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Understanding the heterogeneity of innovation modes: Performance effects, barriers, and demand for state support

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ABSTRACT

This study explores the potential of the innovation modes, a firm-level taxonomy of innovation behavior, to provide a reasonable treatment for the growing complexity and multidimensionality of company strategies, incentives, and demands. The data on the Russian manufacturing enterprises from two complementary surveys are used to estimate broader features of the firms pursuing particular innovation modes, including the intensity, efficiency, and impact of innovation activities, the importance of factors, hampering the performance and the heterogeneity of demand for the policy support measures. Resulting composition of the firm-level patterns and characteristics brings new facilities for the diagnosis-based policy-making in the field of innovation.

1. Introduction

Innovation studies are known for high heterogeneity of the research object. Contemporary understanding of innovation process rests upon a plenty of observable dimensions, variety of strategies for developing innovations and indirect linkages between the success and novelty of cognitive efforts and the overall economic performance of the firms. This diversity nourishes the persistent interest of scholars for classification and taxonomy construction[1] exercises as a means of balancing between dimensionality reduction and the methodological completeness of the conceptual frameworks.

As stated by Peneder (2003), the field of innovation studies usually treats taxonomies as an analytical instrument (as opposed to systematization purposes[2]), linking the types of actors with the overall mechanics of innovation processes.

These efforts can be traced up to the demarcation of types of innovation entrepreneurship inspired by Schumpeter (see (Dosi, 1982). Inductive perspectives followed by more empirically grounded OECD classification of technological intensity (see discussions in (Hatzichronoglou, 1997; Peneder, 2003)) and Pavitt's taxonomy of sectoral patterns of innovation processes (Pavitt, 1984). Understanding innovator types and their relations as opposed to the exogenous (but actively involved) environment proved to be a promising method of developing the models of innovation. The retrospective view on the taxonomy studies shows that along with the evolution of methods and tools, the repeating classification efforts were able to capture the evolution of the innovation processes. Specifically, Archibugi (Archibugi, 2001) proposes to treat innovation taxonomies as a narrative, describing mechanics of evolving innovation systems at given time period.

New data sources accompanied by the development of methods resulted in a range of successive classification exercises based on the large empirical samples. A field of studies (e.g., Cesaratto and Mangano, 1993; Evangelista, 2000; Hipp and Grupp, 2005; Marsili, 2001) was aimed at validating and expanding Pavitt's case study-based approach using data-driven techniques and pursuing the holistic vision of innovation systems via describing the interaction of economic sectors. Other strands of literature emphasize particular dimensions of innovative behavior at the most disaggregate level of data available. Concurrently grows the complexity of the story told. Focus migrates from describing inter-sectoral relations to analyzing the compositions of individual-type behavior. The scholarly discourse is moving towards an understanding of the roles and impacts of specific behavior types in

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[1] From the formal point of view (e.g. Bailey, 1994) "classification" is any process of ordering observations by some criterion of similarity. In our case, typologies are classified on the basis of conceptual and theoretical differences between observations, whereas taxonomies are groupings based on empirically fixed differences in the properties of objects. For innovation studies there is a tendency for blurring this strict separation. Particularly, it is common to refer to the empirically driven classifications as typologies. Following the established practice, in this paper the words "classification", "taxonomy" and "typology" are used as synonyms, without emphasis on the corresponding connotation.

[2] e.g. classifications of economic activities or products, such as ISIC, NACE and other developed for the purpose of consistent and harmonized data collection.

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both sectoral peculiarities and overall innovation system performance.[3]

One of the methodological trends here is keeping the classification procedure simple and with focusing on the *ex-post* exploration of the taxonomy properties. It produces well-demanded insights on the relations between types, validates the preformulated ideas, and the *ex-ante* (here: before classification) stated labels of the firm kinds embedded into the classification rules. This addresses the dynamic nature of the innovation taxonomies, helping to understand the peculiarities and functional roles of particular strategies given a country- and moment-specific properties of the innovation environments. This understanding should comprise a substantial basis for the diagnosis-based innovation policy widely discussed by scholars (see Edquist, 2011).

This study develops a framework to combine the *ex-ante* and *ex-post* steps for the taxonomy analysis. The author pilots this framework using the classification referred as "output-based innovation modes" that was originally presented by Arundel and Hollanders (and adopted within the European Innovation Scoreboard, see (Hollanders, 2006)) while heavily related to Hollenstein's works (Arundel and Hollanders, 2008; Hollenstein, 2003). Later this approach was exploited by OECD Microdata project (2010), providing more ground for cross-country analysis.

For this taxonomy, the author explores the relation of the modes and economic characteristics of the innovation process, complementary specifics of innovation strategy. Another strong focus is made on describing the dissimilarity of the significance of the factors, hampering innovation and the heterogeneous reactions on the innovation policy efforts.

To do this, the author constructs an econometric procedure that follows the tradition of the CDM modeling (Hall, 2011; Mairesse and Mohnen, 2010) and provide the estimates based on the data from two innovation surveys of the industrial production enterprises for Russian Federation – one that.

The structure of the paper is as follows. Next section contains a brief discussion of recent innovation taxonomy efforts. Section 3 outlines the particular typology of innovation modes that is central to the further empirical analysis within the paper. Section 4 covers the data description and the estimates of economic performance of the modes, the importance of factors, hampering the performance and the heterogeneity of demand for the policy support measures. It presents the resulting portraits of the innovation modes. This paper concludes with discussing the consequences of the firm-level heterogeneity for the future of diagnosis-based policy-making.

2. Background: taxonomies of innovation behavior

The complication is one of the critical tendencies of the innovation discourse of recent 40 years. Traced from the exclusive concentration on R&D inputs (linear perception of innovation, see discussion in (Godin, 2006)) towards non-linear or chain-link models (Kline and Rosenberg, 1986, etc.) and even more sophisticated conceptual schemes (e.g., widely discussed open innovation, (Chesbrough, 2006). Parallel development of the National innovation system context (e.g., Nelson, 1993) implied the widening of the scope of actors involved and institutional mechanisms established, thus introducing more dimensions into the innovation phenomenon. Later research integrates the strategic management insights (such as (Enkel et al., 2009, Tidd et al., 2001) that focus on the relation between innovation development and strategic decision-making practice.

Growing complexity brings up a challenge of maintaining the integrity of the innovation researcher's view. New studies have to balance between the cumulative consistency and the realistic scoping and finiteness of the models analyzed. One clue here is a highly careful choice of dimensions concerned, at risk of missing the essential factors of influence. The other natural solution is to introduce taxonomies that allow condensing the desired level of complexity within an observable number of classes of innovation behavior.

Historically the studies of innovation behavior types developed along two levels of aggregation, distinguishing between firm-level and sectoral heterogeneity. Discussions of the firm-level strategy types can be tracked up to Schumpeter's outlining of the different mechanics of innovation in the entrepreneurial and monopolistic environments (Mode I and II, as discussed in Dosi, 1982). The evolutionary economics theorists especially appreciated this focus to create the models of innovation-active companies. Another long tradition aimed at explaining sectoral peculiarities (see (Cohen et al., 1989), developed within the "technological paradigms" discussion (Breschi et al., 2000), (Malerba, 2002)). Both of the research strands had extended impact on the innovation policy theorists and practitioners.

Although these approaches seem somewhat distant from each other, in fact, these studies were very similar regarding the background theory, methodologies and the research questions explored. It would be not an extreme exaggeration to say that one of the critical factors influencing the choice of aggregation level was firm-level data availability. Moreover, as discussed later, it appears that the border between two levels of aggregation can be crossed seamlessly using standard data sources and analytical techniques.

The source of more sophisticated diversity of the taxonomy studies lies within the details of the methodology. Discussing the experience of analytical industry classifications Peneder (2003) distinguished the cut-off practices and data-driven clusterization exercises. This demarcation remains useful for our purpose of describing the methodologies for classification of innovation activities. Two broad approaches exist: "explorative" (based on the clustering procedures that operate with a large number of dimensions and reveal the data-driven types) and "descriptive" (or cut-off, based on a priori chosen classification rules).

The first line of studies starts from the Pavitt's taxonomy (Pavitt, 1984) based on the case-based analysis of 2000 innovations. A famous attempt of the operationalization of innovation behavior heterogeneity in connection with the industrial organization and other sectoral specifics. This taxonomy introduced a de-facto format for succeeding studies. Acting in the same sensual framework, the authors developed the scope (by exploiting new data sources, e.g., Oslo Manual-based innovation surveys) and the methodology (using statistical techniques of multivariate analysis, such as factor and cluster analysis). Provisionally one can treat the papers from the end of 1980 until the mid-2000s as the first generation of the successors (Cesaratto and Mangano, 1993, Marsili, 2001, Evangelista, 2000; Sirilli and Evangelista, 1998, Arvanitis and Hollenstein, 2001, Hipp and Grupp, 2005 and others). The research programme of these papers included empirical verification of the Pavitt's ideas and the construction of a holistic model of the national innovation system based on inter-sector relations. One of the achievements of this line of papers was the integration of services into the methodological discussion. Sirilli, Evangelista, Hipp, and Group had focused on creating joint manufacturing and service taxonomies of the companies to improve the explanatory power of the NIS models based on the sectoral communication.

A sound outcome of the first generation of studies is a merge of sectoral and firm-level methodologies of the taxonomy construction. Two studies (Castellacci, 2008), (Peneder, 2010)) demonstrate a similar technique of combining within-sector heterogeneity and the aggregated labeling of industries. The classification of innovation behavior is done using micro-level data, while the sectors are clustered according to the distribution of the particular types of activities within the sectors.

Second generation (the mid-2000s until now) can be associated with the deepening of the analysis beyond simple identification and description of the innovation behavior patterns. Thus, the paper (Hollenstein, 2003) analyses the economic performance of the types. Another study, (Raymond et al., 2004) introduces a classification based

[3] For notable examples see (; Frenz and Lambert, 2009; Castellacci, 2008; Peneder, 2010).