A theoretical examination and framework proposal for the constituents of innovation systems

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Abstract

A novel examination of the constituents (components and relationships)of innovation systems is presented and a new framework is proposed, based on a comprehensive review of 1922 academic journal papers that were published on the subject between 1990 and 2009. Through a systematic review procedure we narrowed them down to a total of 31 studies which served as the foundations for the new framework. The framework details each component and their main relationships and offers a broad comprehension for the system of innovation as a whole.

Keywords: Innovation Systems, Systems of Innovation, Systems Modeling, systematic literature reviews.

Introduction

It is arguably accepted that firms do not innovate in isolation but in continuous and complex interactions with other actors and sources of knowledge at the industrial, local, regional, national and international levels (C. Chaminade, 2001, Jorge Niosi, 2002, OECD, 2001).In the late 1980s and early 1990s scholars defined those interacting scientific and technological flows and processes as an Innovation System (IS) (C. Freeman, 1987, Bengt Ake Lundvall, 1992, R.R. Nelson, 1993, 1992).

Since then, there has been a rapid and broad diffusion of the IS approach and a wide range of disciplines - from economics to engineering - have used it to explain the relationship between industry, development and innovation (Benoit Godin, 2009, Bengt Ake Lundvall, 2007).

However, the current literature recognizes no single definition nor approach (Jorge Niosi, 2002) thus making difficult to operationalize the concept when, for instance, STI Policy needs formulation. In the pursuit of reducing this gap, scholars have pointed out to different characteristics, elements and flows of the system and with them they have tried to make the IS concept more explicit.

Even though there has been some advance in this research stream, a quick review of the literature evidences a huge number of approaches, characteristics, elements and flowspreviously proposed, which following the rationale of (Jorge Niosi, 2002) it leads us to question to ourselves which one is to be privileged, if any?

This paper aims at offering a theoretical examination of the constituents – components and relationships – of Innovation Systems and at proposing a novel framework (synthesizing a large number of previous work) for their use in future scholarly and practitioner work.

The method used was the Systematic Review (SR), a literature review method that is used to consolidate and analyze large amounts of literature by following a reproducible procedure and a predefined search algorithm, increasing the quality and accuracy of the results obtained by literature search. SR strengthens the capacity to make evidence-informed decisions by providing rigorous and timely assessments of the evidence base to decision makers(Mary M. Crossan and Marina Apaydin, 2010, Khalid S. Khan et al., 2001, Mark Petticrew and Helen Roberts, 2006).

The rest of the article is structured in the following way: a section outlining the Theoretical Background of the article; the next section explains the research design; the following section presents the consolidated framework, result of the synthesis of the literature review; Later, we present the main conclusions that we have come up with this work and we end the article by showing the references we used.

Finally, while this review is primarily intended for scholars who are interested in the Innovation Systems approach, we also believe that it will be of use to policy makers who are interested in aligning policy-making to evidence-based assessments.

Theoretical Background

The roots of the innovation system framework are older than the theory of economic development proposed by Joseph A Schumpeter (1912). The first formal reference with the focus on the national dimension, the National System of Innovation sets Friedrich List (1885) as the first author in pointing out investments in knowledge accumulation as key drivers of economic development. And also in suggesting that differences in the economic development of countries are due to the fact that such countries have different investment levels in knowledge.

Friedrich List developed his perspective of the National Systems of Political Economy, against the Smithian notion, particular notion of the reflections of free trade to the development of Germany in relation to the economically and technologically advanced England.

It is important to say that the contribution of List was not restricted to theoretical analysis. In fact, it offered the conceptual basis for the development of a sophisticated competence-building system for Germany in the XIX and XX Centuries. In a similar way, the National System of Innovation (NSI or NIS) perspective is used by many policy makers as a framework to design institutional policy, especially related to technological development.

From this heterodoxical perspective of economical development, two NSI versions, sensitivelydifferent emerged(C. Freeman, 2004)Nelson, 2007),the narrow one and the broad one. The narrow one focuses on the innovations based on R&D efforts. ForBengt Ake Lundvall et al. (2009) the analysis on this perspective is focused in just one dimension of the learning and innovation process. There is a considerable amount of learning related to "on the job" activities as employees face ongoing changes that confront them with new problems, as well as learning taking place when they interact with external customers". This one refers to the broad perspective of innovation system.

In this sense, both public and private sectors intervene in the process of creating new knowledge and therefore, new technologies are created not only by Science and Technology organizations, such as Universities or Research Labs, but also by firms through formal and informal learning processes, involving learning activities which can be classified as doing, using and interacting – DUI mode(M. B. Jensen et al., 2007). Our efforts in developing the framework for Innovation Systems are based on the broad definition of IS.

Is important to say that the NIS is a historical and geografical perspective of analisys. It means that the past is always an important element to be considered as well as the locus were the system is analized. The evolution of formal and informal institutions in promoting the conditions to innovation is a good example of historical perspective. And the territorial proximity of agents involved in learning processes is a good example of the geografical perspective.

Therefore, the IS framework presents itself as an interdisciplinary approach, since it helps in linking both formal and informal ways of innovating by focusing on the learning process that takes place in order to innovate and on its path-dependency, i.e. developing innovations is usually a long-term process dependent not only of economic but also of institutional, organizational, social and political factors (C. Edquist, 1997). In addition, in order to produce economically useful knowledge, complex interactions between several institutional actors, processes and structures must be taken into account, which cannot be explained by traditional economic variables alone.

Despite the more than two decades of efforts dedicated to offer a new reference to the scholarly and political analysis of technological and economic development, the current literature is still not clear on showing up the main components and linkages of IS. Following Charles Edquist and Leif Hommen (2008)there seems to not exist a dominant design of the concept of Innovation Systems. This paper looks for contributing with the discussion of conceptualizing IS by focusing on a framework that (i) systematizes and explains objectively the components and linkages of the system and consequently, (ii) in serving as an analysis tool in research about IS, by using the notion of IS constituents from Edquist & Homen (2008).

The construction of the framework is based on a set of definitions proposed by Charles Edquist (2005). First: a system of innovation is the set of determinants of innovation processes, including all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion, and use of innovations. Second: Any system is composed of components, relationships and attributes. Edquist named those elements as “the constituents of innovation systems”.

The first element are the components which are “the operating parts of the system” and for Edquist innovation systems account for two basic types of components which are organizations and institutions (Bo Carlsson et al., 2002, Charles Edquist, 2005). “Organizations” are formal structures that are consciously created and have an explicit purpose. Accordingly, examples of Organizations are: firms, universities, venture capital organizations and public agencies responsible for innovation policy; they can also be named as actors. Institutions on the other hand, are "sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations". Examples of Institutions might be: patent laws as well as rules and norms influencing the relations between universities and firms or traditions and social norms.

The second element of an innovation system, are the so-called "relationships", which are the links between the components. These links represent the dependency of each component upon the properties and behavior of at least one other component of the system.As Carlsson (2002)explains, these relationships produce feedback mechanisms that make an "innovation system" to be dynamic, in other words, by enhancing the interactions among the components, the system will be more dynamic. As result of the feedback mechanisms among the components and mainly the actors, their properties may change over time and therefore the whole configuration of the innovation system.

The third element is known as "attributes", which are the capabilities of the actors to develop, diffuse and use innovations within the system.

The framework is novel in the sense it proposes that the attributes of the system can be assessed by flows of two types: (i) financial and (ii) information and knowledge. However, the contribution goes beyond by synthesizing the linkages between the constituents. The understanding of the flows in (i) and (ii) was based in Jorge Niosi (2002).

In fact, we are aware that other factors help in explaining the innovation processes that are typical in different countries, regions and sectors, such as Macroeconomic ones, like monetary stability, interest rates, currency change and tax structure, but also historical or path-dependent ones, such as accumulated knowledge stored in firms and even cultural ones, like entrepreneurship. However, we focused on the ones that would allow comparison between countries, or even between sectors of different countries or even different regions of the same country.

The following Section introduces the research method known as Systematic Review that was used to find related literature in order to build or framework.

Research Design

Systematic Reviews (SR) use an explicit algorithm to perform literature reviews. This algorithm then, represents a reproducible procedure that provides transparency to the critical appraisal of the literature in study and strengthens the capacity to make informed decisions by providing rigorous and timely assessments of the evidence base to decision and policymakers (Mary M. Crossan and Marina Apaydin, 2010, Khalid S. Khan, Gerben ter Riet, Julie Glanville, Amanda J. Sowden and Jos Kleijnen, 2001, Mark Petticrew and Helen Roberts, 2006).

We assumed that literature on the constituents of innovation systems was encompassed within model proposals, meaning that studies of interest to our research were to be propose or use models or schematics. Since models are abstract representations of reality, containing “parts” and “relationships” (Michael Pidd, 1999), we felt .

We used two different electronic databases to retrieve bibliographic literature that had proposed frameworks, constituents or models of Innovation Systemsby using the search phrases ‘innovation system’, ‘innovation systems’, ‘system of innovation’ and ‘systems of innovation’ for the period 1990-2009. Prior to 1990, the literature offered little to no data. The search was restricted to studies published in English-language journals.

Then, we imported out those literature meta-data to Endnote X4® to facilitate the reading procedure. We also used other data sources (hand search on specific journals and communication to authors) to expand the scope of our research. The search procedure started out by reading each and every title of the papers (more than 2000 titles were read), if a title seemed relevant to our previously defined selection criteria, we included it into our second phase, if not, the study would be definitely excluded of the research. The second phase consisted in reading out each and every abstract of the previously selected studies (1922 abstracts were read), again, if the paper seemed relevant to our research it would go through phase 3. In phase 3, we read all studies selected in full-text (72 studies were fully read), all studies that matched our selection criteria went through Quality Assessment and finally all those which passed the quality assessment went to Data Abstraction and Analysis.A total number of 31 studies went through data abstraction and analysis.

The Framework for Innovation Systems

The final number of studies to be included in the qualitative synthesis was 31, out of the 31 papers, 14 of them proposed a whole set of components and relationshipsfor the innovation system. Based on the analysis of those 14 studies, data related to the most important components and linkages was extracted and synthesized in the form of a meta-model of an Innovation System – a representation of the key components and linkages that are needed for the system to operate.

We translate the components and relationships (constituents) found into specific attributes for each category. The resulting framework is composed of a *Financing and Funding component*, a *Science and Technology component*, a *Technological Production component*, a *Consumer Market component* and a *Science, Technology and Production Education component*. Figure 5 shows the five components mentioned above, illustrating the main relationships (in the form of financial and information/knowledge flows) between them.

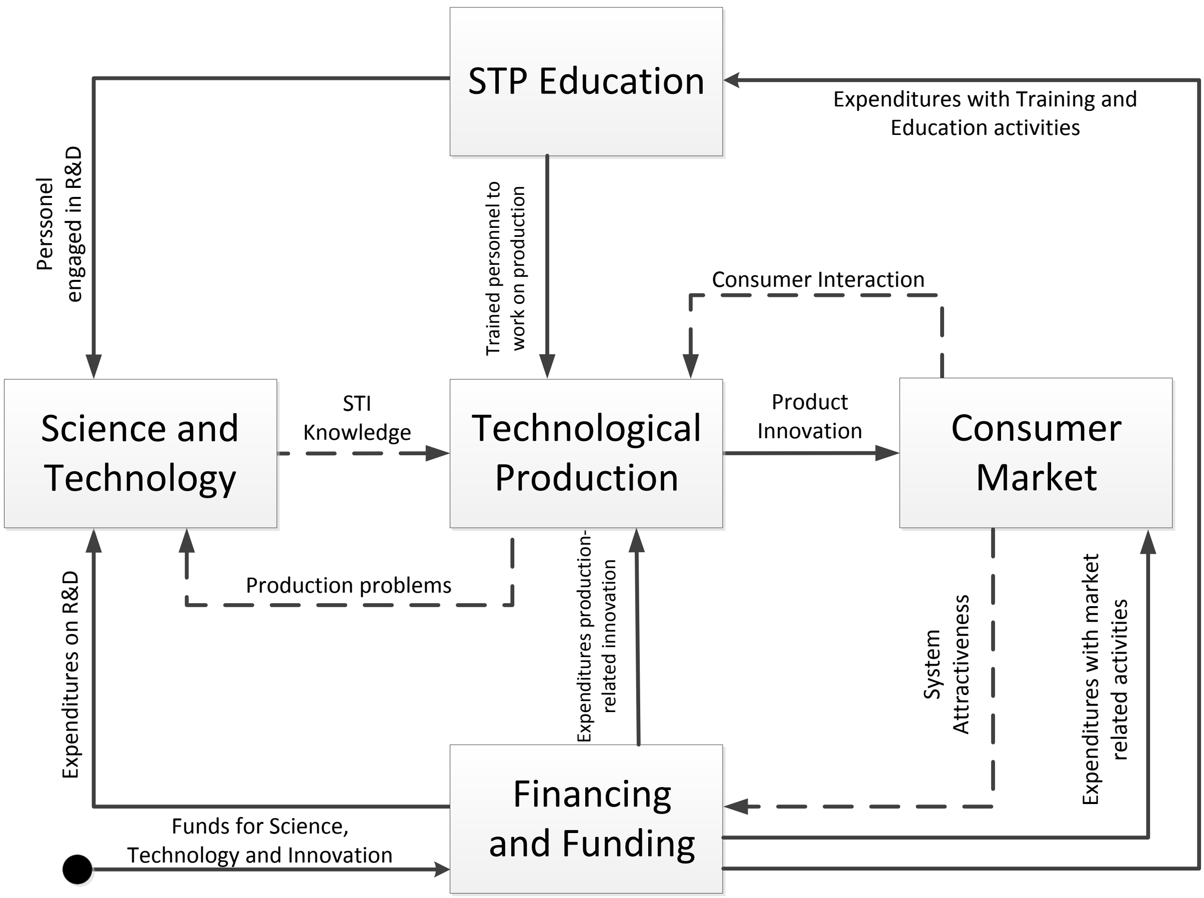

FIGURE 1 – Meta-model of an Innovation System

The components described in Figure 1 above do not group actors or institutions; its focus is on the specific atributesof the innovation system and the relationships between them. For example, different institutional actors within the IS are responsible for using and diffusing financial capital flows (be they banks, public funding agencies, firms, etc.) throughout the system; thus, financial capital flow can group activities such as Public R&D Expending, Private R&D Expending, Firm Expenditure on Machinery and Equipment, etc. as part of a *Financing Component*. Furthermore, institutional actors can be part of the remaining components if they perform functions related to their goals.

- **Financing and funding**: it is composed by financial resources used for loans and grants, which are typically found in public and private institutions like, commercial and investment banks, government innovation agencies, venture capital systems, the capital market and others. It is also related with funding directed for formal education on their various levels (primary, secondary and tertiary education). These agents produce different financial flows that are linked with the other components in the system.
- **Science and Technology**: It is composed by the pool of personnel engaged in R&D (like those engaged in Universities and Research Centers and those engaged within firms).
- **Technological Production**: It is composed by all the resources (financial and human) used to the innovation process, excluding R&D.
- **Education for Science Technology and Production activities (STP Education):** It is composed by the set of human resources with potential to participate on innovation processes, including science, technology, innovation, production and education dimensions.
- **Consumer Market:** it is composed by the set of national or foreign, final consumers, corporate, government and Third Sector. The exigency and competence level of buyers is decisive to the overcome new challenges of technological development. This explains the presence of a consumer market component as part of the system.

In the following sections, each component will be described, by detailing all the possible flows that form each arrow of Figure 1.

Financing and Funding

Access to capital is vital to supporting innovation in firms. Transforming ideas into commercial goods and services requires significant resources including, but not limited to R&D (C. Freeman, 1995). In this sense, the agglomerate of functions in the Innovation

System dedicated to drive financial capital flows within the system are vital for its performance (B. Unger and M. Zagler, 2003).

Funding sources can be private, like venture capital, bank loans, or public, like the case of publicly-funded R&D, taxes incentives, expenditures on educational system, etc... Both examples resemble an external source of funding, but firms also invest part of their profits on future internal innovation activities, suggesting internal sources of funding as well (P. F. Bittencourt, 2012, D. Walwyn, 2007). All of these types of financial resources are part of this component.

Out of the pool of studies accounting for a financial component, the literature offered several denominations, which are shown in Table 1.

TABLE 1. Financing and Funding component of an Innovation System

Financing and Funding Component	
Denomination	**Authors**
National, regional and other financial systems and institutions	(J. A. Johannessen et al., 1997, K. Mohannak, 1999)
Venture capital and government subsidies	(F. H. A. Janszen and G. H. Degenaars, 1998)
Financial Resources	(S. W. Hung, 2009, J. Z. Shyu et al., 2001, Yeoryios Stamboulis, 2008)
Capital Market (Financial Market)	(T. L. Lee, 2006, T. L. Lee and N. von Tunzelmann, 2005)
Public Finance and Private Finance	(T. Ahlqvist and T. Inkinen, 2007)

Source: Authors

Most of the studies proposed a financial component as part of the Innovation System. Despite differences in how they have been named, there is a high consensus that this component must be present on any IS.

Investment decisions and the flow of financial resources are determined by the amount of available information and by the capability of agents in absorbing it. Based on the previous sentence, we define the first inflow variable of this component is related with the attractiveness of the system. System Attractiveness (SAT) is in essence an informational variable (or a group of variables) capable of offering to investors (firms and government) with information regarding the performance (or perceived performance) of the innovation system. In this sense in National Systems, the amount of Foreign Direct Investments (as compared to other national systems) can be a result of system attractiveness, and in Sectoral Systems, the profitability levels of the sector (as compared to other sectors).

In terms of financial resources, we define three additional financial inflows: (1) self-investments on innovative activities, made by the firm who introduced process and product innovations and made profits from them – coming from the consumer market component – modeled as the variable Privately-owned Funding (POF); (2) represent external private funding sources available to firms within the innovation system (venture capital, commercial banking, stock market, etc.) named as Private-external Funding (IPR); and (3) represent external public funding sources (external to the innovation system boundaries) available to firms within the innovation system (development banks, innovation agencies, etc.), represented by the variable named as Government Funding (IPU).

In terms of financial and funding out flows, this component feeds four other components of the innovation system: Science and Technology (ST), Human Capital (HC), Technological Production (TP) and Consumer Market component.

In-House R&D Expenditures (IRD) and External R&D Expenditures (ERD) outflow to the ST component (sources of funding may be public or private as mentioned above). It also includes financial outflows to the Human Capital component, modeled by the variable Expenditure with training and education (EWT). Several other expenditures outflow to the Technological Production component, modeled as Expenditures with External Knowledge (EEK), with Software (ESO), with Machinery and Equipment (EME) and expenditures with other technical preparations and setup (EOP). In terms of outflows to the Consumer Market component it includes the variable named as expenditures with commercialization (EWC)[1]. Figure 2 shows the previously described variables and flows in graphical format.

[1] Those variables are in accordance with the Oslo Manual and are broadly researched on national innovation surveys

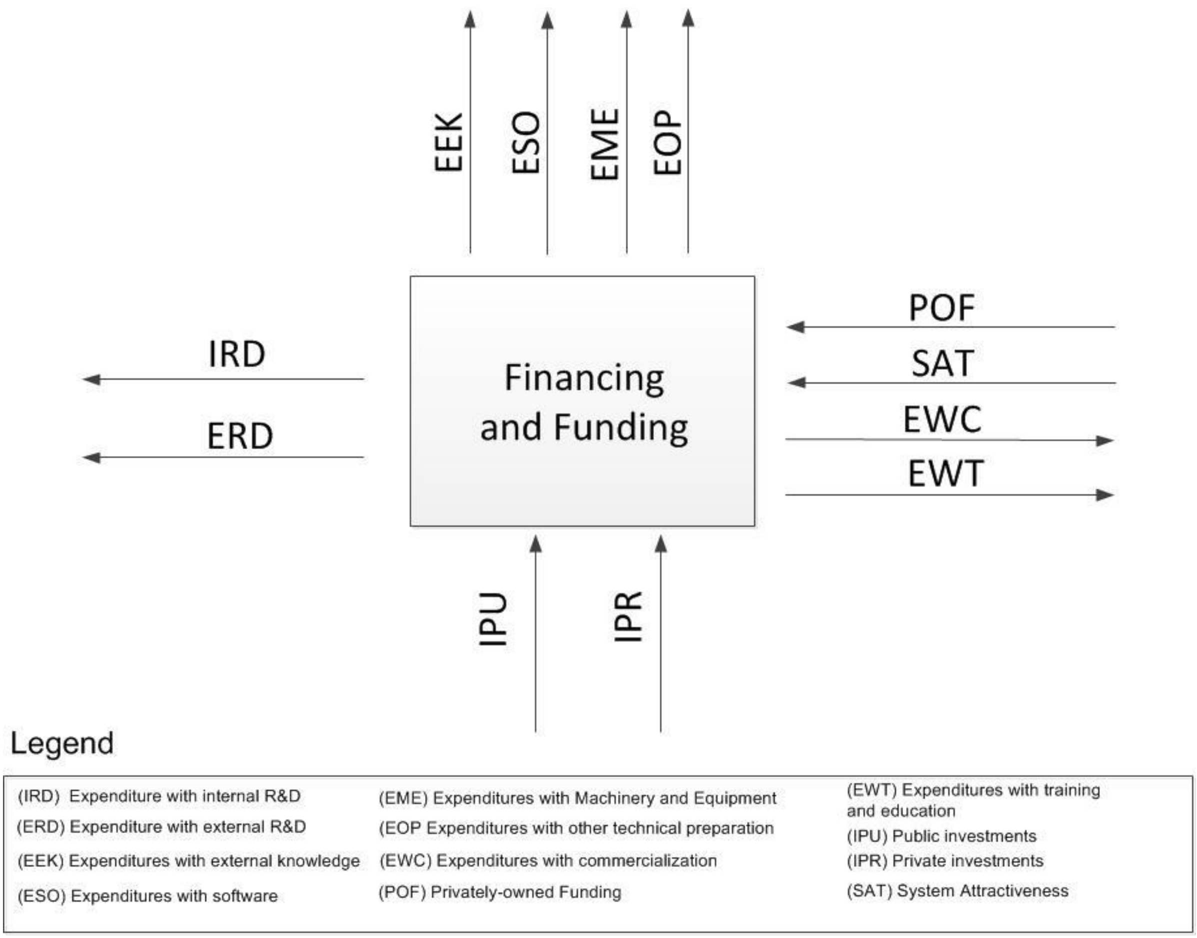

FIGURE 2. Financing and Funding Component – Main Flows

Science and Technology

Table 2 shows the different denominations found in the review of studies to name a scientific and/or technological component as part of the innovation system.

TABLE 2. Science and Technology component of an Innovation System

Science and Technology	
Denomination	**Authors**
Scientific and technological knowledge production system (research institutes and partly, firms)	(K. Galanakis, 2006, H. Hubner, 1996, S. W. Hung, 2009, J. Z. Shyu, Y. C. Chiu and C. C. Yuo, 2001)
Research and Development	(S. W. Hung, 2009)
R&D environments	(J. A. Johannessen, J. O. Dolva and B. Olsen, 1997)
Scientific subsystem	(F. H. A. Janszen and G. H. Degenaars, 1998)
Universities and higher degree institutions	(T. Ahlqvist and T. Inkinen, 2007, H. Etzkowitz and L. Leydesdorff, 2000, C. W. Hsu, 2005, K. Mohannak, 1999)

Science and Technology transfer	(T. L. Lee, 2006, T. L. Lee and N. von Tunzelmann, 2005)

In addition, several previous models have taken into account the importance of R&D activities for technological innovation. In the Chain-linked model for instance, S. Kline and N. Rosenberg (1986)highlight the importance of the interactions between the central chain of innovation and the scientific and technological knowledge base. Lee (2002) and later Lee and von Tunzelmann (2005)describe the inter linkages between R&D and innovation systems by highlighting its importance for product and process innovations. AndTayaran (2011) also links R&D effort with the absorptive capacity of firms to acquire external knowledge and with internal knowledge creation.

From a conceptual perspective, this component focuses on the accumulation of STI knowledge, thus becoming the core variable of the component. Two learning types, learning by internal search variable and learning from external advanced S&T – as proposed by P. F. Bittencourt (2012) - are taken into account to be part of this component.

According to P. F. Bittencourt (2012), learning by internal search refers to the internal research processes of firms when searching for solutions to their problems. In this article, internal search is defined as in-house R&D activities. On the other hand, for the author, learning from external advanced S&T refers to the acquisition of external R&D and other advanced S&T agents which can be applied to the problems firms face when developing technological innovation.

In addition, the levels of employment of personnel with advanced degrees and occupied in S&T activities is also a traditional indicator of STI knowledge (M. B. Jensen, B. Johnson, E. Lorenz and B. A. Lundvall, 2007). We have also included in our model however, personnel with other qualification levels engaged in S&T.

From a modeling perspective, this component interacts with three basic types of flows, knowledge flows, information flows and financial flows (Jorge Niosi, 2002). Knowledge flows, embedded in the qualified Human Capital that is engaged in STI activities (PhDs, Masters and Graduates); information flows from in-House R&D, Testing Centers, Universities and Research Institutes; and financial flows, from Firms investing on STI activities. A graphical scheme is presented in Figure 3.

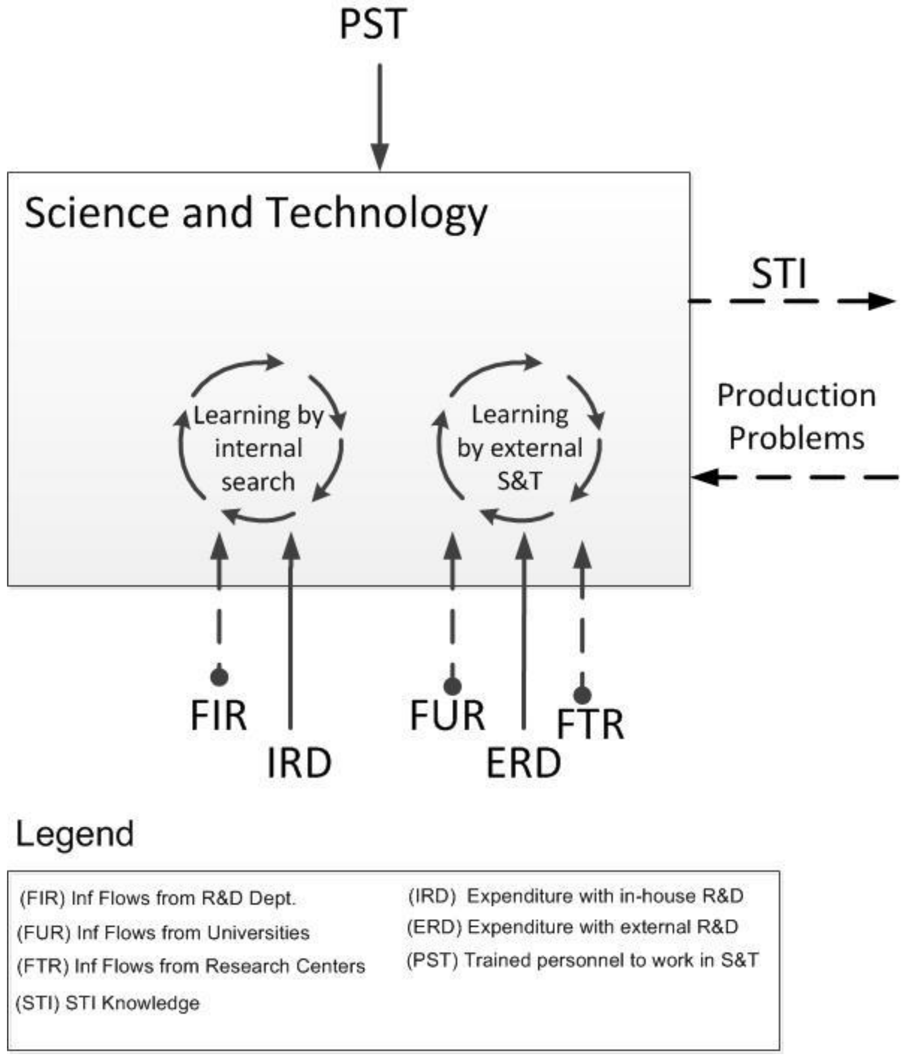

FIGURE 3. Science and Technology Component – Main Flows

According to Figure 3, the Science and Technology component receives knowledge flows from the Science, Technology and Production component, namely personnel to work in S&T activities, which can be holders of advanced degrees, undergraduate degrees and technical degrees. In this sense, we are referring specifically to human capital oriented to R&D activities.

For learning by internal search, the component receives inputs from in-House R&D information flows (FIR) and from expenditures with in-house R&D (IRD). For learning by external advanced S&T, the component receives inputsfrom information flows coming from universities (FUR) and from research centers(FTR) and by expenditures on external R&D (ERD).

The component receives all these flows and transforms them into STI knowledge, which outflows to the technological production component.

It is important to highlight that the adequate functioning of a component of the innovation system depends on its capacity to accelerate the information flows that are pointed out in our framework. In the case of the Science and Technology Component for example, an adequate level of science and technology knowledge (STK) does not only depend of personnel with technical, undergraduate and advanced degrees.

Technological Production

It refers to the resources used in productive and technological activities that translate into technological change of products and processes (OECD, 2005). It receives inputs from S&T components' knowledge, and translate them into innovation (B. Unger and M. Zagler, 2003), using as well knowledge from doing, using and interacting (DUI) sources. As M. B. Jensen, B. Johnson, E. Lorenz and B. A. Lundvall (2007)explains, DUI-mode is acquired "on the job", as employees face problems and on-going changes and that results in a higher level of tacit knowledge. Such interactions constitute additional technological opportunities for firms in the innovation system which can be exploited by collaborating and interacting with other actors outside the traditional STI context (Fulvio Castellacci, 2007).

Specifically, four latent variables from P. F. Bittencourt (2012)are taken into account to be part of the Technological Production component: learning by doing, learning by interacting, learning to learn and learning by imitating.

Learning by doing refers to learning from hands-on-the-job, as employees become experienced and increase the efficiency of their tasks(K.J. Arrow, 1962). The second variable, learning by interacting is composed by three types of learning: learning by interacting with customers, learning by interacting with suppliers and learning by interacting with others sources (P. F. Bittencourt, 2012).

Learning by interacting with customers represents the type of learning when firms interact with their customers. Fulvio Castellacci (2007)sustains that when firms build long-term stable relationships with their customers it creates a positive effect on market competitiveness. For the same author, learning with suppliers is also an important source of learning by interacting¸ especially in industries where the innovative process is strongly based on the acquisition of machinery and equipment, embodying more advanced technologies supplied by other industries. Finally, learning with other agents, represents learning processes from other external agents in which P. F. Bittencourt (2012)includes consulting firms, specialized conferences, etc.

The third learning type for DUI knowledge is learning to learn. This type of learning includes internal efforts of firms in training their human capital, which have been shown to have a positive effect on firm performance (M. Zack et al., 2009) and through external training expenditures, in professional training centers and alike.

The last learning type for DUI knowledge external acquisition is called learning by imitating, which P. F. Bittencourt (2012) describes as learning derived from imitating or reproducing innovations developed by other firms without cooperation with the innovator. Some mechanisms are included in this type of learning: patents and licenses, on the one hand and product imitation (through reverse engineering for example) on the other.

DUI knowledge and STI knowledge (from the Science and Technology component) build up what is called as the Innovative Capability of firms, the ability of the system to produce and commercialize a flow of innovative technology over the long term (Fulvio Castellacci and Jose Miguel Natera, 2013, J. L. Furman et al., 2002, T. L. Lee and N. von Tunzelmann, 2005). In this sense, the innovative capability of firms increases the product attractiveness of commercial products, which out flow to the Consumer Market component.

Table 3 shows the summary of studies that identified a production component as part of an Innovation System.

TABLE 3. Technological Production component as part of an Innovation System

Technological Production	
Denomination	**Authors**
Production System	(H. Hubner, 1996)
Industry and entrepreneurs	(H. Etzkowitz and L. Leydesdorff, 2000, C. W. Hsu, 2005, T. L. Lee, 2006, T. L. Lee and N. von Tunzelmann, 2005, K. Mohannak, 1999)
Product design and development	(K. Galanakis, 2006)
Industrial clusters	(S. W. Hung, 2009)
Private sector	(T. Ahlqvist and T. Inkinen, 2007)

From a modeling perspective, the component receives knowledge, information and financial inflows and transforms them into technological process innovations and technological product innovations, which flow to the Consumer Market component.

As mentioned before, DUI knowledge receives inputs from four types of learning, in the following paragraphswe will describe each one of the learning types. First, learning by imitating is composed of information flows from competitors (FCM), from patents and licenses (FPM) and expenditures to acquire external knowledge (EEK).

Second, learning by doing is composed of information flows from other internal departments excluding the R&D department (FOP), and by expenditures with other technical preparations (EOP).

Third, learning to learn feeds from information flows from professional training (FWT), and by expenditures with trainings (EWT).

Fourth, learning by interacting, is composed of information flows from suppliers (FSU), from customers (FWC), from consulting activities (FWO), from fairs and expositions (IFE) and from conferences (ICP). It feeds from financial flows, in the form of expenditures to acquire software (ESO) and machinery and equipment (EME).

All four learning types build up DUI knowledge and together with STI knowledge form the *innovative capability* of the firm (CAP), which increase the amount to product attractiveness (PAT), the information flow that feeds market decisions in the Consumer Market component. Figure 4 shows a more detailed schematics of this component.

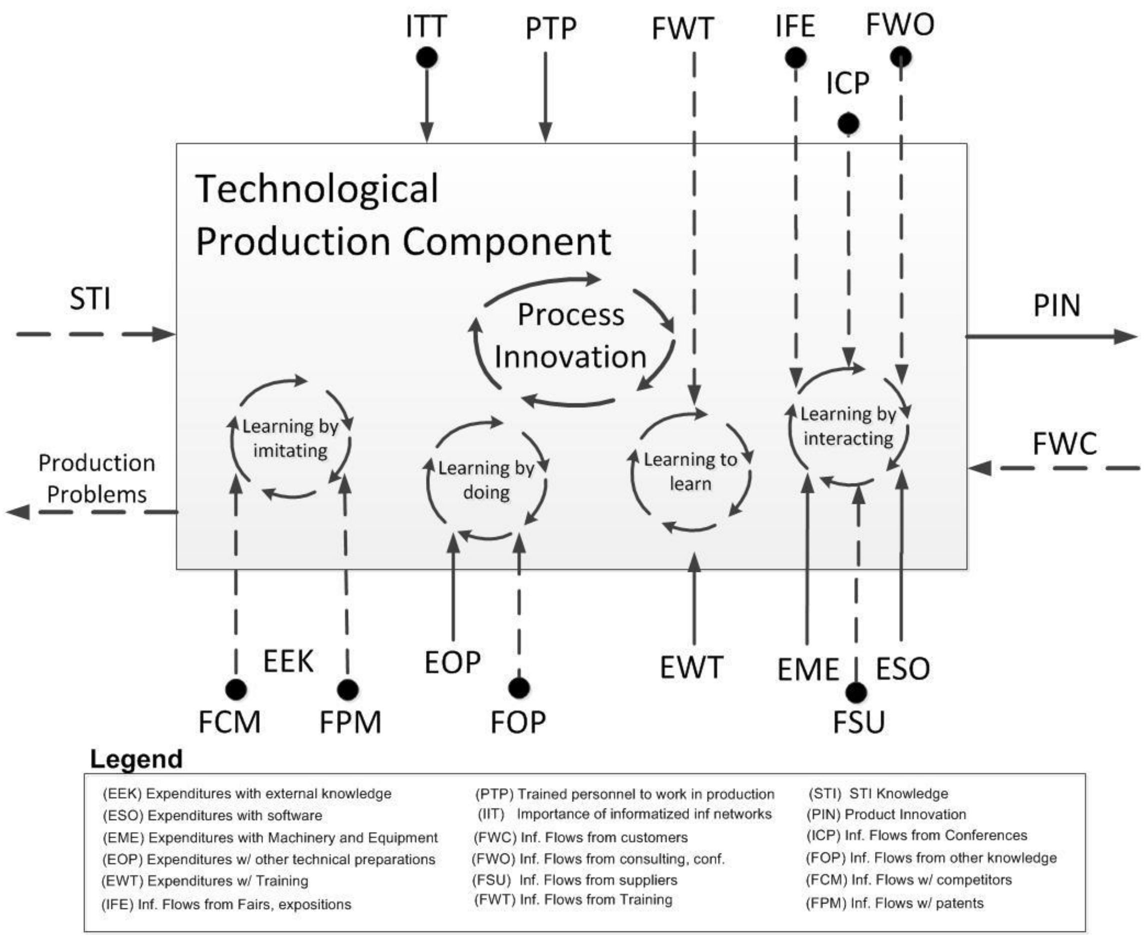

FIGURE 4. Technological Production Component –Flows.

Consumer Market

Innovations get into the market to generate profit in firms (Lee, 2006). This component represents the dynamics of the consumer market (domestic and foreign) which receives technological innovations from firms and accept them or not through diffusion processes.

Dynamics in markets determine many of the strategies related to technological innovation. To sectors for example, asFulvio Castellacci (2007) sustains, different market structures determine different innovative behavior. Ease of entry of new competitors (domestic and foreign) for instance, determines the behavior as well as the size of the current market. AsFranco Malerba (2006) points out, market dynamics can be generated from technological innovation and also from captive demand and consumer learning which may stimulate technological change and the entry of new firms. Moreover,Peter M. Milling (1996) suggests that differences in market structure also cause changes in management decision on investments on R&D and innovative activities and even changes in the rate of the diffusion of innovations.

It is also important to say that the market component includes private and public agents whom are composed by the consumers of innovative products, both individual and corporate and finally, domestic consumers and foreign ones. Table 4 shows several different denominations for the consumer market found on the literature.

TABLE 4. Consumer component of an Innovation System

Consumer Market	
Denomination	Authors
Product consumption system	(H. Hubner, 1996)
Economic competence	(J. A. Johannessen, J. O. Dolva and B. Olsen, 1997)
Consumer market (domestic and/or international)	(S. W. Hung, 2009, F. H. A. Janszen and G. H. Degenaars, 1998, J. Z. Shyu, Y. C. Chiu and C. C. Yuo, 2001)
Product Market	(K. Galanakis, 2006, T. L. Lee, 2006, T. L. Lee and N. von Tunzelmann, 2005)

The consumer market component receives product innovations (PIN) as a result of the technological production componentand financial flows in the form of expenditures with the introduction of innovations into the market (EWC). The component in turn, provides feedback about the attractiveness of products to the technological production component through customer interactions (FWC), an important source of information for the production of innovations (Fulvio Castellacci, 2007).

It also provides feedback to investors about the overall system attractiveness, linked with financial indicators such as revenues and profit margins (Fulvio Castellacci, 2007, F. Malerba and L. Orsenigo, 1993), as compared with other systems, through a flow named as system attractiveness (SAT) that links to the Financing and Funding Component. This feedback flow helps firms on their future investment decisions on the system and influences government decisions on maintaining, reducing or increasing expenditures or promoting incentives as well.Figure 5 shows the schematics of this component.

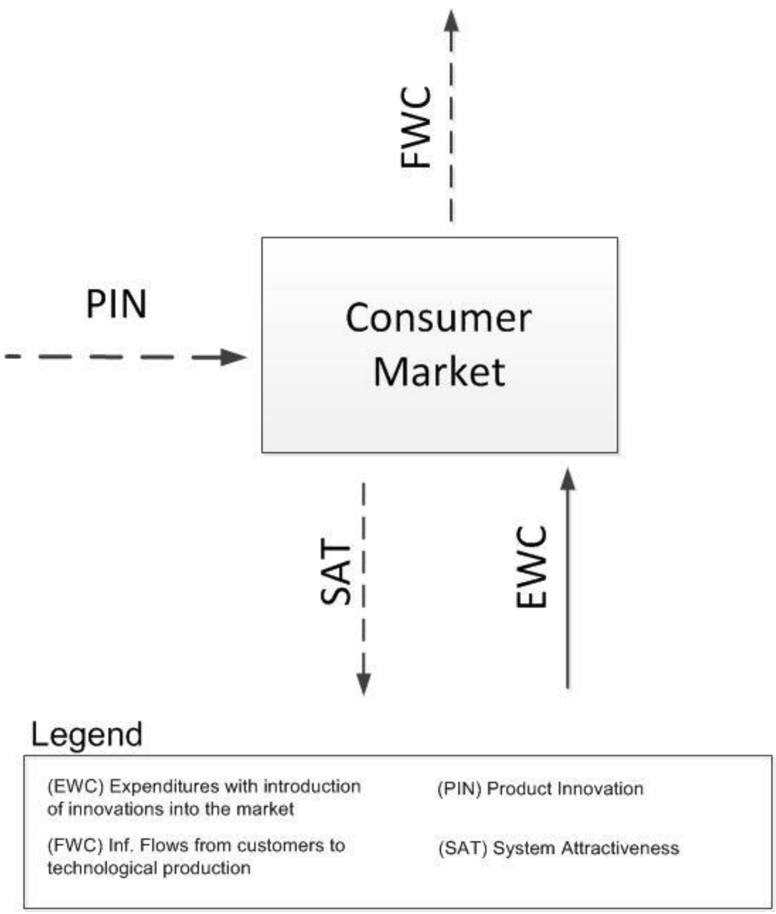

FIGURE 5. **Consumer Market Component – Main Flows**

Additionally, part of the impacts of innovations are also shown in Figure 5, which are related to specific impacts on the market, i.e. keeping or gaining market share.

Science, Technology and Production Education

Talented people generate the new ideas that drive innovation and represent the stock of embodied knowledge on the system. Formal education (technical, undergraduate and graduate) and training activities are important means for continuous learning and skill development(Council of competitiveness, 2005) for human capital.

Human capital is the firm's collective capability to solve problems by using its employees' individual knowledge (Nick Bontis, 1998), that is accumulated mainly through *learning by doing*, *learning to learn* processes, part of DUI knowledge and through *learning by internal search*, part of STI knowledge.

Human capital is also important for acquiring external knowledge and to make use of it in adequate manner, such a property, known as *absorptive capacity*(W.M. Cohen and D. A. Levinthal, 1990).

The degree of cumulativeness of previous knowledge - the extent to which current innovative activity is build up from previous knowledge (Fulvio Castellacci, 2007) - is also linked with the level of absorptive capacity, since the employees ability to acquire external knowledge depends on the amount of previous internal knowledge.

Moreover, current literature has suggested a relationship between education level and the creation of new knowledge (innovation). On the other hand, innovative activities foster skilled human capital demand (Fulvio Castellacci, 2007, Fulvio Castellacci and Jose Miguel Natera, 2013).

In this sense, the component aims at capturing all training and education activities in the system, including formal-like such as education at the technical, undergraduate and graduate levels in public and private institutions as well as training undertaken by firms. Table 5 shows some of the definitions found on the literature.

TABLE 5. STP Education component of an Innovation System

Human Capital Component	
Denomination	**Authors**
Workforce	(J. Z. Shyu, Y. C. Chiu and C. C. Yuo, 2001)
Human Resource Development	(S. W. Hung, 2009, T. L. Lee, 2006, T. L. Lee and N. von Tunzelmann, 2005, Yeoryios Stamboulis, 2008)

The component receives funding for training activities (EWT) from firms with the aim to improve their employees' competencies. It also receives funding from private and public agents investing in graduate and undergraduate education (EHE) and outflows qualified human capital with technical (POD), undergraduate (PUD) and advanced degrees (PAD) engaged in R&D activities in the science and technology component.

On the other hand, Human Capital contributes to the innovation system, with qualified staff with undergraduate and advances degrees, which are the enablers and creators of innovations.

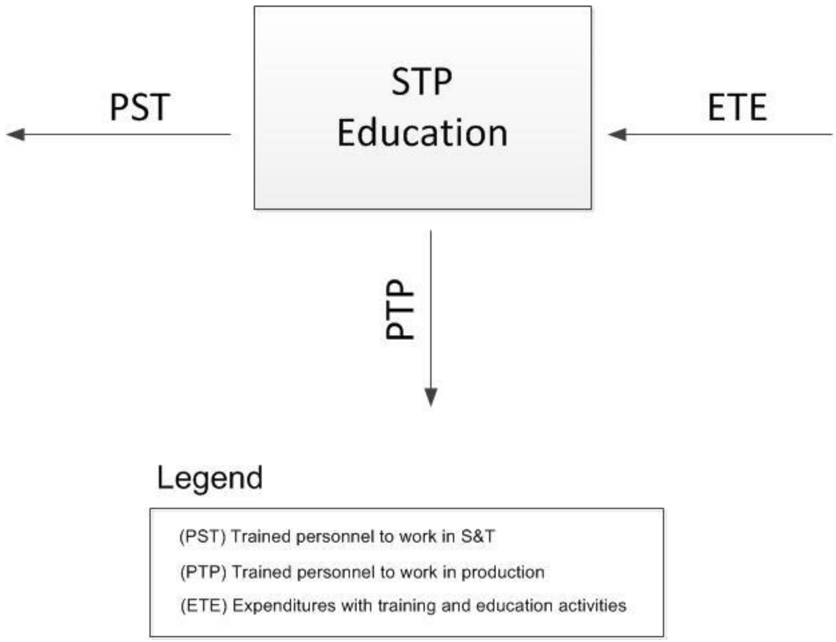

FIGURE 6. STP Education Component – Main Flows

Conclusions

This research deals with one of the main subjects inside IS literature, which is to find ways to properly represent Innovation Systems, considering their complexity in terms of dynamics, non-linear relationships and complex behavior.

Until now, the current development on this research stream has been unable to produce a generalization that could take into account the complexity IS represent and so this paper aims at making an extensive and exhaustive search – by means of a systematic review of the literature -- in several databases in order to find the models that have been proposed so farand synthesizes them into a single and novel framework.

The systematic review served to synthesize a large amount of previous models into a single meta-model, composed of a Financing and Funding component, a Science and Technology component, a Technological Production component, a Consumer Market component and a Human Capital component. Although it may be argued that the variety of models and modeling approaches are specific to each study and that in fact their diversity enriches the innovation systems literature, models are subject to bias, lack of knowledge and subjectivity. Thus, by using a logic and coherent meta-model – composed of a group of essential components and linkages – to design models, the subjectivity and bias problems would be dramatically reduced since there would be a logic to define what is actually contained in the model: the boundaries, the linkages and the components, and which actually may prove even more valuable than the current vast diversity of models out there.

In addition, the framework identifies that different types of learning activities affect different elements on the innovation system and that STI knowledge and DUI knowledge are the main knowledge accumulation mechanisms.

In synthesis, the framework describes in detail how knowledge and learning processes are linked to each other and how they affect the innovation system from a descriptive, yet static perspective.We argue that the constituents(components and relationships) are able to represent any type of innovation system (national, regional, sectoral, technological, etc.), only needing to be instantiated to the specific system in study.

As shortcoming, the framework does not have the ability to produce quantitative inferences and so the further step to improve this research will be to include quantifiable and measurable variables and indicators on the meta-model in order to make it operational.

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