Conceptual Underpinnings for Innovation Policy Design – Indicators and Instruments in Context

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Abstract

In cases where innovation indicators and data fail to serve properly as a (necessary) basis for the design of innovation policies, it often has its roots in conceptual unclarities in the underlying concepts. The aim of this paper is to provide a theoretical and conceptual basis for the design of innovation policy. This serves two important purposes. Firstly, it allows the identification of problems in an innovation system that require public policy intervention through the choice of appropriate policy instruments. Secondly, it allows a theoretically based identification of input indicators as determinants of innovation system performance to be used in cross-country analysis.

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1. Introduction

In cases where innovation indicators and data fail to serve properly as a (necessary) basis for the design of innovation policies, it often has its roots in conceptual unclarities in the underlying concepts. There is today a large number of datasets with multiple and sophisticated socio-economic indicators. However, the extent to which these indicators (on an individual basis or in aggregate indexes) are useful is highly related to the theoretical and conceptual basis behind them. Innovation policy design is the set of specific public interventions aiming at addressing concrete problems in the innovation system. The identification of these problems requires targeted and very specific analysis of the determinants of innovation processes, based on relevant and specific indicators. Likewise, at a more aggregate level, policy-makers need to have an overview of innovation systems' performance in their entirety, with a cross-country perspective. Several indexes on innovation performance have been recently developed by aggregating specific sub-sets of indicators to provide these broad comparative overviews. Yet, without a solid conceptual and theoretical basis, these individual or aggregated measurements are poor tools for policy-makers.

The aim of this paper is to provide a theoretical and conceptual basis for the design of innovation policy. This serves two important purposes. Firstly, it allows the identification of problems in an innovation system that require public policy intervention through the choice of appropriate policy instruments. Secondly, it allows a theoretically based identification of input indicators as determinants of innovation system performance to be used in cross-country analysis.

This paper proceeds as follows. The next section introduces the theme by presenting in a very succinct manner a specific approach on innovation system, based on ten activities or input determinants of innovation processes. This approach is the authors' theorising effort about innovation systems and their dynamics, which is done in the context of discovery and of a continuous development from previous theoretical work from institutional and evolutionary economics. The third section focuses on defining what are policy problems, and their two preconditions (additionality and the organizational capacity of public intervention). This serves to indicate that not all issues related to innovation are automatically subject to public intervention. The section after that focuses on the specific identification of policy problems in a system, and the choice of policy instruments hereto. This section distinguishes between policy-problems, the instruments chosen to address them, and the policy-generated problems (by ineffective policy instruments). Having seen these specific issues, the next section of the paper focuses on innovation systems' performance (in their entirety) and on the flaws of current aggregate indexes. These indexes suffer from a

series of flaws, which limit their ability to provide accurate and theoretically-based overview of the innovation system performance. Section six of this paper aims at putting together some general guidelines for the development of alternative indexes, which should be consistent with specific theoretical and conceptual-basis about the determinants of innovation processes. The last section summarizes the arguments and concludes with a plea. Future efforts must be done to link strongly the scholarly theorizing about the determinants of innovation system performance, and the constant empirical testing of these. Policy problems as well as the choice of policy instruments should be based (and be part and parcel) of the iteration between theory and empirical efforts.

2. Activities in innovation systems

The *innovation systems approach* was put forward in the early-mid 1990s and has diffused rapidly since then (Lundvall 1992) (Nelson 1993) (Freeman 1995) (Edquist 1997). This paper takes its point of departure in one variant of the systems of innovation approach, which is based on the identification of ten activities in innovation systems (which can be seen as determinants of innovation processes). As the notion of innovation system has been gaining track, several alternative definitions have emerged in the literature (See (Sharif 2006) and (OECD 2005) for useful reviews of different definitions).

Systems of innovation may be national, regional or sectoral. These three perspectives may be clustered as variants of a single generic 'systems of innovation' approach. (Edquist 1997a: 3, 11-12). Much of the discussion here is based on the premise that the different variants of the systems of innovation coexist and complement each other. Whether the most appropriate conception of the system of innovation, in a certain context, should be national, sectoral or regional depends, to a large extent, on the questions one wants to ask. (Edquist 2005, 2011).

Our definition of an innovation system is much broader and more general than other variants (e.g. Lundvall's and, especially, Nelson's).[1] It includes *all* determinants of innovation processes in the definition of an innovation system. At the same time the innovation system should not be considered as being the same as the whole economy or the whole society. It is much more sensible to limit the notion of innovation system

[1] Remember that definitions are not right or wrong, they are good or bad for certain purposes. The definitions that we have chosen, among a myriad of possible ones, suit our purposes.

to be constituted by innovations of various kinds and all the activities or determinants that influence their development and diffusion.[2]

Our definition is a *particular specification of the systems of innovation approach* where ten *activities* (or input determinants of innovation processes) define the dynamics of the innovation system (Edquist 2011) (Borrás and Edquist 2013). Here, innovation systems include "*all* important economic, social, political, organizational, institutional and other input factors that influence the development, diffusion and use of innovations" (Edquist 1997) pp: 11-12; (Edquist 2005): p.184. Hence, innovation can be seen as is the ultimate output, whereas the innovation system is formed by a set of input factors or determinants that influence such output.

The ten activities that form the input determinants of innovation processes and hence constitute the innovation system are the following:

1. The provision of research and development (R&D)
2. The building of knowledge competences through education, training and skills
3. The formation of new product markets (on the demand-side)
4. The articulation of quality requirements (on the demand-side too)
5. The creation and change of organizations (as constituents of an innovation system)
6. Networking
7. The creation and change of institutions
8. Incubation and acceleration of entrepreneurial and small firms
9. Financing innovation
10. Consultancy services

It is important to keep in mind that they are not ranked according to importance. They all together refer to different dimensions of input determinants of innovation processes, which complement each other in different ways, sometimes potentially overlapping and reinforcing each other, sometimes pulling in different directions as there are different types of innovation (process, product, etc.). Generally, for the sake of simplification, these 10 determinants might be clustered as:

[2] For a discussion of this definition and its specification in terms of 10 activities or determinants of innovations, see Edquist (2005: 183, and 190-191) and Edquist 2011.

I. Provision of knowledge inputs to the innovation process (e.g. research, education, training and competence development),
II. Demand-side activities (e.g. public procurement for innovation, or articulation of new product quality (or safety) requirements),
III. Support to key constituents in innovation systems (e.g. entrepreneurship, networking, creating and changing organizations, etc.), and
IV. Support services for innovating firms (e.g. financing innovation processes or incubation of innovative firms).

As made clear above, our approach is to focus on the *activities* in the systems of innovation (rather than on the components in the systems). This means, ours is a dynamic perspective. This is so because we address the changes associated to some input factors, for example, we address the *creation and change* of organizations and institutions, rather than organizations and institutions *as such*. Moreover, we focus systematically on the character of the *division of labor* between private and public organizations with regard to who performs which parts of each of the activities.[3] Such a focus is necessarily also dynamic, since this division of labour might change through time and across countries. Hence, our focus on 'activities' within systems of innovation emphasizes strongly what *happens* in the systems – rather than their components. In this sense the activities approach provides a more *dynamic* perspective, and can capture how various activities that influence specific innovation processes may change the performance with regard to these innovations – and thereby how the whole system changes.

For that reason, this list of ten activities should be seen as an effort of theorizing about innovation systems their dynamics, particularly focusing on identifying a set of input determinants of innovation process. In other words, the list is the theoretical effort of the authors of this paper, putting some order in a series of dispersed factors previously identified by the rich literatures of evolutionary and institutional economics of innovation. As any theorizing effort in the social sciences, it is done in the context of discovery, based on organized observation and in a form of pre-study (Swedberg 2012). This list of ten activities as a synthetic effort of organizing the set of input determinants of innovation processes in an innovation system. For that reason, we treat this list (and the arguments linked to each of them) as being necessarily a preliminary and hypothetical exercise, which will be subject to analysis (and contestation) in future empirical research. Given the iterative nature of any theorizing effort in the social sciences, this list will certainly be revised when our knowledge of the determinants of innovation processes improves with time.

[3] This division of labor is important since innovation policy is defined as actions carried out by public organizations that influence innovation processes.

Nonetheless, at this point in time, this list can be used as a theoretically and observation-inspired checklist or signpost to discuss in an orderly and logic manner the input factors that most likely affect innovation processes. This is important, as innovation processes are very complex, and hence are influenced by a variety of factors. Among other things, the list can serve as a tool to avoid some tendency towards simplistic monocausality, i.e. an overly strong emphasis on one single activity (most typically, research or seed funding), to the neglect of other equally important input factors (like education and training, or demand-driven formation of new product markets). This neglect of key input factors is problematic when attempting to causally explain innovation outputs through limited metrics (Edquist 2014), and when designing innovation policy through the choice of innovation policy instruments (Borrás and Edquist 2013).

Moreover, and following from the above, the list is useful for identifying problems in innovation systems, which thereafter might be addressed by a careful selection of innovation policy instruments. If the main cause of a problem is lack of research, then R&D should be in focus. If the cause is lack of demand for certain kinds of product innovations, then a demand-side instrument such as public procurement for innovation can be used. All the ten activities can be related to several innovation policy instruments (Borras and Edquist, 2013).

Before continuing we need to stress that the pursuit of innovation policy should be theory- and evidence-based to the largest possible degree (depending on the state of the art with regard to the existence of theory and data). The question is then how these theories and data are created, and on what bases. This is an important topic all through this paper.

3. What are 'policy problems'?

The design of innovation policy shall focus on solving and addressing problems in the innovation system. For that reason these problems must be *identified*. Policy problems are those problems that should be mitigated or solved by public intervention by means of innovation policy. The question is then how can this be done.

There are two initial sub-questions here:

1. What is a 'policy problem'?

2. How can we identify the policy problems?

A quick glance at the ten activities specified above reveals that each of them is normally performed partly by private organizations and partly by public organizations.[4] Since innovation policy is actions by public organizations that influence innovation processes, policy is a part and parcel in the ten activities. Naturally, the division of labor between the public and private realms varies between countries/regions, and changes over time. From the current perspective innovation policy is the set of public interventions on behalf of the public interest that are directed towards influencing the context in which firms and other innovators operate. In other words, innovation policy is about influencing the input determinants of innovation processes that take place in an economy and society.

Why and in which situations should innovation policy be pursued and when should it not? Two preconditions must be fulfilled for there to be reasons for public innovation policy intervention in a market economy:

(1) Private organizations must prove to be unwilling or unsuccessful in achieving the objectives[5] formulated; a *policy problem* must exist;
(2) The state (national, regional, local) and its public organizations must also have the *ability* and organizational capacity to solve or mitigate the problem, as well as to learn from past experience (Borrás 2011).

A *policy problem*, in our sense - i.e. from a policy point of view - has to do with a series of possible negative situations, the most obvious of which is (a low) *performance* (efficiency, productivity) of the innovation system in economic terms. However, it might as well be related to problems associated with conditions that distort the achievement of specifically defined policy goals for innovation policy, like improving public health, security and defense, or environmental protection. As we shall see in the next sections, the *explanations* of that possible (low) performance are also crucial for the design of innovation policy. (Edquist 2011, section 3). We will return to the issue of performance of innovation systems below.

The precondition of *additionality* is a matter of the division of labor between what private organizations are carrying out in innovation systems, and what is carried out by means of policy intervention. Innovation policy is sometimes needed, but must not replace, duplicate, or crowd out what private actors can do. Public action should *supplement* private action. An important source of problems, might be generated by

[4] However it is seldom that an activity is performed by private or by public organizations exclusively. It is a continuum: both private and public organizations are normally involved in the performance of each activity.
[5] To simplify, we are here assuming that the innovation policy objectives are formulated in terms of innovation intensities for certain kinds of innovations, in a political process, normally not - or only to a very limited extent - by analysts.

policy itself when the additionality precondition was not fulfilled.[6] Lack of additionality has potentially several roots, most likely related to the lack of previous analysis and careful discussion of reasons for public intervention.

Innovation policy's main purpose is to influence positively the context in which innovation processes take place. Accordingly, when examining the problems, (deficiencies, tensions and imbalances) that might plague the innovation system, we shall not disregard the problems that are generated by the negative effects (or lack of any effect) of public-policy initiatives themselves.

For that reason, problems in the innovation system might be those related to some specific socio-economic or technological dynamics, as well as those related to unfocused, ineffective or too expensive public policy itself.
This calls for more effort into analyzing the problems in the innovation system and the potential solutions that might come from public action, securing the effectiveness of innovation policy as well as its additionality. This requires a solid conceptual and theoretical framework to provide underpinnings of such analysis, ultimately guiding policy decisions when devising and re-shaping relevant policy instruments.

4. Identifying Policy Problems & the Choice of Instruments to mitigate them

When we know the policy problems in a system of innovation, we want to use policy instruments to do something about them, i.e. we have to select policy instruments to do so. Hence, we have to know the causes of the policy problems beforehand in order to be able to select policy instruments intended to mitigate or solve them. We are aware that theorising about possible causal explanations in the social sciences is a demanding task. Actually this relates back to our specific version of the systems of innovation approach and the ten activities in innovation systems which we consider to be inputs or hypothetical determinants of innovation processes.

Following from the discussions in the preceding sections, and from our previous academic work on each of these activities, we have identified three separate items. Admittedly, these are interrelated, yet a conceptual separation is a necessary and important task in our current effort of theorising because these are neatly distinct in the logic of our argumentation. Besides, we see that the literature has sometimes treated them as one and single item, generating confusion about the directionality of interactions, and hence providing poor analytical guidance (see below).

[6] We could give many, many examples here. On is that practically all state risk capital funding in Sweden was allocated to late stages in the innovation and firm building process – where plenty of private capital was available.

The first item has to do with the policy-related problems that most typically afflict innovation systems. Here we refer to situations in which it is possible to identify bottlenecks, deficiencies or weaknesses, which are conceived as problems in relation to the expected dynamics and processes of innovation. We call them "policy-related problems" because to be policy relevant in a real-life context they should be able to comply with the two preconditions mentioned above: the additionality of public intervention and governmental capacity to address the problems. Naturally, from the theoretical and conceptual perspective, when looking at each of the ten activities in the innovation system that characterize our input determinants of innovation processes, there is a long list of possible policy problems. Some useful examples are the following. Education, training and skills development is a fundamental activity in the innovation system because the creation of individual-level knowledge competences is a key input determinant for innovation processes. One of the problems that might require policy intervention is when there is a strong time-lag between firms' short term needs on the one hand, and the long term development of skills & knowledge in the labour market on the other. Policy intervention securing a long-term supply of knowledge skills might be warranted in contexts where this gap becomes a problem for innovation processes. Another conventional problem possibly subject to policy intervention, which is again related to education, training and skills is the insufficient level of knowledge competences due to the brain drain of skilled workers (Borrás and Edquist 2015).

The second important item in our conceptual work is to identify the policy instruments most commonly put forward by governments in trying to address these and other policy related problems. Evidence shows the great diversity of policy instruments currently deployed by governments in pursuing different areas of the innovation system. These can be organized following the areas in which they operate (the ten activities) and their overall nature, providing an encompassing matrix about the deployment of policy instruments (Borrás and Edquist 2013). A recent and excellent review has collected the spread and still limited in-depth evidence that is currently available about their relative impact (Edler, Cunningham et al. 2016). In the daily basis of policy making and policy design, the choice of instruments is however far from being driven by an explicit formulation of goals and targets. Oftentimes, instruments are not design with a particular problem in mind, identified and analyzed accurately beforehand. Rather, they might be the fruit of inspiration from other governments' similar interventions, and are chosen on the basis of very generic and insufficiently analysed rationales for intervention. This leads to our next item.

The third item in our conceptualization of policy problems and instruments is the set of policy-generated problems. That is, problems that are generated by the inefficiency, inaccuracy or poor implementation of innovation policy instruments themselves. Following our example from before, it might be so that education and training policy

interventions are implemented using old-fashioned pedagogic methods which are not appropriate for developing knowledge competences needed in the society and economy of the XXI Century. Curricula development and pedagogical methods are a source of intense debates, yet some important dynamics and transformations of educational systems created in the late XIX Century are (have been or must be) undertaken to generate individual knowledge and skills in the innovation context of current times. Policy-generated problems emerge when the policy instruments put in place are insufficient, inefficient or directly against achieving expected outputs. Unclear policy goals in the initial definition of the instruments, poor analysis of real-life problems in the innovationsystem, or uncritical evaluation and assessment of the instruments' true impacts, are behind these policy-generated problems.

As mentioned above, there are many different possible policy-related problems, policy instruments and policy-generated problems. We have been identifying and distinguishing those in a series of previous conceptual works, which cannot be discussed here in detail due to space limits (Borrás and Edquist 2015) (Borrás and Edquist 2014) (Borrás 2016) (Borrás and Edquist 2016) . The table in the Appendix 1 is a summary of these three items, in the attempt to provide a theoretically-inspired and clear conceptual logic about what can go wrong (problems) and what can be done from innovation policy perspective (instruments) about the input determinants in innovation systems.

Why is this three item conceptual distinction relevant? For two fundamental reasons. Firstly, it is our impression that the literature has tended to disregard some policy-related problems (for example, those related to education and skills) to the expense of others (for example, private underinvestment in R&D activities); and it has tended as well sometimes to put the chariot in front of the horses by focusing excessively in some policy-generated problems (for example the possible crowding out effects of some public venture capital instruments) to the expenses of identifying and analysing the policy-relevant problems in the same area (for example, in most countries, the policy problem of critically low demand of venture capital associated to poor levels of entrepreneurship activities). Distinguishing between these items allows analytically to disentangle what is what (what is a problem in the innovation process, what is an instrument, and what is a problem generated by ineffective policy instruments). Secondly, and equally important, this three item distinction combined with the ten activities (from our theorising effort about the input determinants of innovation processes), provides an encompassing view of items that are (or must) be the attention of policy analysis as well as of policy-makers. This permits finding unexamined and under-analysed areas of public intervention in the scholarly literature, as well as possible gaps in real-life policy design.

5. On Innovation Systems' Performance and the Flaws of Current Indexes

Let us return to the issue of *performance*. Innovation systems, being at the national, regional or local level have all idiosyncratic features. This means that the identification of policy problems (including policy-generated problems), as discussed above, is an issue highly related to these idiosyncratic features. Yet, a high level of diversity does not render cross-region or cross-country comparisons futile or irrelevant. Different innovation systems might perform well or less well in some of the ten activities above, and might have successful (or less successful) policy instruments to mitigate their respective problems. Consequently, comparative analysis is highly relevant in order to continue the theorising efforts and a better understanding of what and how these systemic features and specific activities affect innovation. Likewise, comparative analysis is a useful way of learning from other countries' successes and failures in terms of policy instrumentation and policy design in general.

Comparative analysis can take many forms, using qualitative as well as quantitative methods. For the second one, it means that comparative analysis needs to measure innovation intensities for the input determinants of innovation, as well as for innovation outputs[7]. In addition, the data has to be comparable between countries or regions (systems of innovations). It is worth noting that the notion of optimality is irrelevant in an innovation context and in comparative analysis, as we cannot specify an optimal or ideal innovation system, given the idiosyncrasies of all of them. Empirical comparative analysis in the social sciences acknowledges the theoretical assumptions as analytical guidance from the conceptual framework (based on specific attributes), but does not see these assumptions as normative commandments pursuing a single universally optimal ideal model (Goertz 2006) (Collier and Mahon 1993). Instead, comparing innovation systems with each other allows the empirical iteration necessary in the social sciences for theorizing endeavors (Swedberg 2012), and is also a feasible way to identify problems in the innovation system that should be the subject of policy-making and design (Edquist, 1997, 2005, 2011).

Measuring innovation (of various kinds of innovations) means that we need input indicators (the determinants of innovation processes) as well as the output indicators about what 'comes out' of the innovation system. Developing these input and output indicators, and defining comparable data sources is key to achieve the double tasks of comparative analysis (mentioned above). However, and most importantly to achieve that, is the need to use those indicators in a theoretically and conceptually consistent manner, acknowledging fundamental assumptions associated to innovation processes in accordance to current theoretical frameworks. Unfortunately this theoretical

[7] Hence, we need to develop taxonomies or classifications of innovation outputs. We do not pursue this in the present paper, but have done so to some extent in Edquist (2011).

consistency is not entirely respected today by some of the existing cross-country comparative indexes.

We have stressed that it is crucial for innovation policy design to be able to measure innovation output. However, just measuring it, is not enough. The reason is that the same innovation output can be achieved with a lot of resources or with a small amount of resources. If two systems are having similar innovation outputs, but one of them achieves that with much less input resources, the latter one performs better which means that it is more efficient or more productive. This means that the output of innovations must be related to some measure of the input of resources used to produce innovation, in some sort of productivity measure. This measure must be seen as an aggregate indicator of the overall performance of the innovation system in terms of the relationship between the amount and relative performance of its inputs, and its output(s).

Unfortunately, most of the current aggregate innovation indexes developed during the past few years for cross-country comparisons fall short of following this theoretically-based input-output logic. This is the reason behind the increasing attention and growing discontent with these aggregate indexes. In their recent review, van Beers and others have examined the structure of innovation indicators on three dimensions: the aggregation level at which the measurement takes place, i.e. the micro vs. macro levels; what is actually measured, more concretely whether the indicator distinguishes between input and output indicators; and the kind of data the measurements are based on (objective or subjective data) (van Beers, Havas et al. 2015). Their critical assessment of each of these indexes has several remarks, but they coincide to a larger or lesser extent in blurring the input and output dimensions of innovation, and/or in selecting specific measurements of input and output that are unclear in theoretical or conceptual terms.

In a recent study, we illustrate this point of input-output dimensions by addressing and assessing one particular indicator – the Summary Innovation Indicator (SII) of the Innovation Union Scoreboard (Edquist and Zabala-Iturriagagoitia 2015). This is an index developed by the European Union, which serves as a tool to monitor on an annual basis the relative innovation performance of each EU Member State. It is formed by 25 specific indicators, and is used in order to rank EU countries by order of performance. In this particular index, the higher the value, the better performance (European_Commission 2015). The assessment of the SII reaches the conclusion that this index does not measure innovation performance in any meaningful theoretical or

conceptual sense, and for that reason, it is a poor tool for guiding innovation policy design (Edquist and Zabala-Iturriagagoitia 2015).

The problems are essentially two. Firstly, the SII makes no distinction to show whether the 25 indicators reflect (a) innovation inputs, (b) innovation outputs, (c) indicators measuring intermediates between the previous two, or (d) consequences of innovations. The second problem is that all 25 indicators used in the index are given the same weight. Therefore, the IUS draws the conclusion that the country with the highest average score for the 25 indicators (i.e. highest SII value) is also the best innovation performer regardless of whether the sub-indicators with the highest value measure the input or output side of innovation - or something else. The SII score will increase if a country puts more (input) resources into its innovation system (e.g. R&D investments), regardless of how the resources are used or which the (innovation) output might be.

In economic theory productivity is generally defined as the ratio of output and inputs used in the production process (i.e. output per unit of input). This is the case of labor productivity, which is the total production (output) divided by number of employees (inputs). The Summary Innovation Indicator (SII) uses no nominator and no denominator in the calculation of innovation performance, as it puts input and output indicators in the same index. Consequently, the index does not follow the basic theoretical assumptions for measuring ”innovation performance”.

6. Towards A General Alternative Use of Innovation Metrics

In view of the generic problems with composite indexes above, recent efforts have been devoted to develop alternative forms of analyzing and measuring the performance of innovation systems. One of the earliest efforts in this direction was at the regional level (Zabala-Iturriagagoitia, Voigt et al. 2007), and have been followed by other regional composite indexes focusing on different regional typologies according to diverse patterns of knowledge-innovation nexus (Capello and Lenzi 2013).

Whereas the above are useful steps, a major effort to bring forward a generic model for estimating the performance of innovation systems is still needed. This is the purpose of a current work developed by Edquist and Zabala-Iturriagagoitia, aiming at developing an alternative approach to the one used by SII by using exclusively the data provided by the Innovation Union Scoreboard publications of 2014 and 2015 to assess and compare the performance of all EU28 European national innovation systems (Edquist and Zabala-Iturriagagoitia 2015). That paper reexamines these data

using an approach which follows the performance approach of economic theory as discussed above. In so doing, that paper discusses the theoretical reasons for selecting some specific indicators among the 25 of the SII.

More concretely, the study singles out a number of input (n=4) and output (n=8) innovation indicators from the 25 included in the IUS editions of 2014 and 2015.[8] They are used to compare the innovation outputs with the innovation inputs of each of the EU28 countries (i.e., the relationship between the innovation inputs and outputs). Such a ratio shows how efficiently countries or systems use their innovation inputs. Finally, that paper compares the new ranking of countries, with the ranking provided by the Innovation Union Scoreboard. This final comparison results in a different ranking of the performance of the innovation systems of the EU Member States. The two rankings are negatively related to each other.

Naturally, this alternative has to be refined and developed in future research. The current use of only 4 indicators on input, is naturally not satisfactory. There are, of course, other determinants of innovation processes. The list of ten activities mentioned above in this paper would be an obvious start, as is an orderly conceptual and theoretical approach to these determinants in innovation systems, linking back to the extensive scholarly debates on these matters (Furman, Porter et al. 2002)(Ergas 1984). Ideally a theoretically-inspiredindex on innovation system performance should include *all such determinants* as input indicators. That would provide a fully articulated systemic and holistic approach in which all determinants of innovation processes, the feedback loops that make the analysis non-linear, and in which the relative importance of the different determinants of innovation processes were accounted for (Edquist 2014).

In the Oslo Manual, innovation inputs refer to the resources (human, material, financial; private as well as governmental) which are used not only to create innovations but also to bring them to the market (OECD/Eurostat 2005). That serves as a useful starting point, and therefore the next step would be to create measurements that include *all* determinants of innovation processes, as the inputs for innovation processes listed in a previous section of this paper. This would allow moving along the trajectory of building a holistic innovation system and innovation policy theory.

If all innovation input and all innovation output indicators were available and included, we would be able to calculate something corresponding to *total* factor productivity (or multifactor productivity) for innovation systems.

[8] The four input indicators were public R&D expenditures, private R&D expenditures, venture capital and non-R&D innovation expenditures.

7. Summary and Conclusions

In this paper we have addressed the needs for indicators and data for the design of innovation policy and its relations to conceptual and theoretical matters. The pursuit of innovation policy should be theory- and evidence-based to the largest possible degree (depending on the state of the art with regard to the existence of theory and data). The question is then how these indicators (single and aggregated) must be used, on what theoretical basis, and how does this interact with the scholarly endeavor of empirical testing and further theorisation.

Our theoretical framework is a *particular specification of the systems of innovation approach* where ten *activities* (or determinants of innovation processes) define an innovation system together with the innovations as such (see section 2). This holistic approach is very different from the linear model, and from some other specifications of the systems of innovation approach (Edquist 2014).

Why and in which situations should innovation policy be pursued and when should it not? The *reasons* for public policy intervention in a market economy, i.e. the *preconditions* for public policy intervention, may be specified as follows:

(1) Private organizations must prove to be unwilling or unsuccessful in achieving the objectives formulated; a *policy problem* must exist;

(2) The state (national, regional, local) and its public organizations must also have the *ability* and organizational capacity to solve or mitigate the problem.

Adaptive policy-makers, as Stan Metcalfe defined them in the mid-1990s, are those who seek developing policies that are able to make the system adapt and change (Metcalfe 1995). This can only been done if policy-makers understand the specific the problems that afflict their innovation systems and their causes. Thus, ideally, innovation policy design is based on the identification of these concrete problems given (and respecting) the idiosyncrasies of that system. Public intervention might seeks the mitigation of those problems, but it is not free from its own failures, as poorly designed instruments can easily become a problem on their own.

From our perspective, a *policy problem* is related to a specific bottleneck, deficiency or ineffectiveness of a determinant in the innovation system, as conditions that distort the achievement of purposely defined policy goals. Taken collectively, and from an aggregated way, the performance of an innovation system is related to the ratio of inputs to outputs.

We argue in this paper that innovation indicators should be used in a way that truly provides a theoretical-based clue for innovation policy design. This has to do as much with the use of these indicators for the individual identification and analysis of specific problems in the innovation system; as with the use of these indicators in composite and aggregate indexes that provide a comparative overview of the entire innovation system's performance.

We have put forward a detailed, yet summarized, overview of policy problems, instruments and policy-generated problems which are associated to each of the ten activities or input determinants in the innovation system. This provides a solid basis for understanding the complexities of innovation processes, but also to develop further the conceptual basis for careful policy-analysis at concrete countries or regions. The appendix summarizes those.

Likewise, indicators are key for broader considerations regarding the overall performance of the innovation system in terms of input-output ratios. Here the paper has presented a recent critical study of the limitations of the Innovation Union Scoreboard, and in particular its SII (the Summary Innovation Index) as developed by the European Union in 2014 and 2015. The study shows that the index is too poor an analytical tool because it does not distinguish inputs from outputs and puts them together in one single measurement. Disregarding theoretical issues about performance in economics, and about input-output concepts in innovation systems' approaches, aggregate indexes run counter their own intentions of providing policy guidance.

All this brings us to make two interrelated pleas. The first one has to do with the use of indicators by policy-makers. The use of specific indicators should be used to help identifying concrete policy problems in the innovation system, before designing or re-designing innovation policy instruments that are truly able to re-dress mal-functions and bottlenecks. These indicators should also be used into aggregate indexes, in a way that follow well-developed theoretical frameworks, so that the indexes provide consistent and solid overall views and comparisons about the performance of innovation systems in their entirety.

The second plea is that future research efforts must strive to link much more strongly the abstract endeavours of theorizing about the determinants of innovation systems, together with concrete empirical testing of these determinants (using specific sets of relevant indicators). This iterative process between theory and empirical testing is the keystone of social sciences' progress. The scientific study of policy instruments is an essential element of this iterative process. Not only because policy instruments (as the tools governments use to solve policy problems) are objects of scientific study on their own right; but also, and perhaps most importantly, because they are the cornerstone for making social sciences' research results more relevant for real-life policy-maker.

Appendix 1: Policy Problems and Innovation Policy Instruments to Mitigate Them

AREAS of the INNOVATION SYSTEM	POLICY-RELEVANT PROBLEMS IN THE INNOVATION SYSTEM	COMMONLY USED POLICY INSTRUMENTS	POLICY-GENERATED PROBLEMS
Knowledge Creation and Research & Development	Insufficient private investment in R&D. High uncertainty Large time lag between invest and returns.	'En block' support Competition-based public support. Tax incentives. Intellectual Property Rights. Public-Private partnerships.	Lack of additionality and crowding out. Public R&D support does not promote disruptive knowledge. Unbalanced public support between curiosity-driven R&D and strategic R&D. Focus on the quantity not on the quality of R&D.
Education, training and skills	Insufficient skills & competences due to low levels of education or/and brain-drain. Time-lag between firms' short term needs, and long term development of skills & knowledge. Dependence on foreign knowledge competences	Regulation, organization and funding of the education systems including vocational training. Migration policies (including reverse brain drain instruments).	Old-fashioned pedagogics & not developing knowledge competences for XXI Century. Insufficient & inflexible vocational training.

Formation of new product markets & quality requirements **(Demand-side)**	Lack of innovation dynamics in the economy and in the public sector. Technological lock-in. Costs of opportunity if not developing technology and innovative-solutions to complex societal and economic problems.	Public procurement - Repetitive description of existing products. Public procurement - Innovation-related.	Demand for obsolete products and lack of enhancement of innovation.
Organizational change: Entrepreneurship & intrapreneurship	Weak levels of entrepreneurship and new entrants in the economy. Low intrapreneurship in established firms. Poor selection environment does not reward entrepreneurial activity.	Instruments aiming at creating variation and selection environment. Instruments promoting entrepreneurial culture. Disseminating best practices of innovation management practices.	Ineffective policies unable to create variation and selection environments Policies strengthen the incumbents discouraging new entrants.
Innovation networks, agglomerations and clusters	Unexploited potential due to insufficient interaction Network partners are not complementing each other No agglomeration economies or positive network externalities as knowledge spill-overs.	Promoting collaboration between academia and industry. Promotion of local and regional investment, knowledge development and branding. Encouragement of industry's interactions with academia.	Policy reinforces technological lock-in. Mainly local not international networking.

Institutions and institutional frameworks	Lack of incentives to invest in immaterial assets Lack of a level playing field for market interactions. High level of uncertainty. Negative economic and knowledge externalities.	Intellectual property rights. Competition regulations. Publicly sponsored technical standards Mechanisms for conflict-resolution	Limited effectiveness of the regulation: generating insufficient incentives and/or high costs of compliance. Unbalance between private benefits and social benefits of the instruments, particularly regulation. Standards promoting technical lock-in. Lack of adaptability of regulation & red tape.
SMEs access to Venture Capital	Underdeveloped 'demand' of venture capital (weakness of entrepreneurship). Capital market supply underdeveloped (few, unspecialized venture-capital firms, few business angels, etc). Problems associated with the intrinsic logic of financial investments: Asymmetric information & high uncertainty.	Direct public support of entrepreneurial and seed funding activities in firms (soft loans, grants, equity). Support to venture capital industry. Tax incentives to investors. Regulatory incentives for private investment.	Public instruments never manage to stimulate private risk capital markets due to weak capital investment culture (supply) and/or weak entrepreneurial ecosystem (demand). Direct public support crowds out private investors in the venture capital market Contradicting goals or unclear situations about who should benefit from successful direct public support

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