in the last two decades in terms of export growth and FDI attraction, but technological capabilities indicators (both output- and effort-oriented) have not improved.

In the 1980s, 1990s and 2000s STI policies, and industrial policies in general were characterized by a horizontal and passive approach. For instance, R&D tax incentives and public funding of research in universities and research centers were neither focused on specific sectors or technologies nor coordinated with other policies, such as development of endogenous capabilities through FDI attraction. More attention was given to generating a stable macroeconomic framework and simplifying regulations to establish and operate private enterprises.

Therefore, FDI and international trade were seen as substitutes and not as complements of indigenous efforts to develop technological capabilities. Given the weaknesses of domestic local capabilities, foreign sources of technology are crucial. However, demand-led policies did not consider that stronger local efforts must be carried out to develop local capabilities. Since technological learning is a cumulative, dynamic and costly process, foreign technologies cannot be successfully exploited without a local knowledge base.

Table 2. International trade, FDI and technological capabilities

	Exports of goods and services (annual growth rate 1990-2012)	FDI inflows as a percentage of GDP (average 1990-2000)	R&D expenditure as a percentage of GDP		Number of patents by residents (per million inhabitants)	
			1996	2010	1990	2010
Latin America and the Caribbean	8.9	2.6	0.53	0.76	10.3	4.7
East Asia and Pacific	9.7	1.6	2.3	2.45	192.1	332.1
South Asia	13.6	1.0	0.61	0.75	1.1	5.8
High income	6.7	1.9	2.23	2.49	458.5	633.5

countries						

Source: World Bank (2013), World Development Indicators, available on line.

5. Conclusions

The concept of systems of innovation has been widely disseminated among policy makers of both developed and developing countries. This concept has been a useful and comprehensive tool to identify current weaknesses and strengths to adopt, modify and generate technological knowledge and to design systemic STI policies. Yet, quite frequently in developing countries STI policies have not reached the desired results. This chapter has discussed how the lack of vertical and horizontal alignment can lead to ineffective STI policies in developing countries, particularly in emergent or fragmented innovation systems.

STI policies in developing countries have often not been properly aligned with the national development agenda and other economic development policies such as industrial, trade and education policies. If STI policies are not properly aligned and coordinated, the results in terms of capability building are usually poor, as shown in the previous sections of this chapter. Developing countries devote scant resources to STI and misalignment reduces their impact in terms of long-term economic growth.

Vertical alignment means tailoring STI policies to specific needs and characteristics of the innovation system. It implies the alignment of objectives, instruments and specific problems of the system. In turn, horizontal alignment implies the coordination of STI policies among different ministries and other public agencies, as well as their coordination with the overall development agenda.

In addition, developing countries face several barriers to design and implement STI policies. The most important in the short term are lack of funding and weak national commitment to STI as a source for social and economic development. Strong public policies, supported by enough human and financial resources, may help overcome other barriers in the medium and long terms, such as reduced credit, lack of co-ordination among public organisations and poor evaluation of policies and programmes.

The stage-based approach illustrates the importance of adapting STI policies to the current capabilities and needs of each innovation system. But it shows also a close association between active and aligned STI policies and the stage of development of innovation systems. New quantitative and qualitative methodologies to examine the dynamics of technological change, such as those presented in this paper, are offering new inputs for enhancing innovation systems policies and their impact on economic and social development.

STI policies in developing countries need to be the result of continuous policy experimentation (World Bank, 2010, Chaminade et al, 2009). Since not one single innovation system is equal to another, STI policies that have worked in one country may completely fail in another. Although robust public organisations are needed for long-term planning and implementation of STI policies, experimenting with new policy instruments, new constellations of actors and new technologies can lead to very successful STI policies which stimulate both science-based learning as well as experience-based learning.

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