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**Firms’ innovation strategies and complementarities in the national system of innovation**

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In our analysis we study the role of innovation policy and the NSI in shaping the innovation strategies of firms. Relying on data from three waves of the Community Innovation Surveys (CISs) we create a range of indicators for NSIs across Europe with specific emphasis on factors hampering innovation, which we interpret as differences in national innovation policy and institutions. From the CISs we also extract information on firms’ strategies for innovation in terms of the degree to which firms engage in collaboration, the sources of information relied on by firms, the use of worker training by firms and the focus on radical innovation. Following the approach of Fagerberg and Srholec (2008) we use the factor analysis to capture the dimensions of NIS.

In the econometric analyses we put particular emphasis on uncovering complementarities among the NSI indicators and find that [...] The findings have wide ranging implications but more research is also urgently needed.

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1. Introduction

A recent special issue in the journal Industry and Innovation emphasised that innovation policy must have clear objectives, must include a clear definition of the instruments used to attain these objectives, must have a clear plan for implementation of the policy without capture by other interests, and must have a clear alignment between the objectives, instruments, implementation and the method used when evaluating the policy (Christensen et al., 2016). In this paper we contribute to the understanding of the complicated relationship between instruments and objectives by analysing complementarities in innovation policy and between innovation policy and the national system of innovation (NSI) (Mohnen and Röller, 2005, Galia and Legros, 2004). We argue that the NSI and innovation policy are partially overlapping concepts when innovation is understood as interactive and systemic rather than linear, innovation policy is conceptualised as any policy that affects innovation, and innovation must be understood in broad terms where it includes the entire process of innovation, not just the outcome (Fagerberg, 2015).

The paper draws on three distinct but related streams of literature in innovation studies. The first stream of research includes policy oriented studies based on the national systems of innovation approach while second and third line of research include empirical contribution based on the survey data dealing with the hampering factors and/or complementarities of innovation policy and firms’ innovation strategy. More specifically, we follow the recent advances in the theoretical and analytical models of the national systems of innovation approach in the assessment of the dynamics of the NIS in order to characterise the dimensions of the system that are of key policy interest (Chaminade and Edquist, 2006, Bergek et al. 2008, Fagerberg, 2015). Our contribution is to account for a wide set of indicators that capture different dimension of NISs. Relying on data from three waves of the Community Innovation Surveys (CISs) we create a range of indicators for NSIs across Europe with specific emphasis on factors hampering innovation, which we interpret as differences in national innovation policy and institutions. Chaminade and Edquist (2006) put forward systemic problems as a rationale for policy intervention which can be identified by comparison of variables in the systems of innovation over time and place. In Bergek et al. (2008) the weakness or strength of the system expressed in functional terms is explained as an outcome of a balance between different inducement and blocking mechanisms. While Bergek et al. (2008) discuss the dimensions (blocking mechanisms) of the system of innovation in relation to the identified functions (and/or their interaction) of the system in isolation, there is not much theoretical consideration in respect to the nature of interaction between different dimensions of the innovation system or policy actions related to the overall functional pattern. In Fagerberg (2015) there is a consideration that there are strong complementarities between the different elements or policy instruments of an innovation system with the implication that if one critical factor is missing or fails to progress this may block or slow down the growth of the whole system. Moreover, it is argued that there is a need for a supporting knowledge about the interaction between the different parts of an innovation system or policy actions which have other goals than innovation.

The idea that different elements of the system/policy framework interact with each other and with the underlying problem or problems (actors and processes) in a complex manner provides a clear rationale to understand the nature of these interactions. Additionally, each actor in the system may respond differently and the interaction between different elements of the system/policy framework may pan out differently.
regarding different actors’ innovation activities and/or innovation strategies. It is usually stressed that the effectiveness of the single instrument may be improved if accompanied by the complementary policy instrument. Beyond the complementary nature of interaction between the policy instruments within or between policy domains or sub-systems, other forms of interaction may include substitution (trade-offs) and/or no effect (Cunningham et al., 2013). The nature, the types of the interactions and the dimensions in which interactions between policy instruments can occur has been the main concern of the policy mix literature. However, most of the contributions within this stream of research have been concerned with identifying gaps in the policy mix rather than with testing the complementarity of existing instruments. Though literature has discussed the complementarity of innovation factors, little attention has been given, so far, to the empirical verification of those arguments. The main research question is then what is the nature of interactions taking place between different components of NIS measured as the perceived context in terms of institutional and policy framework as far as different firms’ innovation strategies are concerned.

In order to answer our research question we draw on recent empirical contributions based on the survey data dealing with the factors hampering innovation activities and/or complementarities in innovation policy (Baldwin and Lin, 2002, Galia and Legros, 2004, D’este et al., 2008, Lammarino et al., 2007, Tourigny and Le, 2004). More specifically, we apply the complementarity approach in order to test the intuitive idea of complementarity between different interrelated factors of the NIS (Mohnen and Röller, 2005, Galia and Legros, 2004). One of the advantages of this approach is taking into account interaction between different policies/elements of the NIS instead of the evaluation of single policy/element of the system in isolation. The existence of complementarities provides some important insights about innovation policy in terms of the choice of the policy instruments. Unlike the previous studies we test the complementarities as reflected in firms’ innovation strategies. For the purpose of selecting the relevant variables, we also turn to the literature on firms’ innovation strategy based on survey data. More particularly, we focus on studies that try to identify firms’ strategies or modes of innovation based on the CIS data in order to identify innovation strategies undertaken by firms (Laursen and Salter, 2006, Bodas et al., 2008, Verspagen and Srholec, 2008, Clausen et al., 2011, Leiponen, 2012).

In doing so, we rely on three waves of the Community Innovation Surveys (CISs), which refer respectively to the three year periods, CIS4 (2002-2004), CIS8 (2006-2008), and CIS10 (2008-2010). The data set covers 25 EU countries and Turkey. First, we conduct factor analysis separately on the smaller sets of chosen variables from the CIS questionnaire on hampering factors of innovation in order to reduce the set of available variables to a smaller number of distinct dimensions. This part of research is complementary to that of Chaminade et al. (2012) that tries to empirically identify the systemic problems or components of the Thai system of innovation. From the CISs we also extract information on firms’ strategies for innovation in terms of the degree to which firms engage in collaboration, the sources of information relied on by firms, the use of worker training by firms and the focus on radical innovation. Again, we use factor analysis and hierarchical clustering to construct a typology of firms’ strategies (modes of innovation). Finally, we use regression analysis with interactions to determine whether complementarities exist among factors of the institutional and policy framework when they determine firms’ strategies.

The paper is organized in the following manner. In section 2 we provide brief overview the literature on National Innovation System and innovation policy, followed with the review of the empirical literature on
factors hampering innovation and innovation policy complementarities. We also review the empirical literature on innovation strategy based on the CIS data. In section 3 we discuss our analytical approach. In section 4 we present the data that we are going to use. Section 5 presents the methodology, and section 6 presents the empirical results. Finally, section 7 draws conclusion.

2. A literature overview

The paper draws on three streams of literature. The first stream of research includes national systems of innovation and the role of policy. The second stream of literature includes recent empirical contributions focused on the factors hampering innovation activities and/or testing the existence of complementarities in obstacles to innovation (as negative proxies of innovation policy) based on the CIS data. Finally, we also link to the literature on firms’ innovation strategy. More particularly, we focus on studies that try to identify different firms’ strategies or modes of innovation based on the CIS data.

2.1. National systems of innovation and policy

While the NIS stream of research is very broad and has attracted attention of various scholars working on different policy areas in relation to promoting and/or hampering innovation as reflected in the number of publication found in journals associated with policy related matters and allowing for more cross-disciplinary approaches (for a review see Fagerberg and Sapprasert, 2011), our focus here is limited to policy oriented contributions that try to provide a useful theoretical framework for innovation policy based on the recent developments of the NIS approach. These include policy oriented contributions that try to formalize the concept through theoretical or analytical models. More specifically, our focus is on three approaches that might be characterized as a variation of a functional approach to analysing innovation system dynamics (Chaminade and Edquist, 2006, Bergek et al. 2008, Fagerberg, 2015) that can be used for both identifying the systemic problems and for setting the policy goals.

Chaminade and Edquist (2006) provide a theoretical framework for identifying potential systemic problems of NIS that are related to infrastructure, capabilities, networks, institutions and transition and lock-in problems. The problem exists if the system is unable to satisfy the objective of supporting the innovation process defined as the development, diffusion and use of economically useful knowledge. As indicated in the recent paper by Chaminade (2012) the literature on the kinds of systemic problems related to functioning of the innovation system has been primarily theoretical while the empirical contributions have been rather illustrative. Following the study by Chaminade (2012) on Thai innovation system we try to quantify the characteristics of the dimensions of the institutional and policy framework using the relevant survey data with the help of factor analysis.
Bergek et al. (2008) provides an analytic framework that can be used for the assessment of system performances and for the identification of factors that influence the performances. In order to be able to identify areas of policy interest, the authors suggest it is necessary to focus on the dynamics of the system in terms of seven key processes labelled as functions that have a direct impact on the development, diffusion and use of new technologies. These processes or functions include: the knowledge development and diffusion, the influence on the direction of search, the entrepreneurial experimentation, the market formation, the legitimation, the resource mobilization and the development of positive externalities. Further, the weak or strong functional dynamics of the system are found in part as a result of workings of both inducement and blocking mechanisms. Thus, the policy relevant areas are defined in terms of the features of the structural components that act as blocking mechanisms responsible for the weak functional dynamics of the system. Some of the potential blocking mechanisms put forward include institutions, capabilities of the potential customers, and the networks of actors.

While some blocking mechanisms are regarded to affect only one function of the system, other mechanisms are regarded to have influence on several functions. For example, a poor articulation of demand is associated with hampering market formation, the entrepreneurial experimentation, the direction of search and the knowledge generation and diffusion due to the existence of interdependencies between the systems’ functions. Therefore, it is argued that it is of policy interest to reduce the strength of the mechanisms that have a pervasive effect on the functioning of the system (Bergek et al., 2008).

Fagerberg (2015) points to several advances in the NIS approach that needs to be taken into account for the holistic perspective on policy. These include i) the necessary distinction between the characteristics (structure) and the dynamics of the system ii) the focus on technological dynamics of the NIS that can be revealed only by studying the system as a whole iii) while the characteristics differ a lot between the systems, there should be some regularities related to the technological dynamics that are common in these systems. Based on these advances Fagerberg (2015) develops a framework for the analysis of innovation policy which illustrates the technological dynamics of a country as a result of interaction between a number of different processes which are in turn influenced by a range of policies that go beyond more narrowly defined innovation policy. Moreover, if the dynamics of the system are seen as unsatisfactory it is argued that this approach can be used to identify the problems.

According to this framework, the technological dynamics of the system is influenced by five generic processes as follows: i) knowledge, ii) skills, iii) demand, iv) finance, and v) institutions. Moreover, these processes may be shaped by the policy makers. Knowledge processes can be for example influenced through the provision of knowledge by public R&D organizations or through the schemes that promote interaction between different actors. Skills dimension of the NIS can also be affected through general provision of education but also through schemes for supporting vocational training. Demand dimension of the NIS can be supported through the initiative for creation of markers, changing standards and regulations, or through public procurement for innovative solutions. Finance dimension of the NIS can be supported for example through the provision of finance for small firms that may otherwise have difficulties in raising the finance in the ordinary market due to high uncertainty or through R&D tax schemes. Finally, institutional dimension refers to the “rules of the game” that range from the formal rules and laws to informal norms and rules. The examples of relevant institutions include IPRs, regulations regarding firing and hiring personnel and requirements for setting up or closing down the business. However, in order to do
so there is a need for a supporting knowledge base about the interaction between the different parts of an innovation system or policy actions and thus a need for coordination between different policy domains. Additionally, it is argued that the choice of policy makers will be motivated by their visions for the development of the society and the perceived dynamism of the NIS (Fagerberg, 2015).

In this paper we employ the framework for the analysis of innovation policy developed by Fagerberg (2015) that to some extent builds on the previous two approaches.

2.2. Studies on factors hampering innovation activities

Studies in the group of survey based contributions on factors hampering innovation activities can be divided into two main groups. The first group of studies deals with the factors determining the firms’ perception of the importance of obstacles to innovation with the main focus being on differences in firms’ characteristics, the engagement in innovation activities, and/or some context characteristics such as industry sector or geographic location (Baldwin and Lin, 2002; Galia and Legros, 2004; D’este et al., 2008; Lammarino et al., 2007; Tourigny and Le, 2004;). Baldwin and Lin (2002) study the relationship between the advanced technology adoption and the level and frequency of reported impediments to innovation by the firms in the Canadian manufacturing sector. The authors find that with certain exceptions, the percentage of firms that report the impediments to technology adoption is higher for the advanced technology users than for non-users and that the innovators report the obstacles more frequent than non-innovators. D’este et al. (2008) uses data from the UK CIS4 to assess the differences in the assessment of the importance of obstacles to innovation in relation to the firm’s engagement in innovation activities. The study argues for the importance of distinguishing between the revealed versus deterring effects of the obstacles to innovation and the context in which they might co-exist when assessing the effect of firm’s engagement in innovation activities. The authors find the U-shape relationship between the engagement in innovation and assessment of the importance of obstacles in the case of cost and market barriers that supports the existence of both revealed and deterring effects of these obstacles to innovators and non-innovators.

Lammarino et al. (2007) draws on data from the Italian CIS3 survey to assess the differences in the perception of the nine obstacles as important or very important as a function of three sets of regressors including firms’ specific characteristics, geographic location and the industry sector. The study provides evidence that the firms located in the North and in the Center of Italy which also belongs to MNEs tend significantly less frequently to assess hampering factors as relevant when the estimation is carried on the full sample of responding firms. It also shows that geographic characteristic in the perception of obstacles tend to lose its significance when the estimation is performed on the sub-samples of firms belonging to foreign and Italian groups, with the exception of the sub-sample of single domestic firms. The authors also find that the association between the R&D intensity and the firm’s perception of obstacles when performed on the sub-sample of innovative firms tends to be non-linear.

The study by Tourigny and Le (2004) is limited to Canadian manufacturing innovative firms (successful and unsuccessful) with the special focus on firm size as determinant of the firm’s perception of obstacles to innovation. Using the multivariate econometric analysis the study shows that the perception of obstacles to
innovation varies according to firm’s competitive environment, technological intensity of the industry, and firm’s size. It also shows that most hampering factors are correlated with novel innovators and that most firms are able to overcome these obstacles to innovation. The authors conclude that impediments to innovation listed in the CIS should not be interpreted as impediments that prevent innovation but as an indicator of the ability to overcome most of the obstacles. The study by Baldwin and Lin (2002) has reached the similar conclusion.

The second group of studies is dealing with the effects of the obstacles to innovation on the firms’ propensity and/or intensity of innovation (Blanchard et al., 2008; Pellegrino and Savona, 2013; Savignac, 2007). However, most of the earlier studies on the impact of barriers to innovation are limited to financial constraints. While financial constraints have been recognized as an important hampering factor for innovation, other obstacles such as knowledge, institutions or markets have been studied much less. The main conclusion from the earlier studies on financial constraints to innovation is that presence of financing constraints and innovation are positively correlated. However, subsequent research has pointed out that the reason for this conclusion might come from the combination of the several source of bias such as the presence of the heterogeneous unobserved firm-specific factors, the simultaneous determination of the decision to innovate and to invest in R&D project and the selection bias if the sample includes the firms that are not willing to innovate. The most recent studies try to overcome some of the limitations found in the previous studies. Savignac (2007) finds that the likelihood of firm propensity to innovate is significantly reduced by the existence of the financial constrains when the combination of the bias due to the endogeneity problem and the bias due to the sample structure is taken into account.

Blanchard et al. (2008) estimate the effect of different obstacles to innovation on the firm’s propensity to innovate using the data from the French CIS4 survey while differentiating between the sub-samples of firms based on the degree of willingness to innovate. The authors find that distinguishing between the degrees of intensity of willingness to innovate matters for the assessment of the effect on the firm’s propensity to innovate. While for the whole population of firms the result show the positive and significant effect of obstacles on the propensity to innovate, the estimation for the narrow sub-sample of the firms willing to innovate, the effect of obstacle becomes negative and significant. In the recent study by Pellegrino and Savona (2013), the authors test the impact of different obstacles to innovation on the propensity to innovate conditional on the presence of at least one innovation investment.

Mohen and Roller (2005) test the existence of complementarities between obstacles to innovation (that are used as negative proxies for innovation policy) in terms of an output measure of innovation (share in sales of innovative products) and in terms of the engagement in innovation activity. The study draws on the CIS1 survey data from Ireland, Denmark, Germany and Italy. The study provides evidence indicating that the existence of complementarities in innovation policy depends on the phase of the innovation process and the particular pair of policies being considered. For example, the authors find that some pairs of obstacles are substitutable across both phases of innovation while other pairs show at the same time substitutability for the propensity to innovate and the complementarity for the innovation intensity. Another study that investigates the complementarity between the obstacles to innovation includes Galia and Legros (2004). It is based on the CIS2 data for French manufacturing firms. Similar to the previous study it shows that the existence of complementarities in obstacles for innovation differs between the group of the postponed and the abandoned projects interpreted as pace and perseverance of firms’ innovative efforts.
2.3. Innovation strategy

The third stream of literature includes studies that try to identify diversity of firms’ innovation strategies (modes or regimes) based on the CIS data. Previous work on firms’ innovation strategies has focused on one or several dimensions along which the innovative activities of firms may vary. Also, the studies rely on one or several measures along the different dimensions of the firms’ innovation strategies. The dimensions of firms’ innovation strategy include but are not limited to i) types and novelty of innovation (Arundel and Hollander, 2005) ii) engagement in innovation activities (Cassiman et al., 2004, Srholec and Verspagen, 2008), iii) the effects of innovation (Srholec and Verspagen, 2008) iv) the information sources of innovation (Clausen et al., 2011, Srholec and Verspagen, 2008) v) innovation cooperation (Srholec and Verspagen, 2008) vi) protection of innovation (Srholec and Verspagen, 2008) vii) firms’ most significant market viii) innovation goals (Clausen et al., 2011, Srholec and Verspagen, 2008) ix) innovation inputs. The selection of variables to measure differences in firms’ innovation strategies along different dimensions is mainly based on the cumulative research within the innovation studies as well as the empirical studies on taxonomies of innovation patterns or modes of innovation. Also, the studies are based on different levels of aggregation of data and research objectives being to identify the firm, sector or country representative innovation strategies or innovation modes/patterns respectively.

3. Analytical approach

Our focus is on the perceived context in terms of innovation system and innovation policy and how this affects firms’ strategies. When measuring firms’ perception of the institutional and policy context we rely on two groups of variables.

One is the perceived hampering factors to innovation:

- Lack of access to information
- Lack of access to skilled workers
- Lack of finance
- Lack of market demand

The second group of variables include three indexes:

- Property rights
- Freedom from corruption, and
- The business freedom.

We can only identify firms’ strategies indirectly through their actions. The actions we will focus on are:

- The degree to which firms engage in collaboration.
- The sources of information relied on by firms
- The use of continuous worker training by firms
- The focus on radical innovation

Actions lead to outcomes such as innovation and acquiring finance. We do have data on these aspects but outcomes are even further removed from strategy than actions and therefore reflect strategy to a lesser degree. In addition, since the experienced outcome leads to adaptation of the perception of the context, relying on outcomes would increase the risk of reverse causality.

4. Data

The paper uses three waves of the Community Innovation Surveys (CISs), which refer respectively to the three year periods, CIS4 (2002-2004), CIS8 (2006-2008), and CIS10 (2008-2010). We use these three waves of CIS as these have identical questions for the factors hampering innovation activities in which we are interested in. All variables except for the three institutional factors are taken from the aggregate CIS data available on the Eurostat website. The data set covers 25 EU countries and Turkey. We distinguish between two sectors (industry and services) and three size groups (10-49 employees; 50-249 employees; and 250 employees or more) meaning that we have six observations for each country*year combination. Since only firms that introduced product or process innovation regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or ongoing innovation activities) of the period are asked to answer questions on perceived barriers to their innovation activities, our analysis is limited to this subset of innovation active firms. Another reason for the focus on this group of firms is related to the focus of our analysis being on innovation practices of innovation-active firms. The table below presents some descriptive statistics of the data set.

[Insert table 1 here]
4.1. Institutional and policy framework

In order to construct indicators of the institutional and policy framework, we mainly draw on responses to questions in the section on factors hampering innovation activities in CIS4, CIS8 and CIS10. The selection of variables was driven by the conceptual framework described in the Section 2. The rationale for the inclusion of the section on factors hampering innovation activities was to identify the areas that are of relevance for policy intervention. This is also in line with the Oslo Manual guidance where it is stated that aspects of the public policy can be examined through question on firms’ perception of obstacles to innovation. In this section firms are asked to assess the importance of the various barriers hampering their innovation activities or projects or influencing a decision not to innovate, as experienced during the three years period. The complete list of option varies between waves and we initially considered only 11 variables that are found consistent in all three surveys. The questions on hampering factors included in the survey are further originally grouped into four broad categories: cost factors, knowledge factors, market factors and reasons not to innovate. We do not use responses from the questions listed under the category reasons not to innovate since these are only answered by firms that have no innovation activities. As explained in the Section 3 we grouped the selected variables into four categories: i) lack of access to information, ii) lack of access to skilled workers, iii) lack of finance, and iv) lack of market demand.

We use three variables originally grouped into category cost factors that reflect what Fagerberg (2015) labelled Finance dimension. It includes three variables: i) the lack of funds within the enterprise or group, ii) the lack of finance from the sources outside the enterprise and iii) innovation costs too high. We further used two variables to account for what is labelled as Knowledge dimension of NIS. Two variables used are: i) the lack of information on technology and ii) the lack of information on markets. We use variable lack of qualified personnel to measure a dimension of NIS labelled as Skills (Fagerberg, 2015). We exclude the variable related to difficulty in finding cooperation partners for innovations since this variable does not primarily reflect the same area of policy intervention either in the case of lack of information or the provision of skills that are essential for firms’ innovation abilities. We also use variables i) market dominated by established enterprises and ii) uncertain demand for innovative goods or services to measure a Demand dimension of NIS (Fagerberg, 2015). In all questions on hampering factors firms are asked to assess the degree of importance of barriers being high, medium, low or not experienced. The answers are coded as binary variables indicating the presence or absence of highly important hampering factors.

The second source that is used in order to account for what is labelled as Institutions dimension of the NISs is The Heritage Foundation Index of Economic Freedom that provides data on national level indexes on ten economic freedoms. The ten economic freedoms indexes are further related to four broad categories: i) Rule of Law, ii) Limited Government, iii) Regulatory Efficiency and iv) Open Markets. Examples of relevant institutions in terms of their importance as elements of the NIS include IPRs, requirements for setting up or close down business, regulation regarding hiring and firing personnel and the prevalence of corruption (Fagerberg, 2015). We therefore include three indexes: i) property rights, ii) freedom from corruption, and iii) the business freedom. Each of the economic freedom indexes is graded on a scale of 0 to 100. The three institutional variables, however, take just one value for each country*year combination.
4.2. Firms’ innovation strategy

In order to investigate firms’ strategies for innovation we draw on responses to relevant questions in four sections of CIS4, CIS8 and CIS10. As explained in the Section 3 we identify firms’ strategies indirectly through questions on innovation activities, information sources, collaboration and the major focus of firm being on radical innovation. Again, our analysis is limited to subset of innovation active firms because non-innovators are not asked about their sources of information and collaborative arrangements. This part of the research is in line with the several previous studies that attempt to identify firm strategies (innovation modes) based on CIS data provided by Eurostat (Arundel and Hollanders, 2005, Bodas et al., 2008, Srholec and Verspagen, 2008, Clausen et al., 2011). In comparison to previous studies, we do not use the output and outcomes indicators, intensity of the number of innovation related input factors (Clausen et al., 2011) or innovation goals (Clausen et al., 2011). We only use selected indicators of innovation activities since these are considered as results of firms’ strategic choices (Nelson and Winter, 1982; Teece et al., 1997). Another criteria used is the availability of the date.

Dimensions of innovation process analysed in previous studies include the degree of novelty of innovation (Bodas et al., 2008), engagement in innovation activities (Srholec and Verspagen, 2008, Clausen et al., 2011), cooperation partners and source of information for innovation (Srholec and Verspagen, 2008, Clausen et al., 2011), innovation objectives (Srholec and Verspagen, 2008, Clausen et al., 2011) and type of innovation (product vs. process).

The first section we draw on includes response to question on firms’ engagement in innovative activities over the three years period in relation to internal or external training of personnel specifically for the development and/or introduction of new or significantly improved products and processes. The answers are coded as binary variables indicating the presence or absence of the enterprise engagement in training of employees for innovation activities.

The same section also includes responses to question on firms engagement in the following innovation activities: i) intramural (in-house) R&D, ii) extramural R&D iii) acquisition of machinery, equipment and software, iv) acquisition of other external knowledge v) market introduction of innovation and vi) other preparations (procedures and technical preparations not cover elsewhere). Again, the answers were coded as binary variables indicating the presence or absence of firm engagement in different innovation activities. We use information on the firms’ engagement in innovation activities in order to develop empirical indicators to firms’ strategic focus being on radical innovation as based on their reliance on internal creative capabilities as their core strategy. The firms’ reliance on internal creative effort (in-house R&D) might not perfectly reflect the firms’ strategic focus being on radical innovation, but it does approximate the firms’ capacity to explore new knowledge (Arundel et al., 2007). For the reasons put forward in the previous section, we also do not include other variables that can be used in order to identify firms’ orientation on radical innovation such as the level of novelty of innovation, how the innovation was developed or the type of engagement in R&D (continuous vs. occasional).
The second section includes response to questions on firms’ important sources of information for innovation. Firms were asked to indicate on the four-point Licker scale which sources of information are highly important for product and process innovation. A list of options includes: i) Within your enterprise or enterprise group, ii) Suppliers of equipment, materials, components, or software, iii) Clients or customers, iv) Competitors or other enterprises in your sector, v) Consultants, commercial labs, or private R&D institutes, vi) Universities or other higher education institutions, vii) Government or public research institutes, viii) Conferences, trade fairs, exhibitions, and ix) Scientific journals and trade/technical publications, and x) Professional and industry associations. We do not use the answers on highly important source of information being within the enterprise of enterprise group since this may not provide insight on strategy for sourcing information that is external to enterprise. We use only the information on whether the firm finds the source of information highly important for product and process innovation or not. Therefore, the answers are coded as binary variables indicating the presence or absence of highly important source of information that is external to enterprise.

The third section includes response to questions on firms’ cooperation in innovation activities. Firms were asked to indicate which type of cooperation partner they find the most valuable for their innovation activities. Similarly as in the case of the previous question on important sources of innovation, we use only the information on whether the firm finds the cooperation partner highly important for product and process innovation or not. Therefore, the answers are coded as binary variables indicating the presence or absence of highly important cooperation partners. We also exclude the answers on highly important cooperation partners being within the enterprise of enterprise group since this may provide insight on organisational structure and not on strategy for cooperation that is external to enterprises.

5. Methodology

Following the study by Mohen and Roller (2005) we set out to test the existence of complementarities in innovation system and policy framework using the CIS survey data on the obstacles to innovation as a negative proxy for the institutional and policy framework. The difference from Mohen and Roller (2005) is that our dataset covers much larger number of countries. Additionally, unlike the authors we test the complementarities when they determine the firms’ innovation strategy. The study of complementarities is not new to economics, but has only recently been used in the studies of innovation. The potential of the study of complementarities is seen as especially prominent in the study of innovation since it provides a way to test the ideas of synergetic or systemic effects (Mohen and Roller, 2005). It is also argued that the focus on complementarities between the different parts of an innovation system or policy can provide more holistic perspective on the effects of policies. Our empirical strategy consists of several steps.

First, following the approach of Fagerberg and Srholec (2008) we conduct a principal component analysis separately on the smaller sets of chosen variables from the CIS questionnaire on hampering factors of innovation in order to reduce the set of available variables to a smaller number of distinct dimensions. Both individual and the composite variables are later used in the analysis of the complementarities between obstacles of innovation as reflected in firms’ innovation strategies. Second, following the approach of Srholec and Verspagen (2008) we use the exploratory factor analysis to classify firms’ actions and to see
whether the results can be matched into distinct firm strategies. The principal components are interpreted as dimensions of firms’ strategies and are used in a cluster analysis to identify different and mutually exclusive patterns of innovation strategy. These clusters are then interpreted in terms of principal components and original variables.

Finally, we use regression analysis with interactions to determine whether there exist complementarities among factors of the institutional and policy framework when they determine firms’ strategies. For this purpose the institutional and policy variables will be coded as binary variables indicating the presence or absence of a policy or institution. The continuous variables are transformed into binary variables by specifying a threshold. The sensitive of the results to the threshold will be analysed too.

5.1. Identifying indicators of the institutional and policy framework

For identifying the dimensions of institutional and policy framework where there are several variables that may be relevant we constructed composite variables using factor analysis. The method has been recently used in research on innovation (Fagerberg, et al. 2007; Crescenzi, et al. 2007, Fagerberg and Srholec, 2008). Following the approach of Fagerberg and Srholec (2008) we use the factor analysis to classify firms’ perception of factors hampering innovation activities and to see whether the results can be matched to the processes that are considered as dimensions of NIS that can be influenced by policy, labelled as knowledge, skills, demand and finance (Fagerberg, 2015). The observations are weighted in the analysis with the population of enterprises. It is accepted as imperative that analysis of datasets with data for many countries needs to take into account these weights in order to provide representative results. Factor analysis is based on the assumption that some common underlying factor is responsible for the covariation between the observable variables (Kim and Mueller, 1978).

First, we conduct factor analysis separately on the smaller sets of chosen variables from the CIS questionnaire on hampering factors of innovation in order to reduce the set of available variables to a smaller number of distinct dimensions which we label Lack of Finance, Lack of Knowledge and Lack of Demand. The main idea is that if such aggregates do exists firms would have a tendency to respond in the same way to hampering factors belonging to the same dimension. The extraction method is principal component factor. The principal component factor was also used to validate weather the selected variables on firms’ perception of obstacles to innovation reflect previously defined dimensions.

Thus, we use the factor analysis in both exploratory and confirmatory manner. In line with the confirmatory use of the factor analysis, we specify the number of underlying dimensions to be found in the data on the basis of the accepted theoretical framework and partly on the basis of the underlying structure of the factors suggested in the CIS questionnaire. However, we also use the factor analysis in an explorative manner to examine whether selected variables clearly reflect the specific dimension of the institutional and policy framework. Finally, we use factor analysis to obtain composite variables that are going to be used along with other variables in further analysis.

Table 2 presents the results of factor analysis of the three variables of firms’ perception of hampering factors related to financing innovation. These variables are selected to reflect what Fagerberg (2015)
labelled *Finance* dimension of the institutional and policy framework as they refer to the firms’ perception of high costs and financial limitation. As the table 2 shows, the three variables are strongly correlated. The principal factor, called *Lack of Finance*, explains 90.3% of the total variance. This is in line with the results of the previous studies on the basis of data from the Thai Innovation Survey and the Canadian Survey of Innovation in Service Industries (Chaminade et al., 2012, Mohnen and Rosa, 2002). The three variables can also been seen as reflecting the perceived weakness of resource mobilization function of the TIS in relation to finance for innovation (Bergek et al., 2008).

**Table 2**: Factor analysis: Lack of Finance dimension of NIS/ innovation policy

<table>
<thead>
<tr>
<th>Factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of funds within the enterprise or group</td>
</tr>
<tr>
<td>Lack of finance from sources outside the enterprise</td>
</tr>
<tr>
<td>Innovation costs too high</td>
</tr>
<tr>
<td>Number of observations</td>
</tr>
</tbody>
</table>

Note: Estimation weighted by the total population of firms; one factor with eigenvalue> 1 was detected, which explains 90, 3% of total variance; extraction method: principal components factor.

Table 3 presents the results of factor analysis of the two variables selected to reflect the dimension of the institutional and policy framework labelled as *Knowledge*. Again, the two variables are strongly correlated. The principal factor, called *Lack of Information* (INF), explains 96.4% of the total variance. The perceived lack of information on markets and technology can reflect both the lack of knowledge and capabilities on side of customers (uncertain needs and poor articulation of demand) and on side of the firms (associated poor supply of technical solutions for customers’ needs) that may block or weaken the development of knowledge generation and diffusion processes in the system (Bergek et al., 2008).

**Table 3**: Factor analysis: Information dimension of NIS/ innovation policy

<table>
<thead>
<tr>
<th>Factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of information on technology</td>
</tr>
<tr>
<td>Lack of information on markets</td>
</tr>
<tr>
<td>Number of observations</td>
</tr>
</tbody>
</table>

Note: Estimation weighted by the total population of firms; one factor with eigenvalue> 1 was detected, which explains 96,4 % of total variance; extraction method: principal components factor.

Table 4 presents the results of factor analysis of the two variables selected to reflect the perceived features of the dimension of the institutional and policy framework labelled as *Demand* (Fagerberg, 2015). As the table 4 shows, the two variables are strongly correlated. The principal factor, labelled *Demand* (DEM), explains 90% of the total variance. The variable *market dominated by established enterprises* as a hampering factor may reflect the lock - in effect of too tight networks of actors that may lead to direction of search among suppliers and customers along existing trajectories. The market dominated by established
players can also hamper or slow down the new market formation process or institutional adjustment such as changes in standards and regulations needed for the adoption and diffusion of new technology. The same variable can also reflect the lack of market accessibility and inability to establish relations with customers that are important for the innovation processes. The perception of uncertain demand for innovative goods and services may reflect the non-existent or inefficient public procurement procedures, a lack of standardization, and/or insufficient articulation of demand by corporate and public customers that can hamper or slow down the market creation process of the system (Bergek et al., 2008).

**Table 4:** Factor analysis: Lack of Demand dimension of NIS/ innovation policy

<table>
<thead>
<tr>
<th>Factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markets dominated by established enterprises</td>
</tr>
<tr>
<td>Uncertain demand for innovative goods or services</td>
</tr>
<tr>
<td>Number of observations</td>
</tr>
</tbody>
</table>

Note: Estimation weighted by the total population of firms; one factor with eigenvalue> 1 was detected, which explains 90 % of total variance; extraction method: principal components factor.

5.2. Identifying firms’ innovation strategies

[...]

5.3. Model

The empirical literature on testing complementarities between variables proposes three different approaches: i) productivity approach, ii) reduced form exclusion restriction approach, and iii) correlation approach (Athey and Stern, 1998).

We use regression analysis with interactions to determine whether complementarities exist among factors of the institutional and policy framework when they determine firms’ strategies. For this purpose the institutional and policy variables will be coded as binary variables indicating the presence or absence of a policy or institution. The continuous variables are transformed into binary variables by specifying a threshold. The sensitive of the results to the threshold will be analysed too.

The six binary variables are:
1. $I_{aby\text{c}}$ is 1 if firms in size group $a$, in sector $b$, in year $y$ and in country $c$ report that access to 
information is not a constraint on innovation activities.
2. $S_{aby\text{c}}$ is 1 if firms report that access to skill is not a constraint on innovation activities.
3. $F_{aby\text{c}}$ is 1 if firms report that access to finance is not a constraint on innovation activities.
4. $D_{aby\text{c}}$ is 1 if firms report that market demand is not a constraint on innovation activities.
5. $C_{yc}$ is 1 if country $c$ in year $y$ did not have corruption problems
6. $B_{yc}$ is 1 if it was easy to do business in country $c$ in year $y$

The baseline model is a regression of strategy, defined from the CIS data, on the institutional dummy variables.

$$Strategy_{aby\text{c}} = \beta_0 + \beta_1I_{aby\text{c}} + \beta_2S_{aby\text{c}} + \beta_3F_{aby\text{c}} + \beta_4D_{aby\text{c}} + \beta_5C_{yc} + \beta_6B_{yc} + \gamma(Interaction)$$

$$+ fixed\ esffects\ for\ country,\ year,\ size\ and\ sector + error$$

The interaction term will be an interaction of the six different institutional variables in turn. A positive and significant estimate for gamma indicates that the two factors are complements in the sense that their combined effect is larger than the sum of their marginal effects. A negative and significant result will thus indicate that they are substitutes.

6. Regression results

[...]

7. Conclusion

[...]

Annex
References


