Education, Training and Skills in Innovation Policy

Abstract

The main question that guides this paper is how governments are focusing (and must focus) on competence building (education, training and skills) when designing and implementing innovation policies. After a brief literature review, this paper suggests a typology of internal/external and individual/organizational sources of competences that are related to innovation activities. This serves to examine briefly the most common initiatives that governments are taking in this regard. The paper identifies three overall deficiencies and imbalances in innovation systems in terms of education, training and skills: the insufficient levels of competences in a system, the time lag between firms’ short-term needs for specific competences and the long time required to develop them, and the imbalances between internal and external sources of competences in firms. From these, the paper elaborates a set of overall criteria for the (re)design of policy instruments addressing those tensions and imbalances.

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

In the rich literature on innovation, studies have pointed to the crucial role of knowledge production in innovation systems, 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 scientific and technical knowledge (and its production and transformation into prototypes) do not automatically generate innovation (which includes commercialization of products and processes). Some of the crucial elements that “translate” knowledge into innovation are the ways 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”.

The role of competences in innovation systems is complex. 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 them in their conceptual frameworks (Smith 2008) (Vincent 2008).

There is an extensive literature about competences and innovation at the firm level as well as at the system level, as this paper will briefly review. One aspect, however, that tends to be understudied in that literature is the role of innovation policy-making. Even if part of the literature deduces some broad “policy implications” from the findings, the research rarely takes into account the public action that innovation policies have already put into place.

This article focuses on competence and competence building from the perspective of innovation systems, and in particular from the perspective of public policy-making. Hence, the main question it addresses is how public agencies are focusing, and can focus, on competence building when designing and implementing innovation policies. With this approach, the article

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1 We define innovation as “new creations of economic and/or societal significance, mainly carried out by firms (private or public). They may be new products or new processes” p. 1726 in Edquist, C. (2011). “Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures).” *Industrial and Corporate Change* 20(6): 1725-1753.
aims to contribute putting aspects of innovation policy at the forefront of studies about how skills, education and training affect innovation performance in a system, and in particular, examining what are the bottlenecks and tensions in the innovation system that policy-makers need to identify and address.

This article examines how governments and public agencies in different countries and at different times have actually approached the issue of building, maintaining and using competences in their innovation systems. On this basis the article turns a critical eye on the most relevant unresolved tensions and systemic imbalances related to competences in the system. Last but not least, this article elaborates a set of overall criteria for the selection and design of relevant policy instruments addressing those tensions and imbalances.

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 create 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)².

The notion of “dynamic capabilities”, defined a 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

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²Tacit knowledge (as opposed to codified knowledge) is knowledge that is difficult to transfer to another person or organization by means of writing it down.
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 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 from 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” (Cohen and Levinthal 1990) p. 128. 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 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, where they were originally created. However, as mentioned in the introduction to this article, they suffer from an important
limitation. They tend to disregard the role that educational and training frameworks 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 social and formal embeddedness of these competences. Firms are highly dependent on the ability of the innovation system to provide them with some fundamental assets that they can develop as their internal competences.

The remarks above underline the need to move from an individual-firm perspective of these previous notions, towards a view where the innovation system is seen as having a series of formal educational and training frameworks that generate and develop competences that are vital 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 the three concepts. In order to redress this, this article refers to “competences” in a slightly broader manner than the three approaches mentioned above, and in so doing it includes these frameworks (and innovation policies in particular) as essential for the formation and development of competences.

In this article 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 should be noted that we take our 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, Johnson et al. 2002). This view is that the innovative performance in an economy is largely dependent on the learning of organizations and individuals, understood as their constant ability to adapt to and change in relation to the rapidly changing external context, based on their competences and their ability to build those competences constantly.

Box 1: Conceptual clarification on competence and competence building

| 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.

The motivation behind this focus on competences and competence building 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 (OECD 2011). In a rapidly changing (and 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 constantly need to keep upgrading their competences through 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 different ways. 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.” (Lundvall and Borrás 1998) P. 34-35.

This current article focuses on competences (and competence building), rather than on "learning" as such. The organisational and institutional contexts for competence building vary considerably among national systems of innovation. There are, for example, significant differences across different educational and vocational training systems (Brockmann, Clarke et al. 2011) (see sections 3 and 4 below), as well as ways of organizing training and labour market regulations, with significant differences in terms of innovation performance (Lorenz 2011). 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. 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 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 it will always vary according to different markets and contexts. This variety of competences 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, we would like 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 with them. First, we want to mention that competence is a ‘stock’ concept and competence building is a ‘flow’ concept. Further, we 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 (for example in educational institutes) or informal (for example competence building (‘learning-by-doing’) in the workplace). Individual competence building largely consists, unlike R&D, of the dissemination of existing

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

4 The taxonomy presented below and summarized in Table 1 is partly based upon (OECD 2001).
competencies, even if they are new to the individual concerned. 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; as he or she may 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 has 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 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 in the organization that is embodied in, for example, data bases, customer directories, organizational routines and and procedures, 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 firms’ routines and work processes may, in certain circumstances, be retained and transmitted to 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 competences can be of an organizational kind as specified above (structural capital). They are often developed by the firm, but they may also be acquired by the firm from outside. Regardless of their origin, they might become 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 since these employees may leave the firm at any time, this kind of internal competence is not as securely integrated in the firm as internal organizational competence.

The *external* competences, which refer to those assets and resources/skills and abilities that remain outside the firm, are also 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 innovation targets. This type of external source of competence 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 typically originate and are developed inside as much as outside the firm. The internal competences of a firm in the form of “structural capital” is ultimately owned by the firm. Likewise, “human capital” is only accessible to the firm as long as the employees remain employed at the firm. For example, when a company employs an engineer and puts her to work on 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 specific competences inside the firm (organizational routines and processes), as well as her access to relevant data-sets, software, patents, etc. Hence structural and human capital in the firm complement each other.

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 competence building which 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 work place (Carneiro 2003).

Looking at the internal sources of the firm’s competences, perhaps one of the most crucial areas in an innovation system is the quality and organization of primary, secondary and tertiary education. It occurs externally, but the result of it can be acquired by firms. The exact way in which levels and types of formal education affect innovation performance in an innovation system is still partly an open research question. 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 the latter 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 new products and the levels of skills in the workforce (Toner, Marceau et al. 2004).

Levels of educational attainment have been increasing during the past decades; around one-third of the 25-34 year-olds in the OECD countries have tertiary educational levels (OECD 2011). There has also been a substantial growth of the proportion of the population with a doctoral degree compared to recent decades. However, some OECD countries have suffered a relative decline in the percentage of graduates within science and engineering education, and some countries have faced problems of skill shortages (OECD 2011). Education is, of course, also crucial for developing countries: Newly industrializing countries have put considerable effort into boosting levels of education as the 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 (Toner 2011). 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, such as
communication or inter-personal competences. These softer skills are becoming important complements to “hard” skills, particularly in enhancing creativity and new modes of approaching problems inside the organization, as well as in the higher interconnectivity in the globalized economy and society (Lam 2005). A recent study has identified the following “soft skills” as 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 an 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 national and regional institutional frameworks play a fundamental role (Brockmann, Clarke et al. 2011). These authors have shown the large differences in the understanding of core ideas about skills, education and training; and how those core ideas have affected the system and the practices at the national level. For its part, the more recent literature on “varieties of capitalism” has been interested in how vocational training is organized differently in countries. Their findings show that vocational training arrangements have been evolving differently in different countries according to employee and employer relations as well as business and politics relations (Harhoff and Kane 1997) (Culpepper and Thelen 2008), and that they have had different results in terms of innovation performance (Bosch and Charest 2008).

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 the firm level (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 public 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 spillovers. It is worth noting here that the notion of a link between continuous vocational training and innovation performance is widely accepted (Makkonen and Lin 2012) (OECD 2011).
Admittedly, the relationship between levels of vocational training at the workplace and innovation performance in an economy 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 competence in the human resources at the firm level (Smith, Courvisanos et al. 2012). But it has to do with the way in which work is organized as well, and, in particular, whether these skills developments and organizational forms do in fact allow for creativity and employee-driven innovation patterns within the firm (Høyrup 2010). A recent study on the preconditions for creativity at work shows the importance of how work is organized and how national institutional contexts promote creative work. The study finds positive relations between the likelihood of creativity at work, on the one hand, and the development of broad competence-based systems of education and labour market flexicurity, on the other. (Lorenz and Lundvall 2011).

Turning now to the external sources of knowledge and skill competences, these can be seen as the competences that the firm exchanges with other organizations through, for example, collaboration. In the case of 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. We would like to briefly mention three, which we believe are crucial from the perspective of innovation systems. Naturally, there are many other forms of external interaction. However we argue that these three are crucial for two reasons; firstly, because these are among the most common forms for firms’ external interaction in innovation systems; and secondly, because these three show high components of training, experience and/or skills-development in a way that the firm can potentially benefit from external sources of knowledge. These three forms of external interactions are: (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 university-industry relations in order to encourage university researchers to obtain firm-level expertise, skills and competences. This can be achieved, 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 skill” 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 in 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 more generally associated with 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 interpretations 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 with 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. It is typically based on “social media”. (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

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<th>Definition</th>
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<td><strong>Internal competences</strong></td>
<td>A. Organizational competences developed by the firm or acquired from outside. They are integral part of the firm, and often called “structural capital”. B. Individual competences (human capital) that are acquired through employment. They are less firmly integrated in the firm.</td>
<td>Information and knowledge competences in the organization that is embodied in data bases, customer directories, organizational routines and procedures, as well as trademarks, patents, copyrights, trade secrets, etc.</td>
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<td>Human capital: formal primary, secondary and tertiary education of the employees.</td>
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<td>Vocational training &amp; continuous skills development at the workplace.</td>
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<td>Reverse brain drain &amp; immigration of high-skilled workers (see below).</td>
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<td><strong>External competences</strong></td>
<td>Competences that remain outside the firm, but can be acquired by the firm through exchange/collaboration</td>
<td>University-industry interactions for human resources development</td>
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<td>Lead-users interactions</td>
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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 about 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 in terms of 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 relate to issues of competence creation, maintenance and development, with direct and indirect effects on the innovative performance of firms and 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 for vocational training systems; and (3) migration policies (here including immigration as well as reverse brain drain).

(1) 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 by public means alone, or in collaboration with private profit and non-profit actors, 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 on the adequate levels and quality of STEM education and the fact that students’ enrollment in STEM education has not grown as much as in other areas. This has 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 \(^5\), to a series of governmental initiatives at the federal and state levels. A report of the US Government Accountability Office in 2005 identified 207 education programs, which were specifically established and run by 13 federal agencies, to increase the numbers of STEM students in the country (US_Government_Accountability_Office 2005). The total expenditure on these programs in 2004 was about 2.8 billion USD, of which more than 70% was provided by the National Institutes of Health (NIH) and the National Science Foundation (NSF). However, some of these programs were very small.

This topic appeared again in 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 to raise awareness of the importance of STEM. This initiative is intended to complement the existing federal agencies’ programs in the field. It follows 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.

(2) Policy initiatives in the area of competence building refer as well 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.

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\(^5\) Examples of these non-profit organizations in the USA are: “FIRST” a civil society association created in 1989 to conduct 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”, an industry-based organization formed in 2009, involves industry in STEM education and the innovation-based workforce in the US.
“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 recently paid 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 is through apprenticeships. The problem many SMEs in the sector are facing is their lack of capacity to organize and finance encompassing programs that provide the skills their apprentices need, and that secure the quality training and 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. See (Jones and Grimshaw 2012) for a recent review of the literature about evidence on which policy schemes for vocational training are reflected in firms’ innovative performance, 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 organizations and workplace training programs, the more positive the outcomes in terms of firms’ adaptability. In addition, long-term financial
schemes and principles of skill formation schemes seem to give the certainty and stability needed for securing the participation of relevant stakeholders (Jones and Grimshaw 2012).

(3) As mentioned above, the third traditional policy area related to competence and competence building is migration policy, in which countries determine the levels of access of foreign labour 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 offers), and hybrid policies combining both. It is unclear which of these different types, and different policies, achieve their goals of covering deficiencies of competences in the innovation system (Jones 2012).

Another important aspect regarding migration-policy schemes 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 substantial efforts to create a highly educated workforce, but this investment does not revert to their economy if those high skilled workers move to another country, which is highly relevant given current patterns of globalization (Borrás, Chaminade et al. 2009). 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 such approach has been to target individuals directly, offering very rewarding job conditions. A case in point is the ICREA program of the regional government of Catalonia in Spain, which attracts top-scientists worldwide and offers them excellent working conditions. Although the program does not target nationals only, more than 50% of their excellence-based grantees were of Catalan origin during the period 2001-2011 (Technopolis_Group 2011). On this evidence, it may 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’s public action in relation to “brain circulation”. After many years of concern with the loss of talent, particularly the so-called “new Argonauts”, to the Silicon Valley (Saxenian 2006), the Chinese government set up a program in 2001 to encourage those of its students who had settled abroad to return for short visits and relate to ongoing research activities in China, even if they intended to continue living abroad. This “diaspora option” (Kutnetsor 2006), recognizing the difficulties of reversing brain drain as such, has used the strong ties of the Chinese scientific diaspora to develop innovativeness in China (Zweig, Fung et al. 2008). This indicates as well that there are social and cultural differences in the way in which societies deal with the contributions of migrants and with the returnees of expatriates working abroad.

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

Following the previous identification of some 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 emphasizes that innovation is always performed in specific contexts. However, contexts refers not only to the fact that scientific-technological advancements offer new opportunities for innovation, but also that innovation is 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. Accordingly, when examining deficiencies, tensions and imbalances in the innovation system, we include the effects (or lack) of public-policy initiatives.
In our complex societies, whether in advanced market economies or in emerging market economies, the role of public action is “everywhere”. Consequently, it is sometimes 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 extent to which the vocational training framework in a specific country stimulates innovation, it is virtually impossible to ignore the central role that policy-makers have in shaping that framework.

From the previous sections of this article, three general types of deficiencies, tensions and imbalances in the innovation system seem to come to the fore – summarized in Box 2 below. 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 country or region. 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 widespread recognition today that this type of ‘know how’, based on skills and expertise, is important for the levels of competences in an economy.

As a consequence, there has been a political debate during the past few years in Europe and the US on the effects of the offshoring of manufacturing activities on levels of competences in the economy. The concern is that the past decades’ offshoring of firms’ manufacturing activities to countries with lower wages represents a loss of jobs and competences in the home country. Skills and expertise are based on workers and middle-level managers having hands-on experience in the organization of production. Workers engaged in product and process innovation require a deep knowledge of the product and 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 in the country of competences in the form of highly skilled workers and expertise in these cutting edge industrial areas. Still, it is less clear whether these and similar policy initiatives will eventually counteract firms’ continuous offshoring of manufacturing activities.

A second issue has to do with the time lag between firms’ needs for specific competences 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 the supply of labor; namely the specific 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 – and often have to be - designed on a long-term basis, whereas the demand in the labor market is typically more an issue of covering the short- to medium-term needs of the firms. This time-lag between the supply and demand sides 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; these are the dynamics of the labor market itself, the dynamics of technological change, and legal-institutional frameworks. Thus, policy-makers are always confronted with the fundamental question of how to best define and determine the types of competences that the economy will need in the future. This is not just the case for the public education sector itself, but for the private education sector as well.
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 with 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 say 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.

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 against, or in an excessive dependence on, 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 this knowledge 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 isolation, and lose the opportunity to acquire new knowledge and skills available elsewhere. On the other hand, firms which rely too much on external competences might become too dependent on externally-dominated knowledge resources, and might rapidly lose absorptive capacity and thereby their 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, in the sense of both external to the firm and external to the innovation system as a whole. This latter statement puts emphasis on striking a balance between the types of competences
to be developed inside an innovation system, 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 time required to develop competences.
3. Imbalance between internal and external competences, which generates excessive insulation against or dependence on external sources.


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 article has brought forward the understanding that competences can be internal or external sources to firms. “Internal” refers to competences that are an integral part of the firm at a specific point in time. “External” refers to the competences that firms exchange with other firms or agents (for example by collaboration) at a particular point in time. As we have indicated, the employment of human capital is less secured internally than organizational capital. Naturally, external competences can become internalized at a certain point if the firm decides to acquire them, or vice versa. The point at stake here is whether to “own” (internal) or to use without owning (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 article has also identified some deficiencies, tensions and imbalances that typically occur in innovation systems. These can be essentially summarized into three categories. 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 is the time-lag between firms’ short-term needs and the long time required to develop future competence (in the national context). The third is the possible imbalance between internal and external sources of competences, which might generate either excessive insulation against or excessive dependence on external knowledge.

The general criteria for the design of innovation policy that we suggest in this article focus on the imbalances mentioned above. Therefore the first criterion is the creation, retention and attraction of competences 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 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, but this might not happen automatically for several reasons, as we have seen above.

The second criterion is the identification of the specific types of competences that are needed 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 mechanisms for 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 analyses and foresight exercises are policy instruments which can be used in this regard (Borrás and Edquist 2013).
The third criterion is securing levels of absorptive capacity in firms and the innovation system as a whole. Keeping a sound balance between internal and external competences is crucial 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” situations 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.

The three aspects examined here are not only the criteria for the design of innovation policy. They are also the foundations of a theoretical and analytical framework for the study of the multiple linkages of competence building dynamics, the public schemes to develop them, and their final effects on the innovation system. As stated earlier in this article, 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 important gaps in the literature that warrant further research efforts in the near future. One of these gaps is the lack of empirical studies that look at the effects of education and vocational training schemes, as well as migration and brain circulation policies, on the levels and types of competences in an innovation system. One question that remains unanswered is: What specific effects have several decades of migration policy schemes for skilled and trained workers 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? Finally, there is a lack of attention paid to competences and competence development in the public sector itself. Here the question is how the competences and competence building in public, semi-public, and non-profit private organizations also affect the level of innovation performance in a system. This article 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 remain central to any kind of public or semi-public organization in an
innovation system. This question is particularly relevant when looking at innovation processes in the public sector.

References


