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Competence Building:

A Systemic Approach to Innovation Policy

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ABSTRACT

The main question that guides this paper is how governments are focusing (and must focus) on competence building (education and training) when designing and implementing innovation policies. With this approach, the paper aims at filling the gap between the existing literature on competences on the one hand, and the real world of innovation policy-making on the other, typically not speaking to each other. With this purpose in mind, this paper discusses the role of competences and competence-building in the innovation process from a perspective of innovation systems; it examines how governments and public agencies in different countries and different times have actually approached the issue of building, maintaining and using competences in their innovation systems; it examines what are the critical and most important issues at stake from the point of view of innovation policy, looking particularly at the unresolved tensions and systemic unbalances related to competences in the system; and last but not least, it elaborates a set of overall criteria for the selection and design of relevant policy instruments addressing those tensions and unbalances.

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Keywords: Innovation system; innovation policy; public policy instruments; Knowledge; R&D; learning; skills; training; education; competences; competence building; innovation policy instruments

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Abstract

The main question that guides this paper is how governments are focusing (and must focus) on competence building (education and training) when designing and implementing innovation policies. With this approach, the paper aims at filling the gap between the existing literature on competences on the one hand, and the real world of innovation policy-making on the other, typically not speaking to each other. With this purpose in mind, this paper discusses the role of competences and competence-building in the innovation process from a perspective of innovation systems; it examines how governments and public agencies in different countries and different times have actually approached the issue of building, maintaining and using competences in their innovation systems; it examines what are the critical and most important issues at stake from the point of view of innovation policy, looking particularly at the unresolved tensions and systemic unbalances related to competences in the system; and last but not least, it elaborates a set of overall criteria for the selection and design of relevant policy instruments addressing those tensions and unbalances.

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Contents

1. Introduction

The rich literature in innovation studies has pointed to the crucial role of knowledge production in innovation systems and in particular the role of research and development (Jasanoff 1995) (Salomon 1977) (Guston 2000). However, in the same literature there is a widespread recognition that the mere existence of advanced types of scientific and technical knowledge and its production and transformation into prototypes does not automatically generate innovation (which includes commercialization of products and processes). In the history of science and technology there are plenty of situations in which specific firms, regions or even countries, have not been able to create innovations in spite of their high levels and excellent quality of scientific and technical knowledge. Some of the crucial elements that "translate" this knowledge into innovation are the way in which skills and expertise are developed and used by individuals and organizations. The combination of knowledge, skills and expertise is generally referred to as "competences". So do we.

The role of competences in the innovation systems is a complex one. This complexity has resulted in the fact that different strands of the literature have addressed these issues from various angles, using concepts that are sometimes partly overlapping. For that reason, conceptual clarity when dealing with these matters is crucial. Some of the most used notions refer to "competence", "resource", "capacity" and "capability". Whereas some authors in the literature use these words interchangeably, basically referring to the same thing, other authors have distinguished among in their conceptual frameworks (Smith 2008) (Vincent 2008).

Taken together, however, this literature is not particularly useful when focusing on innovation policy-making because these studies rarely include problems of policy-making in their approaches to the phenomenon. Focusing on firm, industrial and territorial dynamics, these studies do not introduce policy-making into their equation. Even if they might occasionally deduce some broad "policy implications" from these findings, their research rarely takes into account the public action that innovation policies have already put into place. The result is a growing gap between the scholars of innovation/business/geography studies on the one hand and innovation policy-makers on the other.

This paper focuses on competence and competence building from the perspective of innovation systems. It does so from the particular angle of public policy-making. Hence, the main question it addresses is how public agencies can and are focusing on competence building when designing and implementing innovation policies. With this approach, the paper aims at filling the gap between the existing literature on competences/capability on the one hand, and the world of innovation policy-making on the other. This gap is characterized by problems of lack of or unbalanced competences in the innovation system.

Generally speaking, there is little in-depth knowledge about the ways in which the organization of competence building, most notably how the formal education, and vocational training as well as learning-by-doing systems influence the development and diffusion of innovations in that economy. Since labor, including skilled labor, is the least mobile production factor, domestic systems for competence building remain among the most enduringly national and regional of elements of systems of innovation. This paper contributes to the study of competences and competence-building and their role in the innovation system. It examines how governments and public agencies in different countries and different times have actually approached the issue of building, maintaining and using competences in their innovation systems. The paper turns as well a critical eye on these matters, looking particularly at the unresolved tensions and systemic unbalances related to competences in the system. Last but not least, this paper elaborates a set of overall criteria for the selection and design of relevant policy instruments addressing those tensions and unbalances.

2. Conceptual Clarification and Definitions

The most widespread concepts in the literature addressed here are essentially three: “core competencies”, “dynamic capabilities” and “absorptive capacity. “Core competencies” is a concept which has been developed in the literature of strategic management (Prahalad and Hamel 1990). In their highly influential paper, Prahalad and Hamel define the portfolio of a firm’s core competencies “[as] the company’s collective knowledge about how to coordinate diverse production skills and technologies” (p.1). Firms must focus on these core competencies in order to exploit emerging markets and invent new markets. Hence, strategic managers must identify the core competencies in their firm in order to organize a new

"strategic architecture". The paper inspired a new and Schumpeterian-focus in the literature on the interplay between tacit knowledge and codified knowledge dynamics in managing innovation through these core competencies (Nonaka 1994)[1].

The notion of "dynamic capabilities" defined some few years later took a similar point of departure (Teece, Pisano et al. 1997). The definition is quite similar to the one above, as these authors see dynamic capabilities as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p 516). But they position this notion in a wider analytical framework where they see the competitive advantage of firms being defined by its distinctive processes and asset positions, as well as the evolutionary path the firm has adopted and the technological dimension of the particular market in which the firm operates.

From the point of view of innovation systems, these two notions of "core competencies" and "dynamic capabilities" have a series of interesting analytical strengths. Firstly, they put emphasis on the interaction between the firm and its external context when developing competences. They also position the development of the competences of the firm in relation to different types of knowledge. And last but not least, they see the development and use of competences in relation to possible issues of path dependency (or current options being dependent on past decisions), a central feature of evolutionary economics (Garrouste and Ioannides 2001).

The notion of "absorptive capacity" is slightly different than these two above. The definition of "absorptive capacity" is: "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" p. 128 (Cohen and Levinthal 1990). This notion is anchored in the knowledge and learning approach to the firm, and in the view that firms interact with their environment in the process of acquiring/developing new own innovativeness. The analytical advantage of "absorptive capacity" is its strong intuitive message that the absorptiveness varies across firms depending on the level and type of their own internal knowledge, and that this affects innovation performance (Murovec and Prodan 2009). More recent studies have found out, however, that the effect of absorptive capacity on

[1] Tacit knowledge (as opposed to codified knowledge) is knowledge that is difficult to transfer to another person or organization by means of writing it down.

the innovativeness of the firm is positive only up to a certain level. When firms become too dependent on external sources of knowledge they tend to be less innovative (Laursen and Salter 2006).

Taken together these concepts of "core competencies", "dynamic capabilities" and "absorptive capacity" have inspired studies in their respective areas for several decades and continue to be very valuable analytical tools, particularly in the fields of innovation management, international business and strategic management, were they were originally created. However, as mentioned in the introduction to this paper, they suffer from an important limitation. They tend to disregard the role that institutional frameworks (here including policy-making) generally play in the development of these competences, such as primary education systems, vocational training arrangements, etc. In other words, they tend to underestimate the institutional embeddedness of these competences. Firms are highly dependent on the ability of the innovation system to provide them with some fundamental assets that firms can develop as their internal competences.

The remarks above underline the need to move from a firm-individual perspective of these previous notions, towards a view where the innovation system is seen as having a series of institutional frameworks that generate and develop competences that are crucial for the innovativeness of firms. It is worth noting that policy might be crucial in the definition of these institutional frameworks. This shows that there is a limitation in these concepts. In order to redress this, this paper refers to "competences" in a slightly broader manner than the previous three concepts, and in so doing it includes these institutional frameworks (and innovation policies in particular) as essential for the formation and development of competences.

In this paper we define competence as the set of knowledge, skills and expertise that individuals and organizations have. Competence building, for its part, is the process of formal or informal development or acquisition of specific competences by individuals and organizations. It is worth noting that we take the point of departure from the perspective of the learning economy put forward by Lundvall and others, as a suitable first step into this theme of competence building (Lundvall and Borrás 1998) (Lundvall, Johnson et al. 2002). This view is that the innovative performance in an economy is largely based on the learning of

organizations and individuals, understood as their constant ability to adapt and change to the rapidly changing external context, based on their competences and their ability to build those competences constantly.

Box 1: Conceptual clarification on competence, competence building and learning

a) Competences refer to the set of knowledge, skills and expertise that individuals and organizations have.

b) Competence building is the process of formal or informal development and acquisition of specific competences by individuals and organizations.

c) Learning (or learning capability) is the individual or organization's own ability to adapt and change making use, combining and recombining specific competences.

The motivation behind this focus on competences, competence building and learning, is the acknowledgement that the pace of innovation and change in other dimensions of the economy and society has a direct impact on the way in which (innovative) firms operate. In a rapidly changing (including globalizing) context, firms and other innovating organizations must be able to adapt to these changing conditions. Therefore, in order to stay competitive and produce new products and processes, these organizations need to keep constantly upgraded with regard to their competences through a constant competence building. They need to adapt and change by combining these competences differently and organizing production and innovation processes inside and outside the firm in a different way. As Lundvall and Borrás put it: "In a context of increased market competition and rapid innovation, firms are faced with non-price competition factors. (…) A firm's capacity to learn and transform in this new context is a crucial competitiveness factor. There is a definite need to constantly rebuild the skills of the individual and the technological and organisational competencies of the firm." P. 34-35.

This paper focuses on competences (and competence building), rather than on "learning" as such. The reason is that competences are crucial in terms of building essential elements in the innovation system. Learning, for its part refers to the innovators' own willingness/ability to make use of those specific competences. This means that learning is associated to risk-taking attitudes and behavioral patterns in a society. Policy makers can design policies to build up competences they see as insufficient or incomplete. However, from the perspective of policy-making, shaping attitudes and social behavior (the learning aspect) is a far more difficult matter. For this reason this paper focuses on competences rather than learning.

The organisational and institutional contexts for competence building vary considerably among national systems of innovation. There are, for example, significant differences between the systems in the English-speaking countries and continental Europe, as explained and showed by the literature on varieties of capitalism (Hall and Soskice 2003) (Thelen 2007) (Culpepper 2007). These authors have emphasized how different national institutional frameworks shape the patterns of competence building in a whole economy. However, scholars and policy makers lack good comparative measures on the scope and structure of such differences, and most importantly, how these features define the innovation system. The matter of competence and competence-building is particularly relevant for developing countries and their processes of catch-up (Fagerberg and Srholec 2009).

3. Internal and External Sources of Competences

From an innovation system perspective one of the most important aspects is the process by which competences are created, maintained, and developed.[2] There are in principle an unlimited number and types of competences that firms and innovation-supporting organizations have and need in order to keep pace with rapidly changing market and societal contexts, such as globalization. Since firms operate in a wide variety of different markets and try to develop competitive advantages in special segments of local or global markets, it is virtually impossible to provide a closed list of competences that firms need, as those will invariably vary according to different markets and contexts. This variety of competences

[2] As implied above, these competences are not the same as creation of R&D results.

becomes even more apparent when we keep in mind that innovation is not solely an issue of commercialization of products per se, but also an issue of providing specific novel solutions to complex socio-economic problems (like poverty, security or ecological sustainability) – in a mediated way. Hence, firms and other innovating organizations have a wide diversity of needs in terms of the competences required to keep them at the frontier of market competition or at the frontier of problem-solving.

Having said that, however, we want to make a general distinction among the different competences that a firm/innovative organization might need at its disposal, as well as the traditional mechanisms and processes of competence building associated to these. First we want to mention that competence is a 'stock' concept and competence building is a 'flow' concept. Further we want to make a distinction between *individual* competences and *organizational* competences. And last but not least, we distinguish between internal and external competence.

Individual competence building refers to the acquisition of information, knowledge, understanding and skills by individual people, through participation in some form of education and training, whether formal (as, for example, within educational institutes) or informal (for example competence building ('learning-by-doing') in the workplace. Individual competence building largely consists of the dissemination of existing competencies, even though they are new to the individual acquiring it. The result of individual competence building is an increased stock of *human capital.*

Individuals exert substantial control over the firms' human capital. The firm, where an individual is employed, can profit from the latter's human capital only as long as the employee continues in the firm's employment; and he or she can leave at any time. All firms live under the threat that the most skilled of their employees may leave for a competitor or create a competing firm, once they have accumulated experience and built up a contact network. Employee ownership programmes and stock option programmes to tie key employees to the firm are therefore becoming more common. The power balance between some employees, defined in terms of their significant human capital, and the owners and managers of firms have changed because of the increased importance of human capital in the current economies.

There are some other forms of competences, however, which are not directly related to individuals and therefore cannot easily leave the firm. These may be termed organizational competences. Generally speaking, these are competences embedded in the working processes of the firm/organization as such. They can also be termed "structural capital" (OECD 2001). Such capital is retained by the firm independently of the presence of particular employees. Structural capital includes the information and knowledge embodied in, for example, data bases, customer directories, trademarks, manuals and technical manuals. It also encompasses assets such as patents, copyrights, trade secrets and other kinds of intellectual property rights. These are controlled by the firm; they belong to the firm independently of the individuals who are employed at any one time. Similarly, the knowledge and skills encapsulated in firm routines and work processes may, in certain circumstances, be retained by firms and, for example, be transmitted into new employees when they join. They have also been included within much broader concepts related to firms' investments, such as "intangibles", "intellectual capital" (Sanchez, Chaminade et al. 2000) or more recently "knowledge-based capital" (OECD 2012).

Competences might be internal or external to the firm/organization. Internal competencies can be of an organizational kind as specified above (structural capital). They have often been developed by the firm, but they can also have been acquired by the firm from outside. They are an integral part of the firm.

Internal competencies can also be of a human capital kind (see above). They are acquired by the firm through employing people. But these employees can leave the firm at any time and this kind of internal competence is hence not as firmly integrated in the firm as internal organizational competence.

The external competences, refers to those assets and resources/skills and abilities which remain outside the firm, but which are very important for the firm's innovation process. These are not an integral part of the firm, as they continue to be owned by external actors and partners. Yet the firm/organization in question might need to tap into them in order to be able to reach its own defined innovation targets. This type of external sources of competences is particularly relevant from the perspective of the innovation system, as it is related to the firm's collaborative patterns.

Turning now to the **internal competences and competence-building**, it is important to understand that, even if these competences are an integral part of the firm, the firm does not acquire, maintain and develop them in isolation from its context. On the contrary, these internal sources of competences are typically originated and developed inside as much as outside the firm. They are "internal" because they become ultimately owned by the firm. For example, when a company employs an engineer and puts her to work in specific projects, the quality and innovativeness of her work would depend very much on the tertiary education she received in the formal education system, but also on the specific training, skills and competence she has developed within that company. These refer to human capital (or individual-level of competences). But her contribution to the innovativeness of the firm will also depend on the particular way of organizing the use of her particular competences inside the firm, as well as her access to relevant software, patents, etc.

We have previously discussed internal organizational competence which is an integral part of the firm. The example of our female engineer, however, emphasizes two specific areas of internal competence building that we would like to focus on from an innovation system perspective, namely, formalized education (primary, secondary and tertiary education levels), and vocational training & continuous skills development at the workplace (Carneiro 2003).

Looking at the internal sources of competences to the firm, perhaps one of the most crucial areas in an innovation system is the quality and organization of primary, secondary and tertiary education. The way in which levels and types of formal education affect innovation performance in a firm and in an innovation system is still little known. Many studies have focused on the link between educational levels and quality of education on the one hand, and economic growth on the other; but few have related these to innovative performance. One of these studies shows that countries investing in the quality of mathematics and science education at all levels (primary, secondary and tertiary) are more likely to perform better in innovation terms (Varsakelis 2006). Other studies show the cumulative interaction between the development of high-end products and the levels of skills in the workforce (Toner, Marceau et al. 2004). However, the evidence is still scarce and inconclusive.

Levels of educational attainment have been increasing during the past decades, and in the OECD countries around one-third of 25-34 year-olds have tertiary educational levels (OECD

2011). The same is the case for doctoral levels, with a substantial growth of the proportion of the population with a doctoral degree compared with previous decades. However, in some OECD countries there has been a relative decline in the percentage of graduates with science and engineering education, and some countries have faced problems of skills shortages (OECD 2011). Education is, of course, also crucial for developing countries: Newly industrializing countries have put considerable effort in boosting levels of education as means for economic growth and innovation. Whereas this is the case for Asian countries like Korea or Taiwan, it has been less so for Latin America and the Caribbean (De Ferranti and others 2003).

One of the main concerns from the perspective of the innovation system is the extent to which the entire educational system is able to produce the type of knowledge, skills and expertise that innovative firms' need. In this regard, there seems to be a growing consensus that primary, secondary and tertiary education is not only crucial for the attainment of adequate levels of literacy, mathematical and science skills in a country. Education is also crucial for the development of "softer" skills that firms need, like communication or inter-personal competences. These softer skills are becoming important complements to "hard" skills, particularly in view of enhancing creativity and new modes of approaching problems inside the organization, as well as in view of the higher interconnectivity in the globalized economy and society (Lam 2005). A recent study has identified the following "soft skills" important for innovation: sense-making in communication, social intelligence, novel and adaptive thinking, cross cultural competency, computational thinking, new media literacy, trans-disciplinarity, new design mindsets, cognitive load management and virtual collaboration (Davies, Fidler et al. 2011).

The quality and organization of vocational training and continuous skills development at the workplace is another important element when considering the internal sources of innovative firms' knowledge competences and processes of competence-building. There are naturally many different ways of organizing vocational training and skills development, as this is typically a topic where the institutional framework plays a fundamental role. The traditional way of looking at this is the observation that labour markets are imperfect, and therefore there are different expectations regarding investment in vocational training at firm levels (Acemoglu 1997). However, this view has long been surpassed by the view that vocational training and continuous skills development at the workplace are related to the creation of

quasi common goods in the economy. This is so because the "stickiness" of knowledge in a given territory means that the overall outcome of skills development tends to revert to the entire local economy via localized knowledge spill overs. It is worth noting here that it is widely accepted that there is a link between continuous vocational training and innovation performance. However, there are in fact few studies that examine this link in detail (Makkonen and Lin 2012).

Admittedly, the relationship between levels of vocational training at the workplace and innovation performance in an economy is not a linear relation, as it is mediated by many complex dimensions not least the organizational dimension at the firm level. Naturally, vocational training and continuous skills development has to do with building knowledge competences in the human resources at the firm level (Smith, Courvisanos et al. 2012). But it has also to do with the way in which work is organized, and in particular, whether these skills developments and organizational forms do allow for creativity and employee-driven innovation patterns within the firm (Høyrup 2010).

The literature on "varieties of capitalism", which examine how the different institutional frameworks at the national level define different forms of market economy organization, has been very interested in how vocational training is differently organized in countries with a liberal market economy (UK, USA, etc) vis-à-vis in countries with a coordinated market economy (Germany, France, etc). Their findings show that vocational training arrangements have been evolving differently in different countries according to employees and employers' relations as well as business and politics relations (Harhoff and Kane 1997) (Culpepper and Thelen 2008), and have had different results in terms of innovation performance (Bosch and Charest 2008).

Turning now to the **external sources of knowledge and skill competences,** these can be seen as the competences that the firm exchanges with other external sources through, for example, collaboration. The ownership of these competences remains in the hands of the external partners. We know from the theory of "absorptive capacity" and from the evidence on open innovation that there tends to be a strong link between the internal capacities of the firm, and its ability to tap into external sources of knowledge (Cohen and Levinthal 1990).

Naturally, firms interact externally with other firms and with other kinds of organizations in many different ways and with many different purposes in relation to knowledge and skills competences. In this paper we would like to briefly mention three, which we believe are crucial from the perspective of innovation system: (1) university-industry relations that aim at developing human resources, (2) lead-users as key external sources of knowledge for innovation processes, and (3) crowdsourcing as a new form of collective pooling of knowledge resources in an innovation system.

(1) Looking at the first, there are many different forms of university-industry linkages. From the current perspective, several countries use of university-industry relations in order to promote university researchers to obtain firm-level expertise, skills and competences; for example, by co-funding industrial PhDs who are co-located in the firm and the university, by supporting university researchers' internships in firms, and by other types of liaison programs. The overall goal of these programs is to develop "firm-oriented" and other types of "soft skills" competences.

(2) The second area that is worth looking at when examining the most important external sources of knowledge for innovative firms is the lead-users. "Lead users" are highly competent and knowledge-producing consumers and users of specific products who get involved into a tight collaboration with the producing firm, giving the firm valuable information and feed-back about the further development of the innovative product. Lead users are related more generally to user-producer relations (Lundvall 1988), and to notions of user-driven innovation (von Hippel 2005), both at the backbone of the innovation systems approach.

(3) Last but not least, a third crucial external source of knowledge and skills that has emerged relatively recently is crowdsourcing. There are many understandings of crowdsourcing (Estellés-Arolas and González-Ladrón-de-Guevara 2012), but a review of the literature defines crowdsourcing as participatory online activities in which individuals or organizations propose the voluntary undertaking of a task which typically involves the pooling of knowledge resources, and is therefore associated to innovative activities. From an innovation system point of view, crowdsourcing can be

seen as competence building by the mobilization and combination of knowledge resources in the wider society. Crowdsourcing creates online-based communities of individuals and organizations with different competences and problem-oriented approaches. Crowdsourcing is typically based on "social media" because this is where people meet (Schenk and Guittard 2011).

The discussion so far can be summarized in Table 1.

Table 1: Internal and external sources of competences for the firm

	Definition	Related policy areas
Internal competences	A. Organizational competences that are developed by the firm or acquired from outside. They are integral parts of the firm. B. Individual competences (human capital) that are acquired through employment. They are less firmly integrated in the firm.	Primary, secondary and tertiary formal education of the employees. Vocational training & continuous skills development at the workplace Reverse brain drain & immigration of high-skilled workers
External competences	Competences that remain outside the firm, but that can be acquired by the firm through exchange/collaboration	University-industry interactions for human resources development Lead-users interactions Crowdsourcing

4. Policy initiatives

Having addressed the internal as well as the external sources of competences in firms and organizations, the question that arises is, what are governments doing on this? How are governments securing the creation, maintenance and development of competences in the innovation system? What are the current/typical policy initiatives taken by governments on

this particular activity? And what are the main focuses of these policy initiatives? These are crucial questions to ask, as many countries are engaged in different types of public action that relates to issues of competence creation, maintenance and development, with direct and indirect effects on the innovative performance of firms and of other organizations in the system.

The three traditional cornerstones of public action for competences and competence-building in an innovation system are (1) the regulation, organization and funding of the education systems (primary, secondary and tertiary – both public and private); (2) the support and incentive schemes towards vocational training systems; and last but not least, (3) migration policies (here including immigration as well as reverse brain drain).

Regarding educational and vocational training policy initiatives, we can note that public action to a large extent regulates, organizes, and (partly) finances formal education and vocational training. At the core of policy intervention is the collective understanding that there is a need for public action, either alone by public means, or in collaboration with private profit and non-profit actors too, when the levels and types of competences in the system are perceived to be insufficient. This may mean that the division of labour between public and private action in the field of education may need to change, or that the character of already existing public action should be modified. As the previous section showed quite clearly, competence building in an innovation system is a complex matter. This is because the issue of "competence" is very wide, spanning from the individual (person-focused) to organizational competences (firm-level). But it is also because "competences" are difficult to identify concretely and because their actual use in the economy depends a lot on organizational and cultural dimensions.

One example of recent education policy schemes that relate to innovation is the USA's focus on STEM education (Science Technology Engineering and Mathematics). In the USA, as in many other advanced economies, there has been a lively debate during the past couple of decades about the adequate levels and quality of STEM education and about the fact that students' enrollment in STEM education has not grown as much as in other areas. This motivated a wave of public and private initiatives in the USA focusing on STEM education,

ranging from the creation of non-profit associations promoting and lobbying for STEM[3], to a series of governmental initiatives at the federal and state level. A report of the US Government Accountability Office in 2005 identified 207 education programs specifically established to increase the numbers of STEM students in the country, which were run by 13 different federal agencies (US_Government_Accountability_Office 2005). The total expenditure in 2004 on these programs was about 2.8 billion USD, of which more than 70% were conducted by the National Institutes of Health (NIH) and the National Science Foundation (NSF). However, some of these programs were very small.

This topic became again on the spotlight of political debates when the 2006 PISA survey (Program for International Student Assessment) showed that USA students ranked 21st out of 30 in science literacy, and 25th out of 30 in mathematics. The Obama administration has launched the "Educate to innovate" campaign raising awareness of the importance of STEM. This initiative was intended to complement the existing federal agencies' programs in the field. It followed from the Presidential focus on advanced manufacturing industries, particularly the Advanced Manufacturing Partnership launched in 2011, and the creation of the federal-level National Network for Manufacturing Innovation in 2012.

Another example of policy initiatives in the area of competence building refers to vocational training & continuous skills development. These are crucial policies for innovation, and considerable focus has been recently put on competence building at the working place. "Policies to promote the learning necessary for skill and competence upgrading at the firm level cannot ignore the potential of the workplace and the strong incentives for upgrading what employers can provide" p. 210 (Steedman 2003).

There are, of course, many different vocational training systems and programs. One interesting example is the "Apprentice service" of Semta, at the UK Sector Skills Council for Science, Engineering and Manufacturing Technologies. This organization runs a program for apprentices in the UK advanced manufacturing and engineering (AME) sector, and has

[3] Examples of these non-profit organizations in the USA are: "FIRST" a civil society association created in 1989 conducting activities that motivate young people to pursue STEM education and careers; "STEM-coalition" is a sector organization advocating policy-makers for STEM education in USA policy-making institutions; "Innovate+Educate" is an industry-based organization formed in 2009 involving industry in STEM education and innovation-based workforce in the US.

recently put more attention to the needs of SMEs. Semta creates individualized programs for firms in the AME sector to develop, train and fund apprentices schemes. The AME sector is highly dependent on getting access to the right (high) level of skilled workers, and one way of accessing it is through apprenticeships. The problem many SMEs in the sector are facing is their lack of capacity to organize and finance encompassing programs for their apprentices that fits the skills they need and that secures the quality of training and its certification. The organization of these individualized programs requires the pulling of resources from different sources according to funding possibilities (age of the apprentice, region where the firm is based, etc.). It also requires specific knowledge competences, e.g. finding suitable trainers and designing the adequate educational framework.

Having addressed some examples of policy initiatives in education and vocational training, it is also important to determine the effects of these schemes and initiatives. However, the existing evidence in the literature is rather scarce. Starting with primary, secondary and tertiary education policy initiatives and structures, there is very little focus on education schemes and innovation system dynamics. Some of this literature has been focusing on regional/local patterns (OECD 2001) (Kitagawa 2004). A similar situation emerges from the literature on vocational training. There is today a rather scarce literature providing evidence on the extent to which policy schemes for vocational training are reflected in firm's innovative performance. See (Jones and Grimshaw 2012) for a recent review of the literature, and a description of some public schemes for vocational training in different countries. Following these authors, some of the findings in the literature indicate that, the more flexibility there is between educational institutions and workplace training programs the more positive outcomes in terms of firms' adaptability. In addition, long-term financial schemes and principles of skill formation schemes seem to give certainty and stability needed for securing the participation of relevant stakeholders (Jones and Grimshaw 2012).

As mentioned above the third traditional policy area related to competence and competence building is migration policy. Here countries determine the levels of access to foreign labour force to the domestic labour market. Following Jones, there are basically three types of migration policies regarding highly skilled workers: "point based" policies (assigning points to applicants regarding their education and other factors), employer-based policies (employers' job offer), and hybrid policies combining both. It is unclear which of these different types, and

different policies, reach their goals of covering deficiencies of competences in the innovation system (Jones 2012).

Another important aspect regarding policy schemes on migration has to do with reversing "brain-drain". For many developing countries as well as weaker developed countries, the problem of "brain drain" has been a source of major concern. Countries make large efforts into creating a highly educated workforce, but this investment does not revert to their economy if those high skilled workers move to another country. Reversing flows of highly skilled workers is a very difficult matter for policy-makers, because many different factors are at play, from good job opportunities and employment conditions, to personal reasons or contextual/scientific motivations.

Several countries have addressed this issue by various combinations of activities. One of such approaches has been to target individuals directly, offering very rewarding job conditions. A case in point is the ICREA program from the regional government of Catalonia in Spain, which attracts top-scientists worldwide offering them excellent working conditions. Although the program does not target nationals only, during 2001-11 more than 50% of their excellence-based grantees were of Catalan origin (Technopolis_Group 2011), and on this basis it can be argued that the program has indirectly served as a platform for reintegrating good Catalan scientists from abroad. Another, yet quite different approach is the Chinese government public action in relation to "brain circulation". Many years of concern regarding the loss of talent, particularly to the Silicon Valley by the so-called "new Argonauts" (Saxenian 2006), the Chinese government set up a program in 2001 encouraging its students settled abroad to return for short visits and relate to ongoing research activities in China even if they continued staying abroad. This "diaspora option" (Kutnetsor 2006) recognized the difficulties of reversing brain drain as such, and hence it has used the strong ties of the Chinese scientific diaspora to develop innovativeness in China (Zweig, Fung et al. 2008).

5. Deficiencies, Tensions and Imbalances in the System and in Policy-making

After the previous identification of some of the most conventional policy initiatives regarding competence building and competence maintenance, it is worth examining now some of the

possible deficiencies, tensions and imbalances in the innovation system. The innovation systems' approach brings forward the view that innovation is always performed in specific contexts. Context refers not only to the fact that scientific-technological advancements offer new opportunities for innovation, but especially that innovation is also related to socio-economic features and dynamics in a wider sense.

Hence, our starting point is to consider innovation policy as part and parcel of the innovation system. This is so because innovation policy's overall intention is to shape the context in which innovation activities take place. For this reason, when examining deficiencies, tensions and imbalances in the innovation system we include the effects (or lack thereof) of public policy's initiatives.

In our complex societies, either in advanced market economies or in emerging market economies, the role of public action is "everywhere". Consequently, sometimes it is difficult to distinguish when the deficiencies, tensions and imbalances in an innovation system are the direct outcome of some socio-economic or technical features as such or when they are related to the dynamics induced by public policy. Because both are intertwined, we need to examine them together. This is particularly relevant for our current focus on competences and competence building in an innovation system. In many countries the educational and vocational training frameworks rely strongly on public policies. Thus, when asking, for example, about the extents to which the vocational training framework in a specific country stimulates innovation or not, it is virtually impossible to ignore the central role that policy-makers have in shaping that framework.

From the previous sections of this paper three general types of deficiencies, tensions and imbalances in the innovation system seem to come to the fore. The first one has to do with **insufficient levels of competences in an economy**. This might be because the economy is not able to create the competences that its firms need for a sustained level of innovation performance, or because there is a net loss of competences due to negative migration flows in the county or region (or both causes simultaneously). Developing competences in an economy is not just related to the levels of educational attainment or vocational training. The competences of an economy are also highly dependent on the continuous development of skills and expertise in the organization of work. There is today a wide recognition that this

type of 'know how' based on skills and expertise is important for the levels of competences in an economy.

For that reason, during the past few years, there has been a political debate in Europe and the US regarding the effects on levels of competences in the economy of the offshoring of manufacturing activities.. The concern is that the past decades' firms' offshoring of manufacturing activities to countries with lower wages represent a loss of jobs and of competences in the home country. Skills and expertise are based on the ability of workers and middle-level managers to have a hands-on experience in the organization of production. Workers engaged in product and process innovation require a deep knowledge of the product and of its production process, which cannot be attained in research laboratories alone. Besides, advanced forms of manufacturing depend not only on substantial levels of scientific-technical knowledge, but also on skilled and experienced workers, i.e. competence. Recent policy initiatives like the High-tech Strategy in Germany (since 2006) and the USA's National Network for Manufacturing Innovation scheme (since 2012) focus on advanced manufacturing sectors, and therefore aim indirectly to boost the development and retention of competences in the country in the form of high skilled workers and expertise in these cutting edge industrial areas. It is however less clear whether these and similar policy initiatives will eventually palliate firms' continuous offshoring of manufacturing activities.

A second issue has to do with **the time lag between the need of specific competences of firms in the short term and the long-time needed to develop them**. When discussing the acquisition and development of competences in an innovation system, demand for labour plays a key role. Naturally, this demand must be met by supply of labour , namely, the concrete competences of the labour force in the innovation system. The tension in the innovation system comes when the provision of such skills and competences (the supply) is subject to educational programs that are designed on a long-term basis, whereas the demand in the labour market is typically more an issue of covering the short- to medium-term needs of the firms. This time-lag between supply and demand-side becomes particularly important with regard to higher education (universities), where there is much specialization.

It takes many years to educate a chemical engineer with a specialization in a certain technical area, but this competence might become obsolete relatively quickly. Several situations might

occur here. One situation is when there has been an 'overproduction' of a specific kind of chemical engineers, which the local economy cannot absorb. This is most acute in situations of rapid industrial restructuring. Another possible situation is when the rapid technological development makes the content of educational programs (partly) obsolete in the short term. For reasons of legal commitments, it might take universities quite a few years to be able to terminate an educational program.

The above shows that several factors are at play in this time-lag tension, namely, the dynamics of the labour market itself, the dynamics of technological change, as well as legal-institutional frameworks. For that reason, policy-makers are always confronted with the fundamental question about how to best define and determine the types of competences that the economy will need in the future. This is not the case just for the public education sector itself, but also for the private education sector. In many countries, private education receives direct or indirect public subsidies, and it is typically subject to some national/regional publicly defined frameworks (i.e. regulatory frameworks regarding academic titles, accreditation criteria for Higher Education Institutions, quality measurements, etc.). Policy-makers are therefore confronted to a great amount of uncertainty when it comes to the future needs of the innovation system. And the problem is that the labour market demand of today does not necessarily tell much about the demand in the future. Whereas current deficiencies might indicate future needs in terms of, for example, the number of medical doctors or engineers, determining what specialization will be most acute in the future is much more difficult to tell.

The third set of potentially problematic issues in an innovation system is **the imbalance between internal and external competences** which result either in an insulation or in an excessive dependence from external competences. This has to do with the notion of absorptive capacity, which refers to the firms' capacity to tap into sources of external knowledge and to combine it with its own internal knowledge in order to generate innovations. The development of innovation systems is highly related to their absorptive capacity (Castellacci and Natera 2013). However, securing the right balance between the internal and external competences might prove to be difficult in reality.

Firms which rely too much on internal competences might run the risk of insulation, losing the grip of new knowledge and skills available elsewhere. The firms which rely too much on

external competences, on the other hand, might become too dependent from externally-dominated knowledge resources and might rapidly loose absorptive capacity and thereby competitive edge. Hence, keeping the balance between internal and external competences is crucial for the development of the innovation system – and for the firms.

From the point of view of the policy-maker this is an important matter, though a difficult one to tackle. When discussing competences in an innovation system, policy makers might have a natural tendency to think exclusively in terms of competences that are solely internal to the firms. The theory of absorptive capacity tells us that external competences are very important too, both in the sense of external to the firm, as well as in the sense of external to the innovation system as a whole. This later remark puts emphasis on striking a balance between the types of competences to be developed inside an innovation systems, country/region or an economy, and those to be tapped from outside.

Box 2 General deficiencies, tensions and imbalances

1. Insufficient levels of competences in an economy, and/or the net loss of competences.
2. The time-lag between firms' short-term needs and the long-term required to develop competences.
3. Imbalance between internal and external competences which generate excessive insulation or dependence from external sources.

6. Concluding Remarks: Policy Design for Competence-Building

There is a wide consensus that competences play a central role in innovation systems and in the dynamics of economic growth. For that reason innovation policy typically has strategic issues to tackle concerning the development and acquisition of competences. Competences have been defined here as the set of knowledge, skills and expertise that individuals and

organizations have. Likewise, competence building is the process of formal or informal development and acquisition of specific competences by individuals and organizations.

Following the literature on these matters, this paper has brought forward the understanding that competences can be internal or external sources to firms. "Internal" refer to competences that are an integral part of the firm at a specific point in time. "External" refer to the competences that firms exchange with other firms of agents (typically by collaboration) at a particular point in time. As we have indicated the employment of human capital is less internal than organizational capital. Naturally, external competences can at a certain point become internalized if the firm decides to acquire them, or vice versa internal competences can become external too. The point at stake here is, which specific competences a firm decides to "own" (internal) and which ones to use without owing them (external). This crucial decision is pertinent to any type of organization (public or private), and by extension to the whole innovation system as well.

After providing some examples of policy actions in this area, this paper has also identified a series of deficiencies, tensions and imbalances that typically occur in innovation systems. These can be essentially summarized in three. The first has to do with the insufficient levels of competences in an economy, and/or the net loss of competences in that economy. The second potential problem is the time-lag between firms' short-term needs and the long time required to develop future competence (in the national context). Last but not least the third problem is the possible imbalance between internal and external sources of competences, which might generate either an excessive insulation or an excessive dependence from external knowledge.

The general criteria for the design of innovation policy that we suggest in this paper focus on the imbalances mentioned above. Therefore the first criterion is the **creation, retention and attraction of competences for innovation in a country or region**. There is a widespread understanding that modern economies have a positive bias towards skilled labour (against unskilled labour), and that this is related to technological change. This is what it has been termed the "Skill Biased Technological Change" hypothesis, which has been confirmed empirically in most developed countries - see (Piva, Santorelli et al. 2006) for a review. Policy-makers must secure adequate levels of skills in an economy, and this might not happen automatically due to several reasons as we saw above.

The second criterion is **the identification of the specific types of competences that are needed for (different kinds of) innovation in the present and in the future**. It might be too obvious to say that countries and regions need to identify their present and future needs of knowledge, skills and experience for their innovation system and their economy more broadly. However many countries or regions actually do not have any systematic monitoring mechanism of this (Jones and Grimshaw 2012). Yet, determining the types of competences that an innovation system needs is a daunting task for policy-makers given the bewildering complexity and variety of competences that innovative firms and organizations need now and in the future. Several sets of statistics, survey analysis and foresight exercises are policy instruments which can be used in this regard.

The third criterion is **securing levels of absorptive capacity in firms and the innovation system** . Keeping a sound balance between internal and external competences is a crucial focus for innovation policy-makers. This is, to avoid too much emphasis on internal sources of competences (which would create an insulated situation), and to avoid too much "invent elsewhere" situation by which firms become too dependent on external sources of knowledge. This requires considering the "give and take" of firms' interaction with other organizations, as well as the internationalization of competences in an economy.

These three aspects examined here are not only the criteria for the design of innovation policy. They are the foundations of a theoretical and analytical framework for the study of the multiple linkages between competence building dynamics, the public schemes to develop them, and their final effects in the innovation system. As state earlier in this paper, public action is a sine qua non element of an innovation system. For this reason studying competences and competence building in a system requires taking on board the existing public action.

These remarks lead us to pinpoint a series of important gaps in the literature that deserve further research efforts in the near future. One of these gaps is the lack of empirical studies that look at the policy effects of education and vocational training schemes, as well as migration and brain circulation policies, in the levels and types of competences in an innovation system. The question that remains unanswered is, for example, what specific effects have several decades of migration policy schemes towards skilled and trained workers

have had on different dynamics of the innovation system. Another highly relevant question is the time-line evolution in the composition of skills and expertise on the one hand, and the innovative performance of a specific economy on the other. Can we see specific patterns in terms of competences and their development that are associated with the particular evolution of the innovation system? And last but not least, there is a lack of attention to competences and competence developments in the public sector itself. Here the question is how the competences and competence building in public, semi-public, non-profit private organizations also affect the level of innovation performance in a system. This paper has focused primarily on the competences of firms, as a crucial asset for their ability to innovate. However it is important to keep in mind that competences and competence building remains central to all and any kind of public or semi-public organizations that populate an innovation system. This question is the most relevant when looking particularly at innovation processes in the public sector.

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