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The impact of business innovation modes on SME innovation performance in post-Soviet transition economies: The case of Belarus

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ABSTRACT

This study analyzes the most effective innovation modes ('science and technology-based innovation', STI, and 'doing, using and interacting-based innovation', DUI) for business innovation performance in the context of post-Soviet Transition Economies (PSTE). Their specificities are expected to influence both their business innovation modes and their impact on innovation output. In particular, we aim at identifying the specificities of PSTE in that the DUI mode alone (and its specific drivers) is more relevant than the STI mode alone (and its drivers). In our hypothesis, this outcome should be even stronger in the context of non-technological types of innovation (e.g. organizational innovation).

1. Introduction

It is widely accepted that in a time of advanced technologies and greater flows of information, a firm's ability to innovate has become a central driver of growth, competitiveness and sustainability (OECD, 2013; GII, 2014; EU, 2014). Over the last thirty and odd years, SMEs have been regarded as a driving force of innovation and economic performance due to their nimbleness and flexibility (Birch, 1981; Piore and Sabel, 1984; Audretsch, 2003; UNECE, 2011. Therefore, innovative SMEs are an important policy target for many governments. This paper aims at contributing knowledge on the modes of innovation employed by SMEs in the context of post-Soviet transition economies (PSTE). In particular, this study addresses the following research question: What is the most effective mode of innovation in PSTE? It is a rather unexplored research area in this strand of the literature that can help to identify and discuss possible country specificities, which may produce relevant implications for multi-level policy coordination and different policy mixes (Vitola, 2015).

The debate on STI/DUI modes of innovation has attracted interest among international scholars. However, the majority of in-country analyses on the modes of innovation have mainly focused on developed countries that operate in market economies (Apanasovich, 2014). These studies have shown that firms that combine STI and DUI modes of learning are more likely to innovate than those relying on the STI and DUI mode alone in Denmark, Norway and Sweden (Isaksen and Nilsson, 2013; Aslesen et al., 2012) and Canada (Amara et al., 2008). However, other studies developed in Spain, China (Chen et al., 2011), Portugal and Colombia (Malaver and Vargas, 2013) show more ambiguous results. This might lead to a context-specific adoption of innovation modes that we aim at exploring in further depth. In PSTE, studies that analyze the effect of modes of innovation on the performance of firms are absent, thus motivating this new research endeavor. The peculiarities of these countries are, on the negative side, the lack of financial capital, innovation management experience and state-of-the-art technology, while, on the positive side, a rather high level of educated human capital (Aidis, et al., 2008; Rees and Miazhevich, 2009; Fink, et al., 2009).

For the sake of completeness, in this paper, the impact of STI and DUI modes is studied not only on technological innovation (i.e. product and/or process innovation), but also on organizational innovation that represents a "non-technological" type of innovation. Yet, it is relevant for businesses that want to be competitive in current globalized markets. In addition, the methodology of measuring the DUI mode is enriched by adding new indicators that capture learning-by-doing and by-using drivers vis-à-vis most studies that focus and measure the learning-by-interaction driver alone.

For our empirical analysis, Belarus has been selected as a representative of PSTE as it displays most features in common within this group of countries (see Section 4). In this study, we exploited

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data of 489 Belarusian SMEs compiled by the National Statistical Committee of the Republic of Belarus (Belstat) collected through a locally-based community innovation survey's (CIS).

This paper is structured as follows. In section two the main streams of research focusing on the adoption of the STI and DUI modes of innovation are examined. In section three the concept of firm's innovation performance is discussed, whereas in section four the geographical focus (i.e. PSTE and Belarus) of our study is clarified. In section five, the core hypotheses are developed. In section six the sample, the selected methodology and the results of the econometric analysis are described. In the final sections, the novel study outcomes are summarized and the implications for SMEs and policy-makers are discussed.

2. The debate on the STI/DUI modes of innovation

The STI mode emphasizes the importance of scientific human capital and innovation infrastructure (e.g. public and private R&D organizations and universities). Following the seminal contribution produced by Jensen et al. (2007), human capital involves employees with a PhD in natural sciences or in construction engineering that are involved in innovation projects. Within this view, engineers working in other relevant areas (mechanics, electronics, chemistry) are considered in line with a DUI approach to innovation as their work is based mainly on synthetic knowledge rather than on analytical knowledge (Jensen et al., 2007). A high level of scientific education across the employees increases the firm's absorptive capacity and, consequently, improves the impact of R&D activities (Cohen and Levinthal, 1989; Herstad et al., 2015). The main partners of STI firms are researchers, universities and other research organizations. Although firm, sector and country specificities mediate a differentiated impact of R&D activities and policies, the general accumulation of scientific knowledge through R&D activities is recognized as a main source of increasing returns and a fundamental component of endogenous growth. This has also meaningful implications for policy-making, particularly in the context of complex national or federal systems in which the coordination of innovation policies, and the related policy mix takes place (Vitola, 2015).

The DUI mode of innovation is based on non-scientific drivers, namely learning-by-doing, learning-by-using and learning-by-interacting (Jensen et al., 2007). The learning-by-doing introduced by Arrow increases productivity by repeating the same manufacturing operations that lead to experiential learning advantages. Amara et al. (2008) relate learning-by-doing to production and non-production-based activities, such as promotion and marketing. Repeating market trials and promotion of new or improved goods and services help problem-solving. Rosenberg (1982) argues that learning from user experience and demand in customizing products contributes to innovation and productivity growth. In fact, the use of technologies, machines and equipment facilitates learning-by-using, e.g. acquiring competences by deploying relevant state-of-the-art technology. Interaction with external organizations conduces to the development of innovations (Lundvall, 1988; Ritter and Gemünden, 2004; Fitjar and Rodriguez-Pose, 2013; Alcalde Heras, 2014; Bengtsson and Johansson, 2014). The need to find a solution to specific problems and to respond to specific requests propels SMEs to adopt this type of innovation process (i.e. DUI). The knowledge is often generated from trial-and-error processes, shared mainly through tacit knowledge flows. The STI and DUI modes of innovation are rarely found in pure forms in specific industries; however, industries can be dominated by either the STI or the DUI mode (Chen et al., 2011; Isaksen and Karlsen, 2012a). For example, pharmaceutical and chemical manufacturing industries are dominated by the STI mode, while machine-tools, cars, textiles, furniture and mechanical engineering are industries in which the DUI mode is widespread.

A third mode of innovation is identified as the combination of STI and DUI modes of innovation. Within this approach, firms that used one mode intensively may benefit from paying more attention to the other. In the context of Denmark, Jensen et al. (2007) argue that firms that combine the STI with DUI modes are more innovative. More recent studies by Aslesen et al., Isaksen and Karlsen, Herstad et al. (2015), and Isaksen and Nilsson (2012) on Norway and Sweden, and Amara et al. (2008) on Canada confirm Jensen et al.'s results (2007). On the contrary, based on empirical evidence from Spain, Parrilli and Elola (2012) and González et al. (2012), and from Colombia, these scholars argue that innovation output (i.e. product innovation) is in fact more sensitive to STI drivers than to DUI drivers, at least for product innovation. Other studies display more nuanced results. For instance, some industries seem to be more inclined to benefit from a combined approach to innovation (high-tech industries in China) while others seem to benefit mostly from DUI drivers, i.e. low tech industries in China (Chen et al., 2011). In the context of Portugal, Nunes et al. (2013) developed a latent cluster analysis that shows the existence of three groups of firms (i.e. low learners, moderate DUI innovators and stronger STI-DUI innovators). It is the third type the one that implements innovation to a significant extent, whereas the other two groups, only focused on DUI innovation, are not capable of producing significant innovation output.

This set of contrasting results sheds light on a novel interpretation of the most fruitful innovation modes across countries. In particular, there may be a sort of country-specific propensity to a certain business innovation mode (Parrilli et al., 2016). The countries that combine successfully STI and DUI innovation modes tend to be very advanced countries (e.g. Scandinavian countries). Countries at a lower development level might find it hard to combine positively the two modes (at least across all industries). This might depend on some country specificities and/or weaknesses, e.g. the more reduced education rate across the population and the poor infrastructures in these other countries vis-à-vis Scandinavian countries that benefit from higher business connectivity and competences and skills standards (the EU context in which most studies on STI and DUI innovation modes have been developed). These aspects are going to be further explored in the case of PSTE, a type of countries that has not been taken in consideration in recent studies.

3. Innovation performance

In order to measure the effect of the different modes of innovation we take into account measures of innovation performance. Following the OECD Oslo Manual for Innovation (OECD, 2005), the idea of innovation is widened to include not only product and process innovation (i.e. 'technological innovation'), but also softer, 'non-technological' innovation, e.g. commercial and organizational (OECD, 2005; Lam, 2005; Stoneman, 2010). This conceptualization permits emphasizing the possibility to invest in innovation without disbursing significant amount of resources for R&D and innovation infrastructures, while investing more in a wider set of human resources (e.g. managers, designers, marketing experts, consultants, technicians) that contribute rich inputs to the innovation process.

In this study, we focus on two types of innovation output, 'technological' and 'non-technological'. Within the first category product innovation is considered, which is available within the database exploited in this study. Instead, process innovation was hardly available. The data provided by Belstat had a lot of missing observations needed to construct the indicators of process innovation. In spite of this limitation, our research continued based on the consideration that data on product innovation represent adequately the business behavior and performance in technological innovation. Within the second category of innovation output, organizational innovation was

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Table 1
Post-Soviet Eastern European countries in transition and Scandinavian countries factsheet (2013). *Source*: UNESCO Institute for Statistics, World Bank, 2013.

	Research and development expenditure (% of GDP)	GDP per capita (current US$)	Enrolment in tertiary education per 100,000 inhabitants	Gross enrolment ratio. Tertiary ISCED (%)	Manufacturing, value added (% of GDP)
Belarus	.64	6685.02	6407.26	91.45	26.84
Ukraine	.86	3866.99	5393.00	79.70	13.71
Russia	1.25	14,037.02	5708.98	76.14	14.82
Norway	1.78	99,557.73	4952.85	74.10	7.29
Denmark	3.06	56,210.23	5080.12	79.60	13.73
Sweden	3.6	55,244.65	4960.58	70.03	16.47
Finland	3.93	46,178.59	5916.92	93.72	16.62

assessed, while commercial innovation was not available in the database (see Section 5). Also in this case, our research continued based on the consideration that organizational innovation explains adequately the business approach to a softer type of innovation.

In the literature on modes of innovation, our conceptualization offers a novelty. In fact, recent studies include product and process innovation, but not 'non-technological' types of innovation. Somehow, the former studies imply a sort of bias towards the STI innovation mode as the usual measured outputs are 'technological', thus tend to stress the importance of hard types of drivers (i.e. R&D and scientific human capital). In our case, we aimed at finding a type of results that reflect a broader approach to innovation not only in terms of drivers, but also of output. This is going to be expressed in the selection of our hypotheses.

In compliance with the Oslo manual, *product innovation* refers to the introduction of a significantly improved good or service. This definition includes 'significant improvements in technical specifications, components and materials'. According to the degree of novelty, innovation can be classified as incremental and radical. Incremental innovations are dominated by the modification of existing products and processes. The modification can take two forms: a simple product may be improved through use of higher performance components or materials, or a complex product which consists of a number of integrated technical subsystems that may be improved by partial changes to one of the subsystems (OECD, 1993). Radical innovations are considered as dramatically changed products leading to new market creation and existing products obsolescence. Despite some authors argue that DUI practices may lead to radical innovation (Lorenz, 2012), the DUI mode is more typically associated with incremental innovations.

In addition to product innovation, *organizational innovation* is also investigated in order to deliver a wider picture of the innovation performance of SMEs. There is a lack of studies on organizational innovation in the current literature on business innovation modes that is more focused on technological innovations that comprise (significantly) new products and processes (Lam, 2005; Damanpour and Aravind, 2012). According to the Oslo manual, organizational innovation is "the implementation of new organizational methods in the firm's business activities (OECD, 2005). Such innovations can improve the quality and efficiency of work and the firms' ability to learn and utilize new knowledge and technologies. Organizational innovations are "normally initially developed through processes of trial-and-error and learning-by-doing within the innovating firms". The process of creative problem-solving is argued to be a source of organizational innovations that requires frequent collaborations and interactions between various people, including managers, office workers, production workers, consultants, among others. In this context, the DUI drivers act through learning from everyday work and interactive problem-solving and decentralized softened functional demarcations that can lead to important organizational innovations (Jensen et al., 2007). Organizational innovations imply new ways of organizing and coordinating business activities. This type of innovation has to do with the coordination of human resources and are not "usually based on formal R&D activities". As it was mentioned above, 'organizational innovation' (i.e. non-technological innovation) has not been studied yet in the context of STI and DUI modes.

4. Post-Soviet transition economies

In the 1990s, Eastern Europe suddenly faced a deep and painful transformation towards a free market economy. This transformation resulted in a sharp initial decline of GDP followed by a recovery in the late 1990s. The collapse of the Soviet Union led to radical changes in economic, social and political spheres that caused significant transformations in scientific and technological development and left a profound mark on innovation performance (Aidis et al., 2008; Krammer, 2009). These characteristics foreordain the business innovation margins. To understand the environment in which firms operate, we explore some crucial peculiarities of PSTE and compare them, as an example, with Scandinavian countries' (Table 1). PSTE try to attain the efficiency advantages of the market economy. However, this process is complex because it requires a fundamental restructuring of a nation's economic, political and social institutions and infrastructure (Feige, 1994). They bring in economic liberalization and shift to an economy where market forces set prices, which are not dictated by central planning institutions (Aidis, et al., 2008; Krammer, 2009).

The peculiarities of these countries are, on the negative side, the lack of financial capital, innovation management experience and state-of-the-art technology, while, on the positive side, these countries count on high levels of human capital and a long-term practice in manufacturing activities. These conditions may lead to the adoption of a business innovation mode that is representative of this kind of countries. In particular, we expect businesses to be able to work quite effectively through the DUI innovation mode because all the company personnel have a significant absorptive capacity, i.e. are able to assimilate relevant knowledge through DUI practices (e.g. purchase of new machinery and learning-by-using/doing), to access to external sources to acquire new knowledge (Hervas-Oliver et al., 2011; Denicolai, et al., 2014) and to discuss and interact for the development of new incremental product, process and organizational innovations (e.g. through technical assistance).

PSTE usually possess a highly educated human capital with tertiary education comparable to Scandinavian countries. The high level of human capital and specific knowledge based on work experience increase the business absorptive capacity (Vinding, 2006) and conduces to interactions between industries and scientific organizations both within the country and with international partners. PSTE are technology latecomers. Thus, due to strong and steady international flows of capital and knowledge firms in such countries do not need to carry out large amount of R&D activities (Crosby, 2000). They can interact with foreign partners that perform R&D activities, purchase patents, licenses, and capital goods. Thus, in the transition period firms can benefit from innovations based on

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learning-by-interacting- and by-using that are developed by leading industrialized countries, or in other words benefit from DUI drivers more than from STI drivers. Yet, the relatively high absorptive capacity of the local population is also likely to lead businesses to benefit from the combined STI+DUI mode of innovation, at least in the technologically-based innovation, whereas a clearer prominence of DUI drivers is expected in the case of non-technological innovation.

For our empirical analysis, Belarus was selected as a representative of PSTE. It is a small open catching-up country with a poor R&D expenditure and a highly educated population (Table 1). Before 1991, Belarus was a part of the Soviet Union, which was among the leaders of world science. Large R&D investments were developed, although that system (including Belarus) lacked effective mechanisms for commercializing research results (Yegorov, 2009). This is why a certain disconnection between science and practice is expected in this country; this is likely to affect the business mode of innovation and the effective capacity of businesses to innovate.

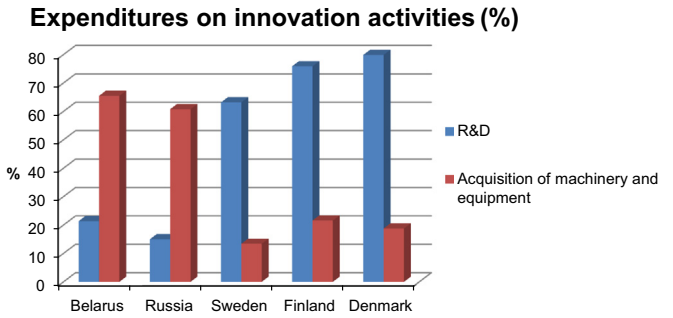

Fig. 1. Expenditure in innovation activities (2011).
Source: Belstat/ Eurostat, 2011A comparison with European countries shows that countries in transition do not fit into the global trend of rising expenditure in R&D; however, they manage to preserve their scientific and engineering potential originated in the Soviet past. In spite of the relatively low level of R&D intensity, the existing knowledge base, which is complemented by current R&D investments, increases the amount of patents produced in countries in transition. This historic scientific base, accompanied by the high absorptive capacity (i.e. tertiary education) of the local workforce is also likely to lead businesses to benefit to the highest extent from the combined STI+DUI mode of innovation, at least in technological innovation (i.e. 'product innovation' in our case).

5. Formulation of hypotheses

5.1. Technological-Product innovation

Many influential scholars recognize that firms that count on a strong science base and perform R&D activities are successful in generating product innovation (Greunz, 2005; Love and Mansury, 2007). Other scholars argue that the probability of assimilation of knowledge and the development of innovations increases when the firm is organized in order to promote learning-by-doing, by-using and by-interacting (Arrow, 1962; Rosenberg, 1982; Jensen et al., 2007). As a means to elaborate accurate hypotheses on which business innovation mode is more effective in economies in transition, it is worth considering the nature of innovation activities in this context. If one compares the shares of different types of innovation expenses on total business expenditure in innovation activities (Fig. 1), Belarusian and Russian enterprises invest respectively three and four times more in acquisition of basic machinery, equipment and software than in R&D. In contrast, Danish enterprises invest four times more in R&D than in machinery and equipment (Belstat, 2011). This high share of expenditures on basic machinery and equipment in PSTE can be explained by the technological gap faced by these countries. They operate behind the technology frontier and innovate through new technology acquisition (Varblane, et al., 2007; Alam, et al., 2008; Radosevic, 2011). Great amount of stodgy machinery dates back to Soviet times. For this reason, in the State Program for Innovative Development of the Republic of Belarus 2011–2015 (SPID, 2011)special attention is given to the technological modernization of Belarusian enterprises. The acquisition of up-to-date machinery and technology in combination with a highly educated human capital is likely to lead to a strong impact of the DUI mode on innovation output. On these bases, and in contrast to western economies, we argue that in PSTE, SMEs that rely on experience-based learning with new technology are more likely to generate product innovation than those relying on the STI mode alone.

Hypothesis 1a. In the context of Belarus (PSTE), firms that rely on the DUI mode alone are more effective in generating product innovation than those that rely on the STI mode alone.

Hypothesis 1b. In the context of Belarus (PSTE) firms combining the STI and DUI modes of innovation are expected to be more effective in generating product innovation than those that rely on STI or DUI modes alone.

5.2. Non-Technological Organizational innovation

In this paper *organizational innovation* is also analyzed as a means to deliver a deeper picture of SME innovation processes. This type of innovation involves new ways of introducing and organizing management systems for production, such as supply chain management systems, business re-engineering, lean production, and quality-management systems. A firm that generates organizational innovations can be characterized as a creative and flexible organization, oriented towards continuous learning and new knowledge creation (Nonaka and Takeuchi, 1995; Lam, 2005; Asheim and Coenen, 2005). Organizational innovation is connected with the coordination of human resources and has no technological elements, thus it is not 'usually based on formal R&D activities' (Edquist et al., 2001:16). Belarusian managers tend to focus on adopting Western managerial approaches, experience and practices, which often arise from co-operation with supply chain partners located abroad (Miazhevich, 2007). As it is corroborated by Kuznetsov and Yakavenka (2005), managers in Belarus possess advanced skills and knowledge that allow them appreciating the value of imported concepts, knowledge and organizational practices. In addition, for the peculiarity of non-technological innovation, particularly in PSTE, DUI drivers are expected to generate organizational innovations with or without the combination of STI practices. On these bases, we propose the following hypotheses:

Hypothesis 2a. In the context of Belarus (PSTE), firms that rely on the DUI mode alone are more effective in generating organizational innovation than those that rely on the STI mode alone.

Hypothesis 2b. In the context of Belarus (PSTE), firms combining the STI and DUI modes of innovation are likely to be more effective in generating organizational innovation than firms relying on the DUI mode alone.

6. Data and methods

6.1. Data

This section presents the sample, describes the variables used in the analysis, and the econometric technique employed. We have applied a well-recognized methodology used in STI/DUI studies. The

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empirical analysis is based on a sample of Belarusian firms taken from an extensive database, which is compiled by the National Statistical Committee of the Republic of Belarus (*Belstat*) on the bases of the CIS format. Our dataset represents a population of firms which are studied by the Belarusian government and the statistical institute as potentially innovative. Belstat dataset is appropriate to test the selected hypotheses for several reasons. First, it allows to identify key characteristics in the firms' innovation activities, capabilities, and strategies. Secondly, the data are compiled from public sources that can be checked and scrutinized. Thirdly, this dataset has not been employed in the literature on innovation modes, which means that these results can test and increase the robustness of previous findings on the impact of STI/DUI modes in shaping business innovation strategies.

The analysis started with a set of 1261 manufacturing and service firms that performed their activities during 2012. Belstat data are not assembled on a panel basis because of the changing sample each year and the anonymity of respondents. Moreover, in 2013 Belstat incorporated significant changes in the questionnaire submitted to firm respondents, which again makes it inconsistent to compare data taken in different years. Notwithstanding this limitation, the current data allow a first approximation of innovation management based on STI and DUI modes (as in the Basque case with data available for 2009 only, Parrilli and Elola, 2012). This statistical effort helps to deliver data that may be compared with the aforementioned set of country studies. In order to restrict the sample to SME only, we attended the European Commission recommendation criteria (2003) based on the number of employees and the business turnover. Therefore, those companies with less than 10 employees and 2 million euros in turnover were excluded insofar as firms with more than 250 employees and 50 million euros turnover. The resulting sample is formed by 489 firms from manufacturing and service industries.

6.2. Dependent variables description

In our study, we have two dependent variables: product innovation and organizational innovation. Therefore, we conduct two regression models. We consider *product innovation output (ProdIO)* as the first dependent variable, which is a widely used measure of innovation performance. Belstat provides data on business turnover related to the development of new-to-firm, new-to-national and new-to-international markets products. This allows classifying product innovation according to the degree of novelty that corresponds to the CIS format (CIS, 2008): no innovation (0), new-to-firm (1) and new-to-market innovation (2) (Table 2). These are measured in terms of 'sales of new products'. The '0' level of the variable indicates that a firm did not report any sales of innovative products during 2012. The degree of novelty classified as '1' demonstrates that a firm sold new or significantly improved new-to-firm products during the same year. '2' was assigned when a firm launched products that were new to the national and international markets.

The second dependent variable is *organizational innovation output (OrgIO)*. This type of innovation is characterized as the implementation of new methods and procedures for organizing business activities that have not been used before in the firm (OECD, 2005). Such innovations improve the efficiency of work and the ability of the firm to learn; these are preconditions for technical innovations. The indicators of organizational innovation show whether or not (1 or 0) a firm implemented new strategy development, new managerial methods, working schedule changes, new control and product certification systems and new corporate knowledge management systems (Table 2). In order to get the final variable characterizing organizational innovations, we calculate the sum of these indicators and transform the value into an ordinal scale. A 'low' level was assigned to the variable that characterizes organizational innovation when the sum of its indicators equaled zero. The variable was equated to 'medium' level (1) when the sum of the indicators' values exceeded zero but was less or equal to the mean. When the sum possessed a value greater than the mean, the 'high' level (2) was assigned. The explanatory table of variable transformation is provided in Table 4.

6.3. Independent variables description

We propose two groups of indicators to identify STI and DUI modes (Table 3). Specifically, in our construct, three indicators define the STI mode and three variables are designated as indicators of the DUI mode of innovation. The first group of STI indicators emphasizes that innovation is the result of science and R&D (Jensen et al., 2007; Chen et al., 2011; Parrilli and Elola, 2012) suggesting that investment in R&D and scientific human capital are considered as key innovation inputs. According to Hong et al. (2012), econometric analyses should use direct measures of innovation, while the indirect measures are relatively narrow due to their potentially weak linkages with innovation and the induced large firm bias. In this regard, the first indicator is the total expenditure on R&D. The next two indicators are the number of R&D personnel employed by a firm, and the number of R&D departments. Previous literature already stressed the relevance of the presence of R&D departments. More specifically, Veugelers used R&D departments as proxy for absorptive capacity. In this sense, Oerlemans and Meeus (2001)

Table 2
Classification of dependent variables.

Variables	Description	Literature
Product innovation		
No innovation	A firm did not report sales of innovative products (0)	(Jensen et al., 2007; Chen et al., 2011; Parrilli and Elola, 2012; Fitjar and Rodriguez-Pose, 2013)
New-to-firm innovation	A firm report sales of innovative products that are new to firm (1)	
New-to-market	A firm report sales of innovative products that are new to market (national and international) (2)	
Organizational innovation		
Strategy development	1 whether a firm reported new strategy development, 0 otherwise	(Pleschak and Sabisch, 1996; Armbruster et al., 2007; Som et al., 2012)
New managerial methods	1 whether a firm reported new managerial methods, 0 otherwise	
Working schedule changes	1 whether a firm reported working schedule changes, 0 otherwise	
Control and product certification systems	1 whether a firm implemented new control and product certification systems, 0 otherwise	
Corporate knowledge management systems	1 whether a firm developed new corporate knowledge management systems, 0 otherwise	

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Table 3
STI and DUI indicators. *Source*: own elaboration.

Variables	Description	Literature on STI/DUI modes of innovation
STI indicators		
Expenditures on R&D	Expenditures on R&D as share of total sales (Belarusian rubles)	(Jensen et al., 2007; Aslesen et al., 2012; Chen and Guo, 2010; Gonzalez-Pernia et al., 2012)
Scientifically trained personal	Number of scientifically trained personnel employed by a firm (units)	
R&D departments	Number of R&D departments in a firm (units)	Veugelers, 1997
DUI indicators		
Preliminary marketing related to technological innovation	Reported firm expenditure on preliminary marketing related to technological innovation (Belarusian rubles)	Amara et al., 2008
Technological preparation for production	Reported firm expenditure on technological preparation for production including design and engineering of products (Belarusian rubles)	Ritter and Gemunden, 2004
Interacting	Indicates whether a firm interacts either with customers or/and suppliers or/and distributors (0, 1)	(Jensen, et al., 2007; Chen et al., 2011; Parrilli and Elola, 2012; Fitjar and Rodriguez-Pose, 2013; Gonzalez-Pernia et al., 2014)

have found out that R&D departments are conducive for R&D co-operation and enhance the capability of firms to exploit external knowledge sources. Therefore, this indicator reflects the business organizational effort to provide a specific structure for scientific innovation management. Moreover, the reference to the number of R&D departments shows whether a firm strategically relies on research and reflects the diversity of research portfolio of a firm. If the number of R&D departments is more than 1, it means that the firm is focused on diversifying its research portfolio (Table 3).

The DUI mode is based on non-science-based indicators. Vis-à-vis former studies that emphasized the 'interactive' component of the DUI mode, we enrich the methodology by adding new indicators that help to measure learning-by-doing and learning-by-using drivers. Firms perform more efficiently if they can learn from repeating operations, get more practice or, in other words, they learn-by-doing. Broadening this view, the view of Amara et al. (2008) is supported as far as learning-by-doing can also be associated with preliminary marketing efforts directed at experimenting new products in new markets. Therefore, the expenditure on preliminary marketing efforts related to technological innovation was chosen as an indicator of the DUI mode of innovation. This non-R&D indicator shows whether the firm undertook marketing activities and conducted studies to evaluate the prospective market impact of a product. Repeating and improving practices of commercial promotion of new or improved goods and services encourages learning-by-doing, which in turn improves the related knowledge, skills and innovation capacity of the firm.

Learning is supported and promoted by using advanced technologies. A firm's ability to understand and use relevant state-of-the-art technology, and to explore new ways of solving technical problems accelerates the process of innovation (Ritter and Gemunden, 2004; Krammer et al., 2009). Learning-by-using includes adopting practices that hasten technological progress. This is particularly important in high-technology industries, although it might serve in any other industry. In this regard, the selected variable is the firm's technological preparation for production, including design and engineering of products with the help of advanced technologies and skills. The third selected indicator is related to the ability of the firm to learn-by-interacting, showing whether a firm closely cooperated with customers, suppliers and distributors. SMEs benefit from such interactions as these create opportunities to access experience-based knowledge and information about markets and technologies (Lundvall, 1988; Ritter and Gemünden, 2004). From this perspective, innovation is seen as collaborative, thus depend on networks and interactions with various business partners (Lundvall, 1988; Chesbrough, 2003; Clausen et al., 2013; McAdam, et al., 2014).

Following a well-recognized methodology used in STI/DUI studies (Jensen, et al., 2007; Parrilli and Elola, 2012), the STI and DUI indicators (0, 1) nominal scale were transformed into an ordinary scale (0, 1, 2). For this purpose, the mean of non-zero cases for each indicator was computed. If the indicator was equal to zero, a 'low' level (0) to a new STI indicator was assigned. The 'medium' level (1) was set if a value of an indicator exceeded zero but was less or equal to the mean. Finally, when an indicator had a value greater than the mean the 'high level' (2) was assigned. After transforming each indicator into the ordinary scale, the final variable that characterizes the STI mode was calculated. This variable was set to 0 ('low' level) when the sum of new STI indicators (transformed into ordinary scale) was equal to zero. 'Medium' level (1) was assigned when the sum of new indicators exceeded zero but was less or equal to the mean. When the sum possessed a value greater than the mean, the 'high' level (2) was assigned. The same procedure was performed to transform variables describing the DUI mode. The explanatory table of variable transformation is presented in Table 4.

7. Results

In the empirical analysis, the Spearman correlation procedure was performed to determine whether constructed STI and DUI variables were not correlated pairwise. The results (Table 5) demonstrate that there are no statistically significant correlations between STI and DUI indicators. The absence of correlation shows that the proposed STI and DUI modes do not share commonalities across the selected variables.

7.1. Product innovation

In order to analyze the effect of the STI and DUI modes on product innovation of Belarusian SMEs, correlation and regression analyses are performed. The results of the Spearman's correlation analysis demonstrate that there is a positive correlation between the DUI mode and product innovation (0.285) and between the STI mode and product innovation (0,147), both significant at the .01 level.

As the dependent variable product innovation output (ProdIO) is categorical (0,1, 2), the ordinal regression analysis was conducted to test the relationship between the modes of innovation and product innovation. In fact, ordinal regression enables the consolidation of the ordinal nature of the dependent variables to the model. Before examining the individual coefficients of the model, the overall test of the model-fit was checked. The chi-square is significant at .001 level (Table 6). This means that the null hypothesis can be rejected (i.e. the model without predictors is as good as the model with the predictors). Secondly, the individual coefficients of the model are examined. Table 6 contains the parameter estimates for the model. The significance levels indicate that the combination of STI and DUI

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Table 4
The explanatory table of transformation of variables. *Source*: own elaboration.

	Indicators	Measure used in survey	Measure of indicators (transformational scale)	Measures of final variable in regression model
STI	Expenditures on R&D	Belarusian rubles (BYR)	If I =0 – low level (0);	If SI =0 – low level (0);
	Number of scientifically trained personal	Units	If 0< I <= m – intermediate level (1);	If 0< SI <= M – intermediate level (1);
	Number of R&D departments		If I > m – high level (2)	If SI > M – high level (2)
DUI	Expenditures on marketing related to technological innovation	BYR		
	Expenditures on technological preparation for production			
	Interacting (customers, suppliers and distributer). If firm cooperate at least with one of the partners 1 was assigned, 0 otherwise	(0) no, (1) yes		
Product innovation	Sales of innovative products and services new to firm	BYR	0 – no innovation;	0 – no innovation;
	Sales of innovative products and services new to local and international market		1 – new to firm;	1 – new to firm;
			2 – new to the market	2 – new to the market
Organizational innovation	New strategy development	(0) no, (1) yes	(0) no, (1) yes	If SI =0 – low level (0);
	New managerial methods			If 0< SI <= M – intermediate level (1);
	Working schedule changes			If SI > M – high level (2)
	New control and product certification systems			
	New corporate knowledge management systems			

* I – value of any indicator
* m – mean of each indicator
* SI – sum of measures of indicators (I)
* M – mean of SI.

Table 5
Correlations between STI and DUI indicators.

Spearman's rho	R&D expenditures	R&D departments	Scientifically trained employees	Technological preparation for production	Preliminary marketing	Interacting
R&D expenditures	1.000	.246**	.275**	−.024	−.038	.061
R&D departments	.246**	1.000	.956**	−.082	−.076	−.007
Scientifically trained employees	.275**	.956**	1.000	−.062	−.088	.002
Technological preparation for production	−.024	−.082	−.062	1.000	−.007	.026
Preliminary marketing	−.038	−.076	−.088	−.007	1.000	.123**
Interacting	.061	−.007	.002	.026	.123**	1.000

* Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

Table 6
Parameter estimates.

	Estimate	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound
[ProdIO =.00]	−3.429	.000	−4.386	−2.472
[ProdIO =1.00]	−1.781	.000	−2.706	−.856
[STI=.00]	−1.089	.000	−1.567	−.612
[STI=1.00]	−.678	.006	−1.162	−.193
[STI=2.00]	0[a]	.	.	.
[DUI=.00]	−2.079	.000	−2.981	−1.177
[DUI=1.00]	−.978	.033	−1.877	−.078
[DUI=2.00]	0[a]	.	.	.
Chi-Square =64.43		.000		

0a-reference level.

modes exerts influence on product innovation. Interactions are added in our model to check whether the STI and DUI modes are additive (Hair, et al., 2010). Interactions turned out not to be significant, thus, the STI and DUI modes are additive. Based on the results of the regression analysis, we conclude that there is a statistically significant relationship between both the STI and DUI modes and product innovation. Thus, firms with greater levels of STI and DUI drivers achieve better product innovation outputs.

In order to analyze if firms combining the STI and DUI modes of innovation are more successful in generating product innovation than the STI and the DUI modes separately, the values of the STI and DUI estimates are introduced in a logistic regression equation (Agresti, 2002). To calculate probabilities using the results of ordinal logistic regression fit (Eqs. (1)–3) were used (see Annex A).

$$Prob(IO{=}0) = \frac{1}{1 + \exp(-a_0 + b_{STI,0}X_{STI,0} + b_{STI,1}X_{STI,1} + b_{DUI,0}X_{DUI,0} + b_{DUI,1}X_{DUI,1}} \quad (1)$$

$$Prob(IO = 1) = \frac{1}{1 + \exp(-a_1 + b_{STI,0}X_{STI,0} + b_{STI,1}X_{STI,1} + b_{DUI,0}X_{DUI,0} + b_{DUI,1}X_{DUI,1}} - \text{Prob(IO = 0)} \quad (2)$$

$$Prob(IO{=}2) = 1 - Prob(IO{=}0) - Prob(IO{=}1) \quad (3)$$

In Fig. 2 the probabilities of generating radical innovation (new-to-market) are observed when both the STI and DUI are in the model. If firms reported 'high' levels of both STI and DUI

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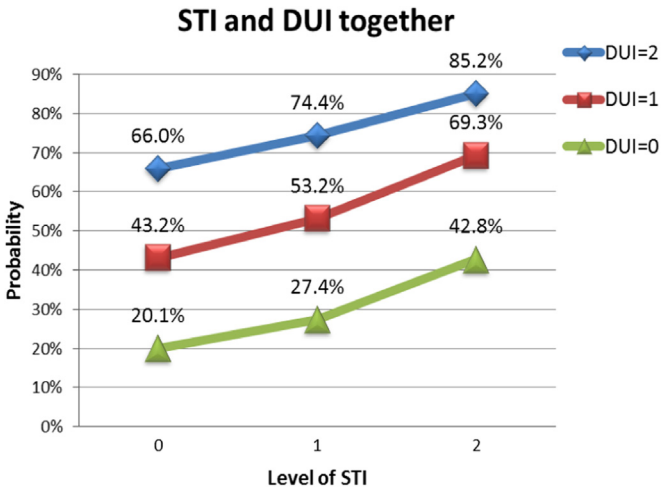

Fig. 2. Distribution of probabilities when both the STI and DUI are in the model.

modes, they would attain radical product innovation with the highest probability of 85.2%. If firms reported 'medium' level (1) of both STI and DUI modes they would attain radical innovation with the probability of 53.2%. We observe that increasing the DUI level to 'high' (2) when the STI remains "medium" (1) provides a higher probability (74.4%) of generating radical innovation than the increase of STI to 'high' (2) (when DUI=1) (69.3%).

If the STI and DUI modes are taken separately, the probability of generating radical innovation is higher when a firm relies only on the DUI mode (DUI=2 'high' level) and equal to 73.9%, vis-à-vis when a firm's innovation activities are based only on the STI mode (STI=2), which equals 56.3% (Fig. 3). The table with distribution of probabilities of generating radical product innovation is presented in Annex B. Therefore, one can see that: If the STI and DUI modes are taken separately, the DUI mode is more effective than the STI in generating product innovation. Hypothesis 1a is thus confirmed here. Simultaneously, the combined STI+DUI mode is the most effective mode of innovation for product innovation. Therefore, our 1b hypothesis is also confirmed. This finding confirms the previous studies focused on Denmark (Jensen et al., 2007), Norway and Sweden. These results confirm that the high absorptive capacity of the local population elicits the combined effective utilization of STI and DUI drivers, at the same time that show the higher propensity of local businesses to exploit their traditional interactive and practice-based innovation mode.

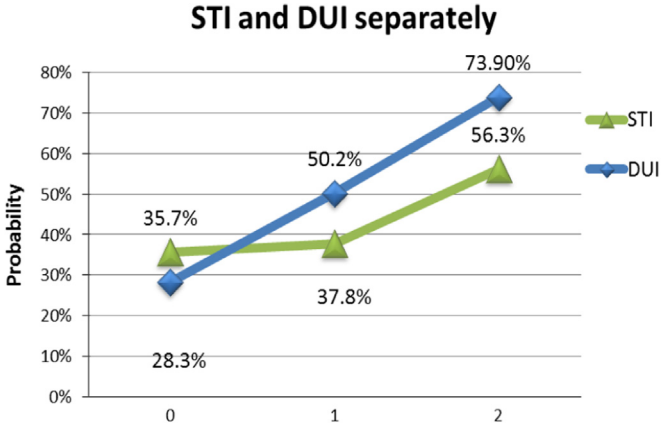

Fig. 3. Distribution of probabilities when the STI and DUI are separately in the model. Source: own elaboration

7.2. Organizational innovation

Correlation and regression analyses are also performed as a means to analyze the effect of the STI and DUI modes on organizational innovation among Belarusian SMEs. The results of the Spearman's correlation analysis demonstrate a positive correlation between the DUI mode and organizational innovation (0.248), significant at the .01 level. However, there is no statistically significant correlation between organizational innovation and the STI mode (.056).

Since the organizational innovation output (OrgIO) is measured on the ordinal scale (0, 1, 2), an ordinal regression model helps to fits the model. Interactions are added in our model to check whether STI and DUI modes are additive. Interactions turned out not to be significant, meaning that in our model the STI and DUI modes are additive. The significance levels observed in Table 7 indicate that the DUI mode exerts influence on the innovation output.

As the STI mode does not have strong relationship with this innovation output, in order to get the best model, the model was re-run without it. Table 8 contains new estimate coefficients in the model. The results of regression analysis show a positive and statistically significant relationship between the DUI mode and organizational innovation. Therefore, firms with greater levels of DUI attain greater organizational innovations. Simultaneously, there is not statistically significant relationship between the STI mode and organizational innovation. Therefore, the combination of the STI and DUI mode of innovation is not more effective in generating organizational innovation than relying on DUI drivers alone. This leads to accept hypothesis 2a and to reject hypothesis 2b (the 'null hypothesis' that we effectively aimed at rejecting as a means to show the country specificities of Belarus).

8. Discussion

Extending the debate on the most effective innovation modes on business innovation output, we apply it in the context of transition economies in which we expected to observe the adoption of specific innovation modes.

The results of the study are potentially useful for academics, policy-makers, and managers. Scholars can measure the DUI mode more adequately if they employ the learning-by-doing and learning-by-using types of indicators used in this study. Simultaneously, it will be important to consider additional and novel DUI type-indicators such as the use of focus groups, problem-solving sessions, and incubator soft-landing facilities, among others. Moreover, as we extend the geographical reach of STI/DUI studies, this research has implications for academics who analyze SME innovation from a geographical perspective. Furthermore, more comprehensive conclusions about the modes of innovation in PSTE

Table 7
Parameter estimates.

	Estimate	Sig.	95% Confidence interval	
			Lower bound	Upper bound
[OrgIO =.00]	−.090	.874	−1.201	1.022
[OrgIO =1.00]	1.232	.033	.099	2.365
[STI=.00]	.418	.413	−.583	1.419
[STI=1.00]	.355	.560	−.838	1.547
[STI=2.00]	0[a]	.	.	.
[DUI=.00]	−3.047	.000	−4.105	−1.989
[DUI=1.00]	−1.783	.001	−2.859	−.706
[DUI=2.00]	0[a]	.	.	.
Chi-Square =32.182		.000		

0*a-reference level.*

Table 8
Parameter estimates.

	Estimate	Sig.	95% Confidence interval	
			Lower bound	Upper bound
[OrgIO=.00]	−.333	.480	−1.254	.589
[OrgIO=1.00]	.984	.041	.042	1.927
[DUI=.00]	−2.894	.000	−3.892	−1.897
[DUI=1.00]	−1.709	.002	−2.765	−.653
[DUI=2.00]	0[a]	.	.	.
Chi-Square=31.488		.000		

0*a-reference level.*

might be delivered once other countries in transition are studied, e.g. Ukraine or Russia. Besides, the studies on innovation modes do not show what the composition of innovation drivers is in the combination of STI and DUI modes of innovation. Therefore, setting up a new classification tool could help to show how SMEs mix STI and DUI modes (i.e. the proportion of innovation drivers applied in each case).

Policy-makers can develop programs and tools that may create a more appropriate environment for the development of innovative SMEs in these contexts. For long innovation was considered a linear process resulting from R&D activities. The whole set of innovation-related regulation and policy acts in Belarus is still based on such a linear (and STI) approach (Djarova, 2011). Recent research instead stresses the variable effect of such policy approach depending on the type of firm, industry and country (Lee, 2011), and the importance to take a policy mix approach that takes into account the multi-level institutional context in which such policy is applied (Vitola, 2015). The relevance of the DUI approach discussed in this paper is currently neglected in Belarus and other PSTEs. A critical task for policy-makers is thus to support the interaction between science and business (the policy mix suggested by Vitola), thus facilitating the transformation of the research results into effective innovations.

This study seeks to help managers to maximize their resource allocations by reducing the uncertainty related to innovation strategy. Before engaging in any innovation activity, managers should analyze their current resources and capabilities associated to the adoption of specific innovation modes. In particular, experienced and well-trained human capital is crucial for firms that aim at producing sustainable innovation outcomes (Kato et al., 2015; Ketata et al., 2015). In addition, company managers are recommended to establish learning alliances, engage in networking, informal relationships, and organizational collaborations, which lead to effective learning and innovations (Lundvall, 1988).

9. Conclusions

This study analyses the effect of STI, DUI and combined STI+DUI modes of innovations on SMEs' innovation performance. The majority of empirical cross-country studies on modes of innovation mainly focus on market economies. This study demonstrates the way in which SMEs innovate in the context of Belarus and provides an analysis of the most effective business innovation modes in Belarus and other PSTEs.

It is important to recognize that there are no definitive indicators of the DUI mode of innovation. Vis-à-vis other related studies, in this work the measurement of the DUI mode is enriched by adding new indicators such as 'preliminary marketing expenditure' and 'technological preparation for production', which measure factors that were not assessed in previous studies (i.e. the D (doing) and U (using) aspects). In addition, the influence of STI and DUI, not only on product, but also on organizational innovation is also studied; this represents a novel and "non-technological" type of innovation, yet relevant for businesses that want to be competitive in current globalized markets.

The results of our regression analysis show that firms that combine the STI and DUI modes of innovation are more likely to generate technological innovation than those firms that focus on STI or DUI modes alone. This finding confirms the previous studies focused on Danish (Jensen et al., 2007), Norwegian and Swedish (Aslesen, et al., 2012; Isaksen and Nilsson, 2013) economies and firms. In our view, this result applies to the context of Belarus/PSTE because of the relatively high absorptive capacity (i.e. higher education) of the local population that supports their capacity to benefit from learning-by-doing and by-interacting (DUI), and from the introduction of new codified knowledge inputs (STI). In this aspect transition economies may resemble more advanced economies vis-à-vis less advanced economies for which the STI+DUI combination offers more ambiguous results. In addition, another important result is that firms that rely on the DUI mode alone are more likely to generate product innovation than those ones relying on the STI mode. This is justified by the fact that Belarus, as other PSTEs, operate behind the technology frontier. Therefore, their innovation dynamics depend to a significant extent on the absorption of new foreign knowledge and technology, and the effective use of machinery (DUI drivers).

Non-technological innovation has not been studied in the context of the debate on STI and DUI modes. We have found out that in PSTEs there is a positive and significant relationship between organizational innovation and the DUI mode. Thus, the probability of successful organizational innovation increases when the firm is organized in a way that promotes learning-by-doing, by-using and by-interacting efforts. In contrast, the STI is observed not to influence this type of innovation to a significant extent. SMEs in PSTE generate organizational innovations performing non-R&D activities, mainly through the use of Western managerial techniques and practices and by-interacting with internal and external partners.

One cannot exclude that a similar relationship exists also in other country contexts, for example developed or developing countries. This outcome is in fact consistent with the theoretical argument that organizational innovation is non-technological and, thus, requires a higher endeavor in managerial and teamwork practices than in 'technological' innovation.

Our work is not without limitations. In this analysis, one-year data (2012) are used. Longitudinal data would be more relevant to verify such tendencies over a longer time span. Unfortunately Belstat data are not assembled on a panel basis because of the changing sample each year and the anonymity of respondents that we have to respect. However, this work is a pioneering effort to measure the impact of different innovation modes in transition economies, and should encourage further efforts to build consistent national innovation surveys. Simultaneously, it might be appropriate to create and conduct one's own survey as a means to obtain more purpose-specific indicators.

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Annex A. Calculation of probabilities

Equations to calculate probabilities using results of ordinal logistic regression fit.

$$Prob(IO{=}0) = \frac{1}{1 + \exp(-a_0 + b_{STI,0}X_{STI,0} + b_{STI,1}X_{STI,1} + b_{DUI,0}X_{DUI,0} + b_{DUI,1}X_{DUI,1}} \quad \text{(A1)}$$

$$Prob(IO = 1) == \frac{1}{1 + \exp(-a_1 + b_{STI,0}X_{STI,0} + b_{STI,1}X_{STI,1} + b_{DUI,0}X_{DUI,0} + b_{DUI,1}X_{DUI,1}} - -\text{Prob}(IO = 0) \quad \text{(A2)}$$

$$Prob(IO{=}2) = 1 - Prob(IO{=}0) - Prob(IO{=}1) \quad \text{(A3)}$$

Calculation of probabilities using results of ordinal logistic regression fit.

$$Prob(IO{=}0) = \frac{1}{1 + \exp(-3.429 - 1.089X_{STI,0} - 0.678X_{STI,1} - 2.079X_{DUI,0} - 0.978X_{DUI,1}} \quad \text{(A4)}$$

$$Prob(IO = 1) == \frac{1}{1 + \exp(1.781 - 1.089X_{STI,0} - 0.678X_{STI,1} - 2.079X_{DUI,0} - 0.978X_{DUI,1}} - \text{Prob}(IO = 0) \quad \text{(A5)}$$

$$Prob(IO{=}2) = 1 - Prob(IO{=}0) - Prob(IO{=}1) \quad \text{(A6)}$$

	Estimate	Sig
$\mathbf{a}_0$	−3.429	
$\mathbf{a}_1$	−1.781	.000
$\mathbf{b}_{\mathbf{STI},0}$	−1.089	.000
$\mathbf{b}_{\mathbf{STI},1}$	−.678	.006
$\mathbf{b}_{\mathbf{DUI},0}$	−2.079	.000
$\mathbf{b}_{\mathbf{DUI},1}$	−.978	.033

Annex B. Distribution of probabilities of generating radical product innovation

STI	DUI	STI and DUI	Only DUI	Only STI
0	0	20.1%	28.3%	35.7%
1	0	27.4%	28.3%	37.8%
0	1	43.2%	50.2%	35.7%
2	0	42.8%	28.3%	56.3%
0	2	66.0%	73.9%	35.7%
1	1	53.2%	50.2%	37.8%
2	2	85.2%	73.9%	56.3%
2	1	69.3%	50.2%	56.3%
1	2	74.4%	73.9%	37.8%

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