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Exploring the Role of Knowledge and Technology Transfer in Innovation Systems

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Keywords: Innovation systems, Knowledge management, Technology transfer, Open innovation, IPR

Introduction

In the light of globalization, innovation has acquired strategic relevance in the quest to increase and sustain the economic growth of nations. In this context, governments from the developed and developing world see innovation as a strategy to increase their competitive advantage in the global stage. Therefore, nurturing innovation through policies and actions has become a priority in both the public and private sectors everywhere. Such policies and actions focus broadly on facilitating and regulating the transfer of knowledge and technology among the multiple actors in the innovation system – notably among universities, governmental agencies, and industry (Grimpe and Fier, 2010; Camison and Fores, 2010; Etzkowitz et al., 2010).

Innovation literature provides a variety of analytical frameworks in which the flow of technology and knowledge can be contextualized. These frameworks refer to systems at different organizational and spatial levels such as for example nations (e.g. Freeman, Nelson, Lundvall), regions (e.g. Cooke, Asheim), industry sectors (e.g. Malerba), or specific technologies (e.g. Hekkert, Bergek, Jacobsson). In general, innovation studies focus on the flows of technology and knowledge among people and organizations. At national level for example, innovation and technology development are seen as the result of a complex set of interactions among agents producing, distributing and applying different types of knowledge. Literature suggests that the innovative performance of a country greatly depends on the particular arrangement of these agents within the collective knowledge system and the technologies they use (Etzkowitz and Leydesdorff, 2000). These agents are primarily private enterprises, universities, public research institutes, and the people among them.

Although the innovation system literature has grown and diversified steadily, the underlying dynamics of knowledge and technology transfer are not yet fully understood, nor are their definitions universally accepted (Grimpe and Fier, 2010). In this context, formal mechanisms for the transfer of knowledge and technology have been better documented – e.g. patents and licences – notably in reference to collaboration frameworks linking university research and firms' R&D activities (e.g. Motohashi, 2008). Consequently, there is little research about the context of informal transfer, although there is evidence suggesting that its occurrence and relevance in national innovation systems it might be considerable (Grimpe and Fier, 2010).

Due to the increasing role of innovation as a strategic driver of economic development in nations, the study and better understanding of the principles governing knowledge and technology flows in innovations systems, acquires greater relevance, notably for strategic making of policies. This observation is even more relevant in the context of knowledge-based economies and emerging views on innovation such as for example the case of innovation as an open system or as eco-system.

The objective of this study is to shed light on the role of informal technology and knowledge transfer in innovation system. The work aims a better characterization and understanding of knowledge as a dynamic component of innovation systems in the light of formal and informal flows, in order to raise interest towards the less studied, yet relevant, informal aspects. This implies a further look into the theory regarding the study and understanding of innovation not only as a system but also as a process. The analytical framework of this study is set within the theory of innovation systems (e.g. Lundvall, 1992; Etzkowitz and Leydesdorff, 2000), and knowledge management (e.g. Nonaka, 1991). The research method is a case study with the Japanese National Innovation System as a subject. Eventually, this study aims a contribution to the theory of innovation and knowledge management, and the practice regarding innovation policies.

The rest of this paper is structured as follow: a state-of-the-art review with focus on innovation as process, as a system, and on knowledge as a function in innovation systems. The review is followed by a description of the methodology and research questions, and followed by a presentation of main findings and interpretations, conclusions, the policy implications and further research directions, and a list of references.

State-of-the-art

Innovation as a process

Innovation has become a keyword in the – yet elusive – understanding of the dynamics leading to economic growth or the stagnation of national economies. In this context, innovation is seen as a key facilitator of the adaptation process to both endogenous and exogenous changes affecting the social, economic, and technological order in countries (Gopalakrishnan and Damanpour, 1997). Accordingly, innovation plays an important role in the strategic decision-making process of public and private organizations within the economic system dealing with the inherent uncertainty brought by deep changes, such as for example by the phenomenon of globalization (e.g. Lundvall et al., 2006). Innovation as such, aims at increasing the economic growth and welfare trough strengthening and sustaining the competitive advantage of firms, industries, and sectors, and improving living standards and quality of life (Gopalakrishnan and Damanpour, 1997). From this particular conceptual perspective, innovation is seen as a strategic mechanism to induce or effectively adapt to changes in order to strengthen and sustain economic growth and welfare.

Relevant as it has become, innovation lacks of a universally accepted definition, for its conceptualization and its practice is highly context dependent. As Gopalakrishnan and Damanpour (1997) suggest, innovation is broadly '*associated with both the creation and adoption of something new*' where the meaning of 'new' would differ greatly among scholars and practitioners of diverse fields. In this context, the association of innovation with a change of state – radical or incremental – through synthesis or adoption gives birth to definition in which innovation is either an *outcome* or a *process*. As an output (of an economic activity) innovation is seen as a distinct product such as a new idea, a method, or a device. As a process instead, innovation refers to the procedure or process of introducing something new into a market. In either case, as a product or as a process, innovation involves the creation of market value and thus, it is deeply related to the entrepreneurial activity, as suggested in the 'Theory of Economic Development' by Joseph Schumpeter (Schumpeter, 1934). In this theory, innovation is at the heart of economic growth, driven by the entrepreneurial spirit of individuals and linked to the constant 'creative destruction' shaping capitalist economies. The suggested link between innovation, entrepreneurship, and growth is still central in contemporary economic development policies (Jofre and Andersen, 2009; Europe INNOVA, 2008).

Naturally, innovation research and practice has steadily proliferated and diversified since the early and inspiring work of Schumpeter and other economists and philosophers in late 1800s and early1900s. In a historic and simplistic perspective, one can say that the conceptual development of innovation has evolved from a lineal (economic) process towards a complex (multi-actor) system (e.g. OEDC, 1997; Lundvall et al., 2006). From an academic perspective, the focus of innovation studies has also diversified over time, beyond the realms of economic views. Today for example, innovation is studied in fields as diverse as sociology, engineering, psychology, and marketing (Gopalakrishnan and Damanpour, 1997). For scholars engaged in economic research, innovation is seen at a high level of abstraction as one more factor inducing high industrial productivity, among players engaged in an 'economic game'. In this abstract perspective, the interests or motivations of

players as well as the outcomes of the game are more important as a research focus than the performance of particular players. Economic studies distinguish between product and process innovation, and broadly focus on radical innovations as the result of noticeable changes in the technical system of organizations and in the patterns of productivity. From the perspective of scholars engaged in technology studies instead, innovation is seen as a process to create new or improve existent technologies. Technology studies also distinguish between product and process innovation but also considers both radical and incremental forms of innovation. In such studies the focus is on the patterns and trends of technology change as innovations are used, assimilated, and diffused. Eventually, scholars engaged in social studies focus on the organizational attributes involved in the adoption of innovations by organizations. This studies considers both process and product innovations inducing radical or incremental changes.

As a process, the dynamics of innovation have been explained initially in the context of a sequential linear process (e.g. Roberts, 1974) linking the actors, resources, knowledge, and technologies involved in basic research (idea generation), applied research, product development, and diffusion (commercialization). Later on, this process has been understood as a rather complex and iterative process with multiple cycles of feedback emerging from multiple convergent, parallel, and divergent activities (e.g. Kline, 1985). The validity and analytical value of either view, linear or non-linear, is yet much debated, while the influence of the linear model (probably due to its analytical simplicity) remains influential, notably in public policy-making (Cummings, 1998; Gopalakrishnan and Damanpour, 1997).

From the analytical perspective of scholars, organizations approach the innovation process as either 'generators' or as 'adopters'. For Gopalakrishnan and Damanpour (1997), in an organization acting as a generator, the innovation process regards problem-solving and decision-making in connection with the design or development of new products. Meanwhile, in an organization acting as an adaptor, the innovation concerns the process of organizational change affecting both the technical and the social systems of the organization. In this case, the process is composed by the stages of 'imitation' and 'implementation'. In organizations acting as generators, the successful outcome of the process is often determined by the organization's capability to improve its performance or to set new industrial standards through the competent diffusion of its innovation. In organizations acting as adopters the measure of success is given by its capability to institutionalize an innovation in order to improve its performance. Gopalakrishnan and Damanpour (1997), suggest that an innovative organization should be able to 'engage in either, or both, the generation or the adoption of innovations'.

Innovation as a system

With the advent of new and more complex economies, no longer based on the simple production of goods for local markets on the solely combination of labour and capital, the conceptual development of innovation and its study as a field of theory and research have changed noticeably (Berkhout et al., 2006; Von Hippel, 1988). In the transition towards an economy based on the intense production and use of knowledge, innovation has been redefined and approached beyond the process level. Berkout and collaborators, explain such a conceptual transition through a sequence of three consecutive generations of innovation models. Accordingly, the initial and traditional linear model of innovation from basic research to commercialization is replaced by a second generation model, in which the source of innovation is not science but the market (reversing the first generation model). In a third generation model instead, innovation is no longer based on a linear sequence of stages but in an 'open' process with focus on organizations' Research and

Development collaboration efforts (R&D), to induce product and process innovations of technical nature. Each generation, although useful to complement the preceding model, exhibits a narrow scope. The first innovation model does focus in excess on the technology push and the role of science generating ideas that often are of reduced or no value whatsoever. The second generation instead, does focus on the market pull emphasising the role of innovation as a driver of performance improvement, neglecting long-term research aiming at radical innovations. Eventually, the third generation, although balancing technology push and market pull in order to increase the technological capabilities of the organization, tends to neglect the role of non-technological innovation. The critique of Berkhout and collaborators to these three successive models of innovation is further elaborated to suggest a fourth generation model in which innovation is embedded in a system of partnerships or 'open innovation'. In this model, emphasis is given to the relation between science and industry, the need to complement knowledge on technologies with knowledge on markets, the need to create or adapt organizational capabilities according to the networking requirements, and the role of entrepreneurship as a fundamental driver.

The open innovation system is not the first attempt to understand innovation beyond the linear process, but one more stream in the increasingly productive and diversifying literature in innovation systems. As a system, innovation is understood as 'a set of institutions, which jointly and individually, contribute to the generation, diffusion and use of knowledge for the development, diffusion, and applications of new technologies' (Gu and Lundvall, 2006). The set of institutions that influence innovation, provide the framework for the formulation and implementation of public policies. Thus, this conceptual framework for innovation emphasizes the role of governments shaping the innovation system, and of policies as instruments of change. In general the innovation system approach suggest the presence of a 'interactive learning' among the actors involved in the exchange of knowledge and information (Gu and Lundvall, 2006).This regards the continuous interaction between industry and R&D agents generating, disseminating, and using knowledge to innovate, in order to (i) increase absorptive capacity, (ii) increase transfer capacity, and (iii) establishing linkages between parties.

The innovation system theory has been applied to different organizational and spatial levels from firms, technologies, sectors, regions, to nations. Initially, the innovation system approach was developed at the national level, giving origin to the popular concept of National Innovation System or 'NIS' (e.g. Freeman, 1987; Lundvall 1992; Nelson 1993). The concept of national innovation systems assumes that the flow of technology, knowledge and information among people, firms and R&D institutions is crucial to the innovative process, and therefore determines the innovation performance of the country (OECD, 1997). The main innovation agents in a NIS are private enterprises, universities, public research institutes, and the people within them. The interaction between agents originates a variety of formal and informal linkages in the form of joint research and publications, personnel exchanges, patents and licences, the purchase of equipment or the transfer of particular technologies or methods for example. At the national level, the structure, functions, and performance of the innovation system are 'affected and shaped by the microeconomic and regulatory environment' (Gu and Lundvall, 2006). The view of innovation as the result of a national system, as suggested by Gu and Lundvall, inherently implies 'an evolutionary approach to social and economic change'. In this evolutionary approach, innovation and technological progress derive from a particular socio-economic path of development constructed by and shaped through history. Therefore, policy-making in the perspective of NIS, follows a path of trial and error to increase flexibility and learning from experience, for uncertainty is inherent to evolution and change.

Knowledge as a function of innovation systems

To a large extent, NIS theory focuses on the flow of knowledge as a driver of economic performance. In this context, although the knowledge embedded in individuals, organizations, and technologies is central to economic development, its importance as a research focus on innovation studies has been acknowledged relatively late in history. In general, the application of knowledge theory into innovation studies builds on contributions from different fields and notably from the prolific organizational research literature focusing in strategic management (e.g. Nonaka, 1991). In this context knowledge is seen as a significant 'organizational resource' that is embedded in and mobilised by entities such as the organization's culture and identity, routines, systems, policies, documents, and more importantly by the individuals within the organization (Alavi and Leidner, 2001). Such assets are difficult to imitate and therefore can be strategically managed to create a distinctive competitive advantage (Grant, 1996).

From an analytical perspective the theory on NIS provides a useful framework, notably for the development and exercise of policies (Etzkowitz et al., 2010; Gu and Lundvall, 2006). In this context, it is useful to identify key functions in the system that can be assessed and compared. In this perspective, 'a system is an entity comprising elements that interact with one another' providing a model of reality designed for analytical purpose (Markard and Truffer, 2008). In innovation systems – at any organizational and spatial level – '*elements*' are often conceptualized as interacting organizations or institutions within a given institutional environment: the '*system'*. The properties of these interactions can be regarded as the *system functions*. Different systems of innovation can therefore, be assessed and compared with regard to the functions they fulfil (Markard and Truffer, 2008).

The identification and assessment of functions – or activities – of innovation systems is acquiring relevance among innovation scholars recently. This 'functional' perspective remarks the importance of 'what the system does or how it works in comparison to how it is composed or structured' (Bergek et al., 2005). Yet function and structure are attributes of a common object, the system, and therefore they are mutually dependant on each other. However, this relationship is ambiguous, and systems with different structure can be similar in terms of function and vice-versa. Although this implies that there is no optimal structure to assure a well performing system, it is yet possible to compare whether a system perform better or worse (Markard and Truffer, 2008). Hence, a comparison of innovation systems performance can be assessed in terms of functions. In the analysis of innovations systems, functional comparisons can support policy recommendations to improve system performance or to eliminate structures that block system functions for example (Markard and Truffer, 2008).

In general, *system functions* can be conceptualized in terms of generation, diffusion, and use of innovation, although several other functions such the generation and diffusion of knowledge, the guidance of search processes, or the creation of markets are also described in some studies (e.g. Bergek et al., 2005; Hekkert et al, 2007). Although there is no consensus over a particular set of functions, innovation studies often assess and compare the innovation performance of countries on according to the functions suggested by Hekkert et al. (2007) including: entrepreneurial activities, knowledge creation, knowledge diffusion, guidance of the (re)search, market creation, mobilisation of (human) resource, and creation of legitimacy (or capability to embrace change).

Literature often distinguishes knowledge from information and data. Alavi and Leidner (2001), suggests that this differentiation is often explained as a hierarchy in which data stands at the bottom and represents raw numbers and facts, followed by information as a form of processed data, and top by knowledge as authenticated information. However, the assumption of a range of content, structure, accuracy, and utility across the hierarchy is challenge by the view of 'knowledge as information possessed in the mind of individuals' which might or may not be completely new, accurate or useful. Alavi and Leider (2001) suggest that as such, knowledge is 'personalized information' involving interpretations, ideas, observations, judgements, facts, concepts, and procedures. This suggests that knowledge cannot exist outside of an agent, and therefore it is influenced by the individual needs of the agent and its initial stock of knowledge. In this cognitive process information is translated into knowledge in the mind of the agent, while knowledge is translated into information when externalized by the agent. This process increases the agent capacity for effective action. However, knowledge can be seen from different perspectives as suggested by Alavi and Leider, as (i) a state of mind, (ii) an object, (iii) a condition to access to information, (iv) a process, or (v) a capability. Independently of the perspective, knowledge in organizations presents two dimensions: tacit and explicit (Nonaka, 1991).

The tacit dimension of knowledge or 'tacit knowledge' regards cognitive and technical elements characteristic of the individual mental model such as for example experience, opinions, and concrete know-how. Contrarily, the explicit dimension of knowledge or 'explicit knowledge', as Nonaka explains, is codified, articulated and communicated in symbolic form and/or natural language such as for example the knowledge transmitted by a book.

Both tacit and explicit knowledge exist individually or collectively. Alavi and Leider (2001) suggest that often tacit knowledge is considered more valuable than explicit knowledge. However, both dimensions are mutually dependent and a fundamental part of knowledge, for tacit knowledge provides the background for the development and interpretation of explicit knowledge. Understanding the dynamics of knowledge is important for the theoretical development of its management. In this context knowledge management as a discipline focuses on the use of collective knowledge at an organization to increase its competitiveness through innovation and responsiveness to changes.

In the context of innovation systems, observed differences in the growth rates of national economies are explained by equivalent differences in the 'social capability' for institutional change, and notably by differences in the capability to organize and advance knowledge (Mina, 2009). In this context, the study of the dynamics of knowledge creation and the characteristics of organizational structures driving the interactive learning in the system are fundamental components of innovation studies (Mina, 2009; Lundvall, 1992). In the perspective of NIS the flow of knowledge and technology is a consequence of the particular structure and functioning of the system (e.g. Hekkert et al., 2007). On the other hand, Etzkowitz and Leydesdorff (2000), suggest that the particular educational, economic and political environments of countries determine the agents and the characteristics of their interaction within the innovation system. In this view, the innovation system is defined by a 'triple helix' relation of university (education), industry (economy) and government (politics). At the heart of the triple helix is the entrepreneurial university that actively create value through creation and diffusion of new knowledge and technologies (Etzkowitz et al., 2008).

Eventually, a considerable volume of innovation literature is increasingly focusing in the attainment and sustainability of knowledge in organizations (e.g. the concept of knowledge abortive capacity

reviewed by Camisón and Forés, 2010), and the mechanisms of knowledge and technology transfer from research institutions towards the business organization (e.g. Grimpe and Fier, 2010; Motohashi, 2005). In the context of knowledge and technology transfer, the role of formal transfer mechanisms such as patenting and licensing has been broadly documented, while informal mechanisms regarding both tacit and explicit forms of knowledge have receive little attention (Grimpe and Fier, 2010). However, the relevance of such informal mechanisms might be higher than initially thought, suggesting the need of more research in the area.

Methodology

The analytical framework of this review is set within the theory of innovation systems (e.g. the concept of national innovation systems by Lundvall, 1992; and the concept of triple helix of university-government-industry by Etzkowitz and Leydesdorff, 2000), and knowledge management (e.g. Nonaka, 1991). The research method is a case study (Yin, 1984) with the Japanese National Innovation System as a subject.

The Japanese innovation system presents a particular structure and functioning that, in a historic perspective, serves to evidence and contrast the dynamics of both formal and informal mechanisms of knowledge and technology transfer. By analysing such particularities from the perspective of innovation systems and knowledge management theories, the review attempts to broaden the discussion of contents and results in order to derive generic recommendations meaningful to decision and policy making in the ambit of innovation.

Research questions

Literature suggests that the Japanese innovation system has undergone a continuous transformation of its structure and functioning since its initial formalization as a system in 1950s, facing both success and failure, but in general exhibiting a high innovation performance (e.g. Suzuki et al., 2002; Motohashi 2005; Odagiri, 2006; Debroux, 2008; Kitagawa and Oba, 2009; Watanabe 2009; Jofre and Andersen, 2009; Watanabe et al., 2010; Lee et al., 2010). This transformation has been broadly motivated by the need to adjust to both endogenous and exogenous changes of social, cultural, technical, and economic nature. Such changes motivated a series of transformations (still ongoing) notably in the national institutions and their interactions, namely universities, governmental agencies, and the industry. As a consequence, the dynamics of knowledge and technology transfer in the triple helix have changed overtime. The main change in this context regards the national universities that have rapidly shifted from a passive and moderate performance in the creation of knowledge towards an active entrepreneurial role as independent ‘corporations’ within the innovation system. Considering this background, the research questions are as follow:

RQ0: Did knowledge and technology transfer dynamics change along the successive transformation of the Japanese innovation system?

RQ1: What is the relation between formal and informal transfer in the Japanese innovation system?

RQ2: Is the informal transfer of knowledge and technology relevant to the functioning of the system?

Findings and interpretation

RQ0: Did knowledge and technology transfer dynamics change along the successive transformation of the Japanese innovation system?

Yes. Amid transformations in the public sector and notably in the public university system, the flow of knowledge and technology particularly among research and industry agents changed in terms of direction, volume, and quality. The (emerging) documentation of this change has been broadly explained through analysis of changes in the relation between (public) university and industry (e.g. Lee et al., 2010; Kitagawa and Oba, 2010).

Before the transformation of public universities into autonomous corporations, the dynamics of knowledge and technology transfer were notably influenced by the proactivity of industrial R&D agents, particularly at large business corporations. Universities, as main producers of new knowledge through the advancement of basic research did have a minor role in the process and product innovation lead by industry and guided by the government. The dynamics of the transfer in this case where driven by the need of extramural knowledge of private R&D activities. Meanwhile, the drivers of R&D activities at firms were increasing technological needs to support the accelerated industrial development of the country in spite of a raising shortage of resources and space as suggested by Watanabe et al. (2010). However, the dynamics of technology transfer after 2004, the year in which the university reform ended, did gradually change as a result of an increasing involvement of universities in entrepreneurial activities.

As suggested by Lee et al. (2010), since 2004 the active link between university and industry in Japan has resulted in an increased amount of cooperation. Collaboration in Japan has taken six different patterns, such as cooperative research (joint R&D project between university and university researchers), contracted research (formal research project commissioned by the industry to the university), patent licensing (licensing of university patents to industry), industry consulting (outsourced consultation to solve particular industrial problems), students internship (involvement of students in industrial R&D with educational purposes), and start-up (creation of university start-ups and spin-offs). All these new forms of collaboration have increased in number during the last years, particularly after the increasing presence of Technology Licensing Offices inside universities (see Sun et al., 2007).

The main determinants for the type of collaboration between universities and industry regard the size of the firms, the prestige of the university, and the cost of the collaboration as suggested by Motohashi (2005). Small firms are less active in collaborations with university while firms in general will work with few (prestigious) universities, universities on the contrary will collaborate with several firms. Among collaborations forms, Motohashi (2005) indicates that joint R&D activities are preferred while licensing of patents is the least active. However, as suggested by Debroux (2008), these initiatives might not have a significant economic impact for the time being but might serve to set the right policy framework to enhance the flow of knowledge and technology between university and university. Contrarily, Kitagawa and Oba (2010) suggest that in the current system, universities are compelled to build excellence and diversify in a competitive environment that might undermine their nature as education entities. As independent entities, public universities in Japan have to compete for resources while fulfilling the national aspirations of an increased presence in the global arena. In this context, Kitagawa and Oba (2010), explain that as a result of the university reform, in the current Japanese higher education system three different sectors with different legal status, degree of autonomy, and market interests coexist: public universities (yet

autonomous), local universities (dependent of local government), and private universities. National and private universities compete for resources nationally although national universities receive the majority of research grants. Local universities on the other hand, have been important drivers of regional development through knowledge and technology transfer to the community and local businesses.

Whether national, local, or private universities in Japan are rapidly moving from a national-oriented collaboration towards a global-oriented networking (See Lee et al., 2010; Kitagawa and Oba, 2009). Indeed, Sun and Negishi (2010), suggest that the current collaboration between university, industry, and government in Japan is weakening due to the increasingly foreign-centred nature of the knowledge creation and diffusion networks. Nicholas (2011) suggests that the economic success of the Japanese innovation system in the past was supported by the development of domestic capabilities rather than by inflow of foreign knowledge, in opposition to the common understanding of the Japanese modernization as a process focused on the openness to the 'West'.

Eventually, amid the changes in the dynamics driving the collaboration between university and industry in Japan, the role of IPR mechanisms regulating the flow of technology and knowledge is suggested to be important as both a driver and a barrier. In this context, Sterckx (2011) and Swamidass and Vulasa (2009), agree over the fact that the role of IPR mechanisms as an incentive for knowledge and technology transfers in universities is not considerable as initially thought, and that in general terms, licensing is not a profitable activity in universities.

RQ1: What is the relation between formal and informal transfer in the Japanese innovation system?

The findings suggest that the relation between the formal and the informal forms of transfer in the Japanese innovation system is of mutual dependency. This pattern has been sustained through the historic development of the innovation system in which both forms co-exist and co-evolve (See Watanabe et al., 2010; Lee et al., 2010; Debroux, 2010). In this context, both forms have been employed simultaneously but at a different extent. In a historic perspective, the formal use of technology transfer in Japan is currently encouraged by public policies and strategies for Science and Technology. This development has been focused on a reform of the university system and the adoption of an IPR system.

However universities and firms still make use of both forms of transfer. This situation is currently explained as a cultural matter (See Debroux, 2010) that might trouble the advancement of formalization. In this context, a major policy challenge is to increase the involvement of universities in the formal stream of transfer as well as to increase the interest of firms – notably of SMEs – on the formal acquisition of extramural knowledge. This challenge also should address the increasing role of foreign knowledge within the innovation system as denoted by Sun and Negishi (2010). In this context the spontaneous openness of the current innovation system might play against the desirable formalization of transfer mechanisms by creating conflict of interest between the agents producing and commercialising knowledge. The rise of such conflicts has been already documented (See for example Kitagawa and Oba, 2010), although the extent of their impact is not yet clear. This is consistent with findings in the American and European innovation systems in which IPR mechanisms do not significantly increase nor facilitate the collaboration between university and industry (Sterckx, 2011; Swamidass and Vulasa, 2009).

RQ2: Is the informal transfer of knowledge and technology relevant to the functioning of the system?

Yes. In the particular evolution of the structure and functioning of the Japanese innovation system, the role of informal transfer is considerable. As denoted by Suzuki et al. (2002), Motohashi (2005), Odagiri (2006), Debroux (2008), Kitagawa and Oba (2009), Watanabe (2009), Jofre and Andersen (2009), Watanabe et al. (2010), and Lee et al. (2010), informal forms of technology and knowledge transfer particularly among university and industry were dominant until the year 2004. The informality encouraged by the active development of intramural R&D at large corporations, the exclusive role of universities as producer of basic research, and the considerable role of the government as a guide and regulator of the transfer, was also rooted socially. In this context, the spontaneous and extended informal collaboration between academics and R&D staff at firms was and continues to be a considerable driver of the knowledge flow.

Current innovation policy frameworks aim at a increasing the formalization of such collaborations notably by the removal of legal impediments to academics to formally participate in entrepreneurial activities outside the university. This practice, although successful in entrepreneurial cultures (See Suzuki et al., 2002), is still resisted by the Japanese academia. This finding contradicts the idea of promoting the entrepreneurial university as a core strategy to induce and sustain innovation as suggested by Etzkowitz et al. (2008). In the context of the Japanese innovation system the role of the social structure, and its evolution, seems to be a major driver of the functioning of the system. This observation is consistent with the principles of co-evolution postulated by the literature in National Innovation Systems (See Gu and Lundvall, 2006).

Eventually, this review confirms the findings of Grimpe and Fier (2010) suggesting that literature on informal transfer is scarce and that existent studies on the topic focus on the interactions between university scientists and industry personnel. Unlike formal transfer mechanisms such as for example patents, licenses, and royalty agreements, informal mechanisms are difficult to assess quantitatively. Grimpe and Fier (2010) suggest that in the lack of a proper incentive, informal transfer will continue to occur and conflict with formal mechanisms. Naturally, policy instruments can be developed to provide such incentives. However, policies in this regard, should not underestimate the contextual (socially rooted) nature of technology and knowledge transfer, as evidenced in this study.

Conclusions

The purpose of this study was to shed light on the role of informal technology and knowledge transfer in innovation systems. A review was presented on different aspects regarding the link between different forms of knowledge and the structure and functioning of innovation system. As suggested in the state-of-the-art review, innovation is still developing as a concept and therefore there is no universally accepted viewpoint but several theories and analytical frameworks. For the objective of this study, the analytical framework given by the theory in innovation system, notably by the concepts of NIS and the triple helix, was adequate. However, this theoretical framework was of limited usefulness to fully address the dynamics of knowledge as process within the system.

The choice of Japan as a case study to further investigate the dynamics of informal technology transfer was adequate. In this case, the role of informal transfer has been of relevance in the past and the present condition of the innovation system. However, as the innovation system is in a state

of transition, the validity of observations and conclusions are limited and context dependent and should be interpreted accordingly.

The overall conclusion of this study is that the informal flow of knowledge and technology is as relevant to the performance and evolution of innovation systems as it is the formal flow. The relation between both forms is of a mutually dependent nature, context dependent, and socially rooted. Thus, the increasing openness of contemporary innovation system might not exclusively depend on the prevalence of just one form of knowledge transfer, but on the system's capability to facilitate, sustain, and capitalize on any form of endogenous and exogenous collaboration.

Policy implications and directions for further research

The design of formal collaboration mechanisms such as an IPR framework should consider the historic and cultural context of the innovation system. Under a rigid policy framework, formal and informal flows of knowledge and technology in the system might act as opposing forces weakening the overall performance. Thus, strategic policies aiming the openness of an innovation system should consider these issues carefully.

Opposed to current trends in literature focusing on systems of innovation, this work suggests the need to further develop innovation research from a process perspective. Although the systemic approach has proven useful to analyze the overall dynamics of innovation, notably in the policy context, the functions in the system, like the flow of knowledge and technologies, might not be fully understood nor easily explained in the lack of an overarching process. Considering these arguments, the directions for further research should focus on the characterization of a primary and generic process linking the functions and the structure of innovation system. Such a process should consider knowledge as its core element.

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