The role of firm-level factors and regional innovation capabilities for Polish SMEs

Lukasz Arendt[1], Wojciech Grabowski[2]

Abstract

The paper elaborates on the innovativeness of Small and Medium-Sized Enterprises in Poland from the regional perspective. The empirical evidence is based on data collected among 820 Polish SMEs which actively use ICT tools in their business processes. Identifying firm-level (internal) and regional drivers of innovations in these enterprises was the main aim of this study. The originality of the utilized research approach lies in combining within one framework firm-level data with meso data describing the innovative potential of the regional environment and using multilevel random-effects models to analyze the relevance of firm-level and regional drivers of SMEs' innovativeness. By deploying a regional random effects approach, we assessed indirectly the effectiveness of innovation policies conducted in Polish NUTS 2 regions within a RIS and S3 framework. Interestingly, the research hypothesis, stating that regional (external) factors are more important to enhance innovativeness of SME than firm-level (internal) drivers, was verified negatively. The study revealed that SMEs in less-developed regions of Poland rely more on in-house capabilities, than on the regional innovative potential, to introduce different types of innovations. This suggests that the S3 framework in less-developed regions should concentrate more on linking firm-level factors and regional innovation systems to enhance companies' innovation capacity.

Keywords: *SMEs, innovations, less-developed regions, multilevel probit model*

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INTRODUCTION

Innovation capacity at the enterprise level (micro) is, to a large extent, dependent on the meso and macro-level drivers related to the innovation climate, as well as the systems and processes which constitute innovation policy. From this point of view, Central and Eastern European countries (CEECs) face additional challenges compared to countries with an advanced market economy system (e.g., the EU15). It seems that insufficient development of social capabilities is the main issue hindering the catching-up process in CEECs – this includes such institutional factors as the availability of an educational system which provides high-quality human capital and managerial skills; a stable and efficient political system; and financial institutions which enhance capital accumulation and its transfer into innovative investments (Bakovic, 2010; Kleibrink, Laredo, & Phillip, 2017). As a consequence, the economies of Central and Eastern Europe have been lagging behind global leaders regarding innovativeness. The problem has been more severe in the case of less-developed regions, which have rather weak social (and economic) capabilities to enhance innovations. At the same time, however, their need to be innovative is relatively strong – this situation is known as the "regional innovation paradox" (Oughton, Landabaso, & Morgan, 2002). Although CEECs and their regions have taken a major step forward in terms of developing coherent innovations policies within the framework of the EU's cohesion policy, innovative capacity at the macro and micro level is still relatively low.

Poland is an example of a country which transformed its economy from being centrally-planned to a market economy. It recovered from a severe economic slowdown in the first half of the 1990s, becoming one of the best-performing countries in the group of post-communist economies which joined the European Union in and after 2004. However, as Ghinararu (2017) argues, practically all CEE countries (and the regions within these countries), including Poland, are at the periphery of the EU core. Importantly, the contemporary understanding of the periphery goes far beyond the notion of geographical distance, but takes into account other "measures" of proximity – e.g. institutional, organizational, economic base (supply-side), or network-oriented cooperation (Dahl Fitjar & Rodriguez-Pose, 2011), and is very focused on different forms of relationships between regions on a local and global scale (Burcher, Habersetzer & Mayer, 2015). Poland, and the Polish regions, surely should not be perceived as peripheral in the European Union in the spatial dimension; however, all NUTS 2 regions, except for Mazowieckie, are still categorized as less-developed in terms of economic and innovation potential.

Though regional factors are important in explaining the innovativeness of enterprises (Sternberg & Arndt, 2001; Golejewska, 2018), not much attention has been devoted to the role of regional drivers in explaining innovativeness at the micro-level, including CEECs. Numerous studies based on CIS questionnaires (Lewandowska & Kowalski, 2015; Lewandowska, 2016; Szczygielski & Grabowski, 2014; Szczygielski, Grabowski, & Woodward, 2017) do not take into account regional variables. Moreover, in the studies devoted to the role of ICT in explaining the innovativeness of Polish enterprises, only dummy variables associated with consecutive regions are taken into consideration (Arendt & Grabowski, 2017). Such an approach makes it possible to measure only fixed differences in innovation behavior. In order to identify random differences in the propensity to innovate, differences in the impact of consecutive variables among regions on the innovativeness as well the role of regional variables, then the parameters of the multilevel model should be estimated.

The paper focuses on the innovativeness of Small and Medium-Sized Enterprises from a regional perspective - at the NUTS 2[3] level in Poland. One unique feature of the approach utilized in this study is that the empirical analysis covered only those SMEs which actively use Information and Communication Technologies (ICT) in their daily operations. It implies that the study deals with companies which are, by definition, more innovative than the "average enterprise" in Poland, as there is a positive relationship between ICT utilization and innovativeness (Arendt & Grabowski, 2017). The main goal of the paper is to identify the firm-level (internal) and regional drivers of innovation in Polish SMEs[4] which use ICT tools. Among the research questions addressed in this paper (which may be perceived in terms of the specific goals of the study) include the following:

- How do ICT use and co-innovative sources of productivity influence SMEs' innovative potential at the micro-level?
- What is the impact of regional innovation capacity on innovations in Polish SMEs?
- What is the relative significance of internal (company) and regional (external) drivers of companies' innovativeness in different NUTS 2 regions?

Though there are some studies in which the role of internal (within a firm) and regional factors were analyzed (Sternberg & Arndt, 2001; Broekel & Boschma, 2016), to the authors' best knowledge, there is a lack of studies combining, within one framework, the role of firm-level factors, regional capacity and regional random effects as determinants of SMEs' innovativeness. By using a multilevel approach, the study reveals which

3 We refer to the NUTS 2013 classification.

4 When describing the results of our study in this paper, we use the terms "companies", "enterprises", and "SMEs"; however, one should bear in mind that we are referring to Small and Medium-Sized Enterprises that use ICT.

factors (firm-level or regional) play a more profound role in explaining the innovativeness of SMEs in Poland.

The next section discusses, in a synthetic manner, the types of factors which determine innovations and regional innovation policy approaches. It is followed by a presentation of the research methods used in measuring the innovation capacities of regions and explaining the innovativeness of SMEs. This section expands the literature review. The fourth section describes the results and discusses the empirical study. The last section concludes.

LITERATURE BACKGROUND

Innovation drivers and regional innovation policy

An enterprise's innovativeness is driven by factors which can be classified into two broad categories: internal and external. Additionally, external factors may be split into three sub-categories: regional, extra-regional and technological – including innovation policy (which, in fact, is a mix of actions taking place at the regional and extra-regional level). Internal factors include, among others, organizational structure, R&D spending, the quality of the personnel or the attitude of the management and line workers towards innovations. In the group of external factors we may distinguish the availability of skilled labor, the performance of regional infrastructure, R&D facilities (regional), market development and demand, industry performance, competition, technical progress (extra-regional), and support schemes in terms of R&D efforts, cooperation (technology and innovation policy) (Sternberg & Arndt, 2001; Kosala & Wach, 2011).

The quite detailed statistical analysis by the European Bank for Reconstruction and Development (EBRD, 2014) as well as analyses conducted in other studies (see, e.g., Martinez-Roman & Romero, 2017) reveal that among the main drivers of innovations we may find the following:

- company size and age (innovations are more common among larger enterprises that have operated on the market for a long time. At the same time, start-ups are perceived as an important group of innovators);
- ownership (foreign ownership gives more opportunities to innovate);
- internationalization (exports support innovations as fixed costs may be spread among a larger number of clients. Moreover, exporters meet more competition so are more prone to innovate in order to create competitive advantage) – see Boermans and Roelfsema (2012);
- R&D spending – R&D investments are positively correlated with innovations, especially in high-tech manufacturing (see Griffith, Huergo,

Mairesse, & Peters, 2006; Van Leeuwen & Klomp, 2006; Raffo, Lhuillery, & Miotti, 2008; Masso & Vahter, 2008, for studies based on CIS data);
- the availability of skilled human resources – having qualified personnel is crucial not only for creating innovations but also for the adoption of those which are already on the market (see Rodriguez-Pose & Comptour, 2012);
- ICT utilization – broader ICT usage in enterprises increases the probability that innovations will be introduced (see Polder, Van Leeuwen, Mohnen, & Raymond, 2009; Hall, Lotti, & Mairesse, 2013; Nguyen Thi & Martin, 2015; Arendt & Grabowski, 2018);
- the business environment (strong rule of law, low taxation, and reduced bureaucracy are perceived as innovation drivers).

These factors encompass both internal and external drivers of companies' innovativeness, and, in many cases, are inter-related. It should be emphasized that many of the above-mentioned drivers fall into the category of "co-innovative sources of productivity," which includes the use of ICT, organizational change (including changes in business processes), the organization of work, or investing in employees' skills (Torrent-Sellens & Ficapal-Cusi, 2010), and plays an important role in enhancing productivity in Polish companies (Arendt & Grabowski, 2017).

The problem of creating an innovation-supporting socio-economic milieu has not only a theoretical but also a very practical meaning. This practical approach has evolved from the concept of a National Innovation System (NIS), through a Regional Innovation System (RIS), to the most recent Smart Specialisation Strategy (S3). From the point of view of enhancing innovations at the regional level, RIS and S3 are the most influential concepts, since a "one-size-fits-all" approach to innovation policy has proved to be ineffective (Sörvik, Teräs, Dubois, & Pertoldi, 2018). Both RIS and S3 have been the building blocks of the European Union's innovation policy. Importantly, reforms of the EU's cohesion policy have moved towards more region-oriented solutions, enhancing potential economic growth and innovativeness, even in less developed or peripheral European regions.

RIS as a theoretical concept has been discussed academically since the early 1990s – it may be perceived as both a goal and a toolbox for developing innovation policy at the regional level. It is a framework in which interactions (cooperation) between companies, institutional milieu, and support infrastructure are interlinked and create a basis for innovation and entrepreneurship. In the RIS approach, it is assumed that proximity between different stakeholders makes it easier to share and accumulate knowledge (especially in knowledge-intensive regions), which is more complicated in the case of cooperation between stakeholders from different regions

(Capello & Lenzi, 2015). Within this framework, Isaksen and Trippl (2014a) distinguished three types of RIS: organizationally thick and diversified (well-performing regions characterized by many different industries and a well-developed support infrastructure); organizationally thick and specialized (regions with a highly specialized support infrastructure and less diverse industries); and organizationally thin (regions often dominated by traditional industries with a low capability of support infrastructure). The concept of RIS has been further developed by the inclusion of dominating modes of innovation, leading to the emergence of STI (Science, Technology and Innovation) or DUI (Doing, Using and Interacting) approaches (Jensen, Johnson, Lorenz, & Lundvall, 2007). The development of RIS has fueled actions aimed at clustering, and it seemed to be more promising than NIS in terms of enhancing innovation capabilities at the regional level. However, one of the main weaknesses of the RIS approach has been weak territorial anchoring in the local institutions and structures (Isaksen & Trippl, 2017).

The weaknesses of RIS have been eliminated to a large extent within the S3 concept, which was proposed by the Knowledge for Growth expert group, and then integrated into the regional policy framework (Varga, Sebestyén, Szabó, & Szerb, 2018; McCann & Ortega-Argilés, 2015). In comparison with RIS, the novelty of the Smart Specialisation Strategy, which is rooted in the place-based paradigm, is found in the following features (Uyarra, Marzocchi, & Sörvik, 2018):

- decisions on specialization priorities involve many actors from different areas of expertise, which means it is a process of entrepreneurial discovery rather than a top-down manner of introducing innovations (which is in line with the belief that no single agent has a complete/comprehensive understanding of the economy/regional economy – thus, the role of government is to coordinate the actions of different agents – see Varga et al., 2018);
- the main focus of S3 is put on innovation domains, not sectors;
- there is an outward orientation – meaning the strategic perspective should be developed which takes into account the relative position of the region in a national and international context (D'Adda, Guzzini, Iacobucci, & Palloni, 2018).

S3 contribution to regional growth is described by three pillars: specialization (concentrating resources on selected fields/industries to achieve a critical mass); strong path dependence (innovation capacity is embedded in the industrial structure of the region); and linkages between specialization domains (spillover effects are stronger if newly developed/introduced technologies are related to those which already exist in the region – see D'Adda et al., 2018).

It has been argued that approaches to innovation systems which have been introduced in highly-developed (core) regions are often inappropriate for less-developed (peripheral) regions. It has become evident that enhancing innovations requires that specific challenges and needs of the region be taken into account[5] - in the case of the EU's less-developed regions, innovation policy must go beyond R&D and S&T indicators (Rodriguez-Pose, 2014). Since regional systems of innovation play an important role in enhancing regional development, they should be complemented by "geographically sensitive" actions to counteract specific issues at the periphery (Hall & Donald, 2009). Isaksen and Trippl (2014b) argued that models of endogenous regional growth are incapable of describing the path development of less-developed regions as development and innovations are linked to the knowledge base which is available inside and outside the region.

This gives a critical argument towards the Smart Specialisation Strategy concept – since S3 is a place-based policy, which, to a large extent, relies on the innovation capability of the region, less-developed regions lack the research and knowledge base on which the strategy might be built (D'Adda et al., 2018). Another issue is the lack of internal critical mass required to trigger innovation processes – that is why intra-regional cooperation is crucial to enhance companies' innovativeness in such regions (Sörvik et al., 2018). It has been argued as well that the effective enhancement of a smart specialization strategy in less-developed regions requires the incorporation of human development and R&D promotion actions into the S3 framework (Varga et al., 2018). Also, the RIS concept has been criticized regarding its relatedness to less-developed regions – Almeida, Figueiredo and Rui Silva (2011) argued that even at the beginning of the second decade of the 21st century, the concept of RIS was still vague, and thus using RIS as a policy tool by less-developed (follower) regions may be challenging. Moreover, Capello and Lenzi (2015) emphasized that the RIS concept is not a useful theoretical concept to analyze development strategies in less-developed regions – instead they perceived the concept of territorial patterns of innovation as more promising.

Undoubtedly, the innovation potential of companies located in less-developed regions is largely dependent on their collaboration patterns and the availability of external knowledge. Grillitsch and Nilsson (2015), who studied collaboration patterns of innovative enterprises in Sweden, showed that companies located in periphery regions tend to collaborate more than their counterparts in developed regions to compensate for weak

5 For instance, a serious challenge for sparsely populated regions is the limited availability of human capital and the lack of agglomeration effects regarding economic growth (Sörvik et al., 2018).

opportunities to access the local knowledge base. Moreover, the efficiency of this compensation mechanism is driven by the "in-house capabilities" of the enterprises – those with strong capability take advantage of inter-regional, national or even international collaboration, while those with a weaker capability (usually small ones) are more dependent on regional knowledge infrastructure. Wassmann, Schiller, and Thomsen (2016) revealed that the innovativeness of companies in a low-technology region (they focused on Lower Bavaria) is dependent on the scale and scope of cooperation in spatial terms: cooperating with regional partners led to low-innovation outcomes, while companies cooperating with distant partners were capable of introducing product innovations. This implies that intra-regional cooperation may be not sufficient for enterprises from less-developed regions to innovate, or it may lead to technological lock-in (Santoalha, 2018).

Bearing in mind that contemporary approaches to innovation policy at the regional level (RIS, and more recently S3) put a lot of attention on the role of the institutional milieu in innovation creation at the company level, and that studies analyzing innovativeness in less-developed regions point to the important role of knowledge transfer within and between regions – in both cases, these are factors which may be classified as external drivers of innovation. The main research hypothesis to be tested in this study is as follows: *regional (external) factors are more important to enhance the innovativeness of SMEs in less-developed regions in Poland[6] than firm-level (internal) drivers.*

RESEARCH METHODS

The Regional Innovation Scoreboard is a widely used synthetic measure to analyze innovation performance at the regional (NUTS 2) level in the European Union. It classifies all regions into four broad groups, from the best performing Innovation Leaders, through Strong Innovators and Moderate Innovators to the worst performing Modest Innovators. Each group is additionally split into a top one-third (with "+"), a middle one-third and a bottom one-third (with "-").

In this study, we constructed a new synthetic index measuring regional innovation capabilities – we named it RIC. It was derived from the concept of studies on national technological capabilities. RIC incorporates both categories defined by Bell and Pavitt (1992) – productive capacity and technological capability. The first one relies on the availability of resources required to produce goods and services while the other is related to the availability of skills, knowledge, and experience acquired by individuals and organizations. RIC may also be treated as another version of the Revealed

6 15 out of 16 Polish NUTS 2 regions are classified as less-developed in terms of the EU's cohesion policy.

Comparative Advantage (RCA) index (see D'Adda et al., 2018). It takes into account the following categories[7]:

- the number of patents granted by the Patent Office of the Republic of Poland per person in 2015;
- the ratio of the number of graduates of universities to the population in the years 2010-2015;
- the cumulative dynamics of employment in R&D in the years 2002-2015;
- in-house R&D expenditure per capita in 2015;
- the ratio of expenditure on innovation to the gross value of fixed assets in 2015;
- the percentage of enterprises with foreign capital in 2015.

The number of patents reflects the creation of technology. The ratio of university graduates to population and the dynamics of employment in R&D provide information about the skills availability in a region. Variables associated with R&D expenditure and innovation expenditures reflect technological effort (Archibugi & Coco, 2004), while the percentage of enterprises with foreign capital reflects openness and technology transfer (Fagerberg & Srholec, 2008). The values of these variables are taken from the Local Data Bank of the Polish Central Statistical Office. The values of all six variables are calculated for 16 Polish regions. If RC_l_j denotes the value of the *l*-th regional variable (*l*=1,…,6) for the *j*-th region (*j*=1,2,…,16), the measure of a region's innovation capability may be calculated in the following way:

$$RIC_j = \frac{1}{6}\sum_{l=1}^{6} \frac{\left(RC\_l_j - min(RC\_l)\right)}{\left(max(RC\_l) - min(RC\_l)\right)} \tag{1}$$

This normalized measure takes values between 0 and 1.

In order to identify the impact of firm-level factors and regional innovation capabilities on innovativeness in Polish small and medium-sized enterprises, the parameters of a multilevel probit model are estimated. The following mixed effects models are considered:

$$INNOV\_k_i^* = \boldsymbol{x}_i\boldsymbol{\beta}_k + RIC_{ij}\theta + \boldsymbol{z}_i\boldsymbol{\gamma}_k + \varepsilon_i^k, \tag{2.a}$$
$$INNOV\_k_i = I\{INNOV\_k_i^* > 0\}, \tag{2.b}$$

7 The reference year to calculate RIC is 2015, when primary data in the companies was collected.

where k=*PROD, PROC, ORG, MARKET*. It means that $INNOV\_PROD_i$, $INNOV\_PROC_i$, $INNOV\_ORG_i$ and $INNOV\_MARKET_i$ are binary variables taking value 1 for firms which introduced a product, process, organizational and marketing innovation respectively.

These types of innovations refer to the categories defined in the Oslo Manual (OECD, 2005). $\boldsymbol{x}_i$ is a vector of explanatory variables associated with firms. Firm-level data was collected in the first half of 2015 in 820 SMEs located in all Polish NUTS 2 regions. A random sampling approach with additional stratification by company size (micro, small and medium entities – in line with the definition of SMEs in force in the European Union), sector (manufacturing, services), and region (NUTS 2) was used. Data collection was done using face-to-face interviews, with the use of the PAPI technique. Interviews were processed by a professional research agency to assure the high quality of data, and they provided information on the companies' performance in the areas of ICT utilization, innovativeness, organizational change, and human capital development. $\boldsymbol{\beta}_k$ and θ are parameters for consecutive variables. In order to take into account the similarity of the innovation performance of enterprises located in the same region, as well as random differences in the impact of firms' features on innovation performance among regions, a random part $\boldsymbol{z}_i\,\boldsymbol{\gamma}_k$ is included. ε_i^k is the error term, which follows standard normal distribution. Table 1 presents a list of potential determinants of enterprise innovativeness used in econometric modelling[8]. Expectations regarding the direction of the impact of consecutive variables and literature references are also discussed.

These determinants may be grouped, according to previously presented categorization, into firm-level/internal factors *(RD, UNIV_MAN, UNIV_WORK, INVEST_ICT, MOT_PAY, ICT_USE, ORG_CHANGE, sectoral variables*)[9] and external (mainly regional) factors *(RIC, INT_COV, ICT_SKILLS)*.

The parameters of all four multilevel probit models are estimated using adaptive Gaussian-Hermite quadrature (Pinheiro & Chao, 2006). The choice of a probit model is due to the fact that an enterprise will or will not decide to introduce innovation. Since enterprises located in the same region may compete or cooperate, the choice of a multilevel approach enables the identification of innovation diffusion, technology spillover, or competition among enterprises.

8 Summary statistics of the dependent variables and regressors are presented in the Appendix.
9 Most of these factors are categorized as co-innovative sources of firm productivity.

Table 1. List of potential determinants of innovativeness of enterprises

Name of variable	Definition of variable	Expectation about the impact of the variable on innovativeness
	Binary variables	
RD	1 for firms with their own R&D department	When a firm has its own R&D department, the probability of introducing innovation should increase, which is in line with the standard CDM model (Crepon, Duguet, & Mairesse, 1998)
UNIV_MAN	1 if the majority of the management of the company possess a university degree	The level of education of entrepreneurs should be positively correlated with the level of knowledge in management and the probability of having a development strategy (Grabowski & Stawasz, 2017; Stawasz, 2019). As a result, the awareness that innovativeness brings benefits is higher.
UNIV_WORK	1 if the majority of line-workers in the company possess a university degree	A positive relationship between human capital at the firm level and innovation performance was found by, among others, D'Amore, Iorio, and Lubrano Lavadera (2017)
ICT_SKILLS	1 for firms which require ICT skills from all new employees	An increase in ICT skills of workers is associated with an increase in their human capital. As a result, the innovativeness of a company should improve.
ICT_TUT	1 for firms which organize ICT training	Investing in employees' skills by organizing training (Torrent-Sellens & Ficapal-Cusi, 2010) plays an important role in enhancing the innovativeness of enterprises
INVEST_ICT	1 for firms investing in ICT in the last 24 months	The positive relationship between investing in ICT and innovation performance of enterprises was identified by Arendt and Grabowski (2017).
MOT_PAY	1 for companies which introduced a motivation pay system	A motivation pay system could improve the creativity of workers and encourage them to find innovative solutions (Rynes, Gerhart, & Minette, 2004)
INT_COV	1 for firms which have national or international market coverage	Firms, which are active not only on the local or regional market, should increase their competitiveness. The introduction of innovations could be treated as a method of increasing competitiveness (Despotovic, Cvetanovic, & Nedic, 2014)

Name of variable	Definition of variable	Expectation about the impact of the variable on innovativeness
MANUFACTURING *CONSTRUCTION* *SERVICES* *MTF*[10]	1 for firms from the manufacturing sector 1 for firms from the construction sector 1 for firms from the services sector 1 for firms from the MTF sector	Sectoral differences in innovativeness were identified by, among others, Dahl Fitjar and Rodríguez-Pose (2015), Forsman and Temel (2016), Malerba (2005)
	Other variables	
ICT_USE[11]	Firms reported on ICT use in the following business processes: office management, accountancy, production management, supply management, HR management, ERP software, CRM software, CNC systems, and CAD/CAM systems. If *NBP* denotes the number of business processes, in which a firm operates, then variable ICT_USE is constructed as follows: $ICT\_USE = \frac{NBP-2}{7}$.	The results obtained by, among others, Polder, van Leeuwen, Mohnen and Raymond (2009) indicate that ICT use has a positive impact on all types of innovations.
ORG_CHANGE	Synthetic measure of the readiness of a given company to make an organizational change. Greater values of this variable reflect a greater readiness to make an organizational change. A detailed description of the definition and construction of this variable is provided by Arendt & Grabowski (2017)	According to the complementarity hypothesis (Milgrom & Roberts, 1990), using the potential of new technologies requires changes in work organization.
Size	Logarithm of the number of workers within a firm	According to Schumpeter's (1994) theoretical idea, firm size (and monopoly power) may have a positive effect on innovation.

Using a multilevel model is justified if random differences in innovation performance, as well as random differences in the relationship between the features of firms and their decisions, are valid. It means that the feasibility of a multilevel probit model should be verified. Therefore, in the first step, parameters of the most general mixed effects model (2.a)-(2.b) are estimated, and hypothesis $\boldsymbol{\gamma_k = 0}$ is verified using the likelihood ratio test. If hypothesis H0 is not rejected, then a binary choice model without random effects is considered. In the next step, the adequacy of region-specific variables is tested (hypothesis $\theta = 0$ is verified). If the H0 hypothesis is not rejected, the parameters of the specific standard binary choice model should be estimated. The logit/probit model is appropriate if the error term follows symmetric distribution. Therefore, the symmetry of the distribution of the error term is verified using Stukel's (1988) test. In the case of asymmetry, the parameters of the (multilevel) complementary log-log model are estimated.

10 A class of Manufacturing-Trade and Services enterprises was distinguished. These enterprises conduct a vast array of activities and therefore cannot be classified into one type of business. The trade sector is used as a reference category.
11 As already mentioned, the surveyed sample covered only those SMEs which used ICT tools (firms which reported the use of at least 2 out of 9 business processes included in the survey questionnaire). However, as the variable *ICT_USE* is not a binary type and measures the scale of ICT use, it may be incorporated into the econometric modelling as the explanatory variable.

STUDY RESULTS

The RIC approach utilized in this study revealed the dominant position of the Mazowieckie region (Table 2), which is in line with the results of other studies, including the Regional Innovation Scoreboard, which is used to evaluate the innovativeness of regions in the European Union (RIS, 2014[12]). Plawgo, Klimczak, Czyz, Boguszewski, and Kowalczyk (2013) argued that the Mazowieckie region is so far ahead of the other Polish regions in terms of innovative potential that it would be hard to identify any similarity between them. They also confirmed a statistically significant relationship between innovative potential and regional development measured by GDP in the Polish regions. It seems that the opposite relationship also holds – Rozanski and Socha (2017), using taxonomy methods, proved that development potential at the regional level has a positive impact on the scale of innovation activities undertaken by companies.

The use of the RIC framework brought similar results to the Regional Innovation Scoreboard 2014. Mazowieckie, Dolnoslaskie, and Malopolskie appeared to be the best-performing regions with respect to RIC. The worst performing regions include Podlaskie, Swietokrzyskie, Lubuskie, and Warminsko-Mazurskie. Though the level of correlation between the wealth of the regions and innovativeness is quite high, it should be stressed that the Podkarpackie region seems to be an outlier. Though this region is among the poorest in Poland, its innovation capability is much better than the performance of many other richer (than Podkarpackie) regions (Table 2).

Nevertheless, research studies usually point out that eastern Polish regions are lagging behind regarding innovation potential. Dziemianowicz and Peszat (2016), who analyzed the innovative capacity of Polish peripheral NUTS 2 regions in the east of the country in the light of smart specializations and EU co-funded innovative projects in the period 2007-2013, came to three disturbing conclusions: an increase in innovation inputs will not necessarily enhance economic growth in these regions; the development gap between these regions and the best developed Polish regions may broaden not decline; positive changes may occur in small groups of companies.

This study revealed that innovativeness at the firm-level is indeed dependent on the regional innovation performance measured by RIC – the propensity to introduce product, process, organizational and marketing innovations is higher for regions characterized by higher levels of innovation capabilities (Table 2; columns 3-5). A high percentage of firms from

12 Research within the Regional Innovation Scoreboard was conducted in 2014, 2016 and 2017, among other years.

Dolnoslaskie, Malopolskie, and Pomorskie declared that they had introduced product, process, organizational, or marketing innovations.

Interestingly, the highest percentage of innovative enterprises was reported in the Zachodniopomorskie region, which is located in the middle of the ranking of innovation capacity. At the same time, the percentage of innovative enterprises in the Mazowieckie region turned out to be lower than expected. There may be a few explanations for this phenomenon.

The first is related to the way in which the innovation in companies was measured – during the survey, managers were asked if their companies had introduced different types of innovation within the 12 months prior to the interview[13]. The collected data did not contain information on the value of sales from innovative products or whether the innovation was new to the firm or new to the market. Therefore, it was difficult to distinguish between radical or incremental innovations.

Table 2. Innovativeness of Polish regions – RIC measure. The share of companies introducing product, process, organizational and marketing innovations in different Polish regions (in %)

Region	Value of RIC (1)	Product innovation	Process innovation	Organizational innovation	Marketing innovation
Dolnoslaskie	0.538	29	18	43	15
Kujawsko-Pomorskie	0.171	10	22	24	12
Lubelskie	0.303	8	10	27	8
Lubuskie	0.088	19	12	12	5
Lodzkie	0.330	15	13	20	10
Malopolskie	0.473	24	23	19	16
Mazowieckie	0.827	19	26	25	9
Opolskie	0.180	14	3	3	0
Podkarpackie	0.447	3	36	28	19
Podlaskie	0.136	12	15	17	9
Pomorskie	0.382	20	11	24	17
Slaskie	0.335	18	9	9	5
Swietokrzyskie	0.112	21	14	14	4
Warminsko-Mazurskie	0.086	14	15	10	6
Wielkopolskie	0.362	10	10	12	11
Zachodniopomorskie	0.322	76	8	20	29

13 In this way we were able to “identify” innovation processes taking place in SMEs over a longer period, not only at the time the survey was processed.

However, as we surveyed SMEs, we should remember that in the case of small companies, innovations do not have to be linked to "formal" R&D, but may be a result of their "daily" business activities (Santamaria, Nieto, & Barge-Gil, 2009). In such an approach, innovation is defined by the token of development and implementation of new/improved product or service, or the way in which these products/services are manufactured and delivered (Forsman & Temel, 2016). As a consequence, small companies are more likely to develop incremental innovations rather than radical ones.

Nevertheless, the subjective evaluation of a company's innovativeness seems to be an acceptable approach, since knowledge about innovations and innovative potential is tacit – researchers from the University of Warsaw showed that official data and international rankings of innovativeness may significantly underestimate the potential of Polish firms, as many Polish companies undertake innovative actions but do not report them in their financial statements as R&D expenditures for tax reasons (Bialek-Jaworska, Ziembinski, & Zieba, 2016). Thus, the very high percentage of companies introducing product innovations in the Zachodniopomorskie region may be a result of the assessment of managers who treated solutions as innovative, even if they would not be considered innovative by the managers of enterprises from other regions. Secondly, the analysis of the innovation performance of regions in the period 2005-2015 indicates the Zachodniopomorskie region belongs to the group which made very strong progress in terms of innovativeness. Consequently, we may expect dynamic innovation activity in this region. Thirdly, it should be emphasized that we model innovations in small and medium-sized enterprises, while the Regional Innovation Scoreboard and RIC take into account the overall innovative potential of the region, including input generated by large companies. This may explain the relatively low level of SMEs innovativeness recorded in our study in the Mazowieckie region, which hosts many large national and international corporations.

The results presented in Table 3 indicate that enterprises which have their own R&D department, with well-educated managers and skilled line-workers, which invest in ICT, introduce a motivation pay system, and are active on the national or international markets, are characterized by a greater propensity to introduce innovations. It seems that the stock of human capital of line-workers, proxied by completion of a university degree, is the least important driver of innovation among the factors listed in Table 3.

Table 4 presents the results of the estimation of the parameters of the multilevel binary choice model[14]. For the binary explanatory variables, their

14 As a robustness check, the RIC variable was replaced by a synthetic measure from the Regional Innovation Scoreboard 2014. The results of the estimation turned out to be very similar. These results are available upon request.

effects on the probability that the dependent variable equals 1 are provided. The relationship between the probability of introducing innovation and the size of an enterprise appeared to be ambiguous. Larger SMEs are better at introducing process, organizational and marketing innovations than smaller ones. This result is in line with Schumpeter's (1994) idea that the large size of a firm (and monopoly power) may positively affect innovativeness.

On the other hand, the size of a firm turned out to be insignificant in the equation explaining propensity to introduce product innovations.

This result is, however, in line with the conclusions obtained by Symeonidis (1996), who did not empirically confirm the positive relationship between size and innovativeness. The ambiguity of this result may be explained by the fact that small and large companies have different innovation strategies. As Plehn-Dujowich (2009) and Vaona and Pianta (2008) argued, large companies focus more on process innovation and market expansion, while small companies introduce such innovations rarely. Product innovations are, however, introduced by all firms regardless of their size (Table 4).

Table 3. Companies introducing product, process, organizational and marketing innovations for firms with different values of binary explanatory variables (in %)

Binary variable and its value	Product innovation	Process innovation	Organizational innovation	Marketing innovation
RD=0	12	9	13	8
RD=1	68	37	41	35
UNIV_MAN=0	8	7	10	6
UNIV_MAN=1	25	19	23	14
UNIV_WORK=0	19	15	19	12
UNIV_WORK=1	21	19	22	12
ICT_SKILLS=0	14	15	19	4
ICT_SKILLS=1	21	16	21	13
INVEST_ICT=0	12	8	13	6
INVEST_ICT=1	31	23	26	18
MOT_PAY=0	11	9	12	7
MOT_PAY=1	27	19	25	15
INT_COV=0	8	6	13	9
INT_COV=1	29	21	24	13

There is a higher probability of a company introducing each type of innovation if it has its own R&D department. However, the estimates of parameters and marginal effects are different in all four equations. Internal R&D has a stronger impact on the probability of introducing product innovations than process, organizational, or marketing innovations. This result is in line with Lee, Olson and Trimi's (2012) finding that the link between the R&D department and innovation capacity was especially important in the closed innovation framework.

The results show a positive relationship between the human capital of managers and line-workers and the probability of introducing innovations; however, this relationship is statistically significant, but not for all types of innovation. If the majority of managers had a university diploma, then the probability of product innovation being introduced was greater by 0.26 than in the case of companies with less educated managers. When the majority of line-workers had a university diploma, then the probability of a marketing innovation being introduced was greater by 0.02 in comparison to an enterprise with less educated line-workers.

Table 4. Results of the estimation of the parameters of multilevel binary choice models[15]

Variable	Product innovation	Process innovation	Organizational innovation	Marketing innovation
Constant	-2.514***	-2.668***	-2.583***	-2.625***
RIC	-	-	0.745*(0.44)	0.834* (0.07)
RD	0.929*** (0.55)	0.579***(0.07)	0.427***(0.13)	0.634***(0.29)
UNIV_MAN	0.418*** (0.26)	-	-	-
UNIV_WORK	-	0.345***(0.07)	0.300**(0.12)	0.118*(0.02)
ICT_USE	0.885***	0.554**(0.14)	0.476**(0.24)	-
ICT_SKILLS	-	-	-	0.324***(0.06)
ICT_TUT		0.251**(0.04)	-	
INVEST_ICT	0.381*** (0.25)	-	-	0.225**(0.14)
MOT_PAY	0.309** (0.23)	-	-	-
INT_COV	0.347*** (0.30)	-	-	-
ORG_CHANGE	-	0.488***(0.08)	0.600***(0.11)	0.268**
Log(SIZE)	-	0.183***(0.03)	0.193***(0.04)	0.216***
MANUFACTURING	0.417**(0.38)	-	-	-0.336*(-0.04)
CONSTRUCTION	0.375*(0.13)	-	-	-0.350*(-0.03)
SERVICES	0.047(0.05)	-	-	-0.217(-0.02)
MTF	0.501***(0.28)	-	-	0.011(0.00)
Model	Mixed-effects probit. Random coefficient with *RD, ICT_USE* and *INVEST_ICT*	Mixed-effects probit Random intercept	Mixed-effects probit Random intercept	Mixed-effects probit. Random intercept

15 We used Vuong's (1989) test for non-nested models in order to check whether the random effects model outperforms the fixed effects model. In all four cases, the results indicate that a multilevel model (a model assuming the presence of random effects) provides better results.

The human capital of line workers also had a positive impact on the probability of process and organizational innovations being introduced. Moreover, the estimated marginal effect for the ICT_SKILLS variable shows that the probability of a marketing innovation being introduced is larger by 0.06 for firms in which all new employees were required to possess sufficient ICT skills, compared to firms with less skilled candidates (Table 4). These findings are in line with the argument present in the empirical literature pointing to human capital as being one of the principal factors of innovation capacity of enterprises (Smith, Courvisanos, Tuck, & McEachern, 2011; Van Uden, Knoben, & Vermeulen, 2017).

The results of the estimates indicate that sector dummies are significant in equations explaining the propensity to introduce product and marketing innovations. Enterprises from the manufacturing sector are characterized by a higher propensity to introduce product innovations, while companies from the Trade and MTF sector report a higher propensity to introduce marketing innovations. These results confirm that innovation drivers differ across the industries (Dahl Fitjar & Rodríguez-Pose, 2015; Malerba, 2005) and that there are significant discrepancies between manufacturing and service SMEs in terms of innovation (Forsman & Temel, 2016).

The $INVEST\_ICT$ variable turned out to be significant in the equations, explaining the propensity to introduce product and marketing innovations, which proves that investing in ICT raises the innovation potential of enterprises (Spiezia, 2011). Moreover, the readiness of a company to make an organizational change has a positive impact on the probability of introducing process, organizational, and marketing innovations. This result is in line with the complementarity hypothesis (Milgrom & Roberts, 1990). It indicates that in Poland, using the potential of new technologies requires changes in work organization, too. This result also confirms the conclusions from the empirical research conducted by Arendt and Grabowski (2017), who found that the organizational change in Polish enterprises moderates the role of ICT in stimulating innovativeness.

The INT_COV variable turned out to be significant only in the equation explaining the propensity to introduce product innovations (Table 4). It may imply that inter-regional knowledge transfer is an important driver for SMEs in Poland to enhance innovativeness only in one dimension – while entering external markets, Polish SMEs try to build their competitive advantage by extending their product offer, not relying so much on organizational, process and marketing capacities. This finding contradicts the results of Lewandowska and Golebiowski's (2014) study, which pointed out that process innovations were more strongly linked to internationalization than product innovations. However, differences in the results may be due to different periods of analysis.

Lewandowska and Golebiowski (2014) used data covering the period shortly after Poland's accession to the EU when Polish enterprises had to restructure and introduce process innovations in order to be competitive. In 2015, introducing product innovations was treated as a method of competing in international markets.

Finally, it appeared that innovation potential measured by RIC influences positively only organizational and marketing innovations introduced by SMEs, while it does not have an impact on product or process innovations. This may be due to the fact that enterprises introduce standardized products in all markets where they are present. Moreover, firms compete with enterprises from other regions and introduce process innovations in order to reduce costs and to be more competitive than other enterprises from the same industry. As a result, regional innovation capabilities do not have any impact on the probability of introducing product and process innovations.

Table 5 presents the random effects for an intercept and the parameters measuring the impact of variables $RD,\ ICT\_USE\ and\ INVEST\_ICT$ in the equation which explains propensity to introduce product innovation. The random effects for equations of the process, organizational and marketing innovations are given in Table 6. By calculating random effects, we capture the impact of the regional institutional milieu on the differences in the innovative potential of the surveyed SMEs.

The results indicate that the propensity to introduce a product innovation in SMEs is, ceteris paribus, highest in the Dolnoslaskie, Malopolskie and Zachodniopomorskie regions. It does not contradict expectations since these regions are characterized by a very high concentration of firms within small areas. The probability of introducing product innovation in regions characterized by a lower concentration of firms and lower academic potential (e.g., Lubuskie, Podlaskie, and Warminsko-Mazurskie) is, ceteris paribus, lower. This result is in line with the finding of Brouwer, Budil-Nadvornikova, and Kleinknecht (1999), who noticed that firms in urban agglomerations, compared to firms in rural regions, use a greater share of their R&D for product development. This confirms the finding of Gonzalez-Lopez, Dileo, and Losurdo (2014), who noticed that cooperation with universities positively affects innovativeness of enterprises. It is also in line with the New Economic Geography approach, which indicates that proximity plays an important role in increasing innovativeness (Benos, Karagiannis, & Karkalakos, 2015). As Fujita and Thisse (2003) argued, firms in densely populated areas learn from the co-presence of similar firms in related activities, thus implementing new technologies efficiently.

Table 5. Random effects for intercepts and coefficients for the equation explaining the propensity to introduce product innovation

Region	Product innovation (random intercept)	Product innovation *(RD)*	Product innovation *(ICT_USE)*	Product innovation *(INVEST_ICT)*
Dolnoslaskie	0.305	-0.138	1.428	-0.133
Kujawsko-Pomorskie	-0.074	-0.366	-0.520	0.000
Lubelskie	-0.195	-0.098	-0.034	-0.059
Lubuskie	-0.139	0.041	-0.094	0.020
Lodzkie	-0.060	0.045	0.630	0.000
Malopolskie	0.247	-0.210	-0.524	-0.030
Mazowieckie	-0.241	0.327	0.052	0.069
Opolskie	0.078	-0.035	0.018	0.025
Podkarpackie	-0.052	0.084	0.035	-0.030
Podlaskie	0.004	0.202	-0.218	-0.065
Pomorskie	-0.116	0.293	-0.189	0.020
Slaskie	-0.018	-0.471	-0.702	0.069
Swietokrzyskie	-0.115	-0.032	0.187	-0.026
Warminsko-Mazurskie	0.057	0.100	-0.167	0.071
Wielkopolskie	-0.087	-0.017	-0.495	0.050
Zachodniopomorskie	0.406	0.276	0.593	0.019

Interestingly, the propensity to introduce product innovation appeared to be lower than average in the Mazowieckie region. However, the SMEs in the Mazowieckie region are characterized by a stronger relationship between having an R&D department and introducing product innovation, which means that in this region, R&D departments are used most effectively for introducing product innovations. The efficient use of R&D is also found for the Podlaskie, Pomorskie, and Zachodniopomorskie regions. The impact of the use of ICT on the probability of introducing product innovation proved to be the highest in Dolnoslaskie, Lodzkie and Zachodniopomorskie regions, while the weakest role of ICT use in product innovations is found for the Slaskie region. Investments in ICT translate into product innovations most intensely in the case of enterprises located in the Warminsko-Mazurskie, Mazowieckie, and Slaskie regions (Table 5).

The propensity to introduce process innovations is, ceteris paribus, higher for SMEs located in the Kujawsko-Pomorskie, Malopolskie and Podkarpackie regions, and is perceptibly lower in the Lodzkie, Swietokrzyskie, and Zachodniopomorskie regions. Relatively strong negative regional effects discouraging companies from introducing organizational innovations are reported in the Mazowieckie, Opolskie, and Slaskie regions, while the group of leaders includes Dolnoslaskie, Kujawsko-Pomorskie, and Lubelskie regions. Regional milieu has a positive impact on the probability of introducing marketing innovation for enterprises from the Dolnoslaskie, Podlaskie and Podkarpackie regions. On the other hand, a propensity to introduce this kind of innovation is, ceteris paribus, lower for enterprises from the Opolskie and Slaskie regions (Table 6).

Table 6. Random effects for the intercept in the equation explaining the propensity to introduce process, organizational and marketing innovations

Region	Process innovation (random intercept)	Organizational innovation (random intercept)	Marketing innovation (random intercept)
Dolnoslaskie	0.198	0.649	0.445
Kujawsko-Pomorskie	0.450	0.485	0.113
Lubelskie	-0.116	0.380	0.173
Lubuskie	-0.112	-0.084	-0.016
Lodzkie	-0.348	-0.225	-0.254
Malopolskie	0.365	-0.015	0.094
Mazowieckie	0.214	-0.324	-0.297
Opolskie	-0.288	-0.326	-0.388
Podkarpackie	0.573	0.117	0.221
Podlaskie	0.233	0.237	0.278
Pomorskie	-0.135	0.151	0.083
Slaskie	-0.282	-0.419	-0.335
Swietokrzyskie	-0.354	-0.315	-0.218
Warminsko-Mazurskie	-0.197	-0.024	0.059
Wielkopolskie	-0.065	-0.102	-0.119
Zachodniopomorskie	-0.531	-0.185	0.160

It should be noticed that the positive impact of location in a specific region on innovativeness is strongly visible in the case of enterprises from the Dolnoslaskie region, and to a lesser extent in the Kujawsko-Pomorskie and Podkarpackie regions.

This result can be justified by more intensive cooperation among enterprises from these regions. In particular, enterprises located in the Podkarpackie region cooperate very often with others in comparison with firms from other parts of Poland. It confirms the findings obtained by Grillitsch and Nilsson (2015) and Wassmann, Schiller and Thomsen (2016), who found that the innovation potential of enterprises located in less-developed regions is largely dependent on their collaboration patterns. In “Marshallian” terms, linkages among firms reduce transaction costs due to the geographical, social, and organizational proximity of innovation agents (Bengoa, Martinez-San Roman, & Perez, 2017).

In order to evaluate the goodness of fit of the multilevel probit model as well as the importance of firm-level (internal) and regional variables for enhancing innovations, the percentage of correctly predicted zeros and ones were calculated for three models:

- the full model;
- a standard probit model without the RIC variable;
- a multilevel model without firm-level variables.

The results presented in Table 7 indicate that the full model (with regional and firm-level variables) provides the best prediction; the predictive powers of the models at about 80% means that the selected explanatory variables are important drivers of innovativeness in Polish enterprises. Excluding regional variables brought a slight decrease in explanatory power while excluding firm-specific variables resulted in a substantial drop. This confirms that both groups of variables are significant; however, firm-specific variables seem to be more important than regional ones in enhancing innovations.

Table 7. The percentage of correctly predicted values for the full model and models without internal and regional innovation drivers

	Product innovation	Process innovation	Organizational innovation	Marketing innovation
Full model	82%	75%	77%	77%
Model without regional variables and regional random effects	78%	72%	73%	73%
Model without firm-level variables	67%	55%	56%	60%

In order to verify whether a firm located in an unfavorable environment may be a successful innovator, ranges of probabilities of introducing different types of innovations were calculated for regions with the lowest innovation potential. In order to check, whether the reverse is true, analogous ranges were calculated for firms from the least innovative sectors, assuming that firm-specific stimulants of innovativeness (the variables *RD, UNIV_MAN, UNIV_WORK, ICT_USE, ICT_SKILLS, ICT_TUT, INVEST_ICT, MOT_PAY, INT_COV)* are equal to 0.

Table 8. Ranges of probabilities of introducing different types of innovation for low-performing regions and firms with low values of innovation drivers

	Product innovation	Process innovation	Organizational innovation	Marketing innovation
Low innovativeness of region	between 0.01 and 0.86	between 0.01 and 0.76	between 0.01 and 0.74	between 0.00 and 0.26
Low innovativeness of firm	between 0.00 and 0.02	between 0.01 and 0.25	between 0.01 and 0.27	between 0.01 and 0.08

The results from Table 8 indicate that an SME with favorable “in-house capabilities” can have good innovation performance even if the region exerts less favorable conditions. Firms from less innovative regions may work actively and successfully to develop strategies in order to overcome regional constraints – they may acquire so much market intelligence that they outstrip counterparts in more innovative locations. The greater importance of firm-level variables in comparison to regional ones in enhancing innovations is in line with the findings of Keeble and Vaessen (1995) or Sternberg and Arndt (2001).

DISCUSSION AND CONCLUSIONS

The research study presented in this paper was aimed at identifying firm-level (internal) and external (regional) drivers of innovation in the regional dimension in Polish Small and Medium-Sized Enterprises which had undergone ICT upgrading and used modern technologies in their day-to-day operations. As almost all NUTS 2 regions in Poland (except Mazowieckie) are classified as less-developed regions in the context of the EU’s cohesion policy, this study has brought new insight to the discussion on enhancing the innovation potential of companies located in disfavored regions in a Central and Eastern Europe country.

Firstly, the results confirmed that having an R&D department, the quality of labor employed in enterprises, investments in and the use of ICT, organizational change, and motivation systems are key firm-level drivers of the innovativeness of Polish SMEs – most of these drivers are classified as co-innovative sources of productivity (Torrent-Sellens & Ficapal-Cusi, 2010). Secondly, the study revealed that regional factors influence, to a different degree, SMEs’ innovativeness – knowledge transfer and spillover effects stemming from the inter-regional presence of enterprises enhance only the introduction of product innovations, while the institutional milieu, proxied by the RIC measure, drives organizational and marketing innovations. Thus, we proved that the innovative behavior of Polish small and medium-sized enterprises operating in less-developed regions (by European Union standards) is dependent on the regional innovation policy and companies' collaboration patterns (Isaksen & Trippl, 2014a; Grillitsch & Nilsson, 2015; Sörvik et al., 2018). Thirdly, this study demonstrated which drivers are more important in enhancing SMEs' innovativeness. Interestingly, the main research hypothesis was verified negatively – even though we might assume that enterprises located in less-developed regions would rely more on regional innovation drivers, it appeared that firm-level factors are more significant for enhancing innovation than external ones. At the same time, the mixed effects model, which reflects the importance of technology spillovers among enterprises located in the same region, proved that firm-level and regional innovation drivers are reinforcing themselves. Taking advantage of the regional random effects approach made it possible to assess indirectly the effectiveness of innovation policies conducted in Polish NUTS 2 regions within RIS and then the S3 framework – by this token, Dolnoslaskie, Podkarpackie and Kujawsko-Pomorskie may be perceived as leaders.

Finally, though regional innovation potential influences the innovative behavior of SMEs, the innovation patterns of companies in regions do not always reflect the regional potential measured by the Regional Innovation Scoreboard or RIC index. In other words, SMEs in some regions (e.g., Podkarpackie or Zachodniopomorskie) report a bigger scale of innovation activities than would be expected from the level of regional innovation potential, while in other regions (e.g., Mazowieckie) this situation is reversed. It should be emphasized that the Mazowieckie region is an interesting example – on the one hand, it is the best developed Polish NUTS 2 region in terms of economic and innovation potential; on the other hand, SMEs' propensity to introduce all types of innovations analyzed in the paper is, ceteris paribus, lower than expected. At the same time, SMEs in the Mazowieckie region are more effective than average in translating R&D effort, ICT use, and ICT investments into product innovations.

The practical conclusion stemming from this research study posits that regional policies (within the framework of the Smart Specialisation Strategy) in less-developed regions should focus more on linking firm-level factors and regional innovation systems to enhance companies' innovation capacity (Hauge, Kyllingstad, Maehle, & Schulze-Krogh, 2017). Since SMEs rely more on in-house innovation capacity and, at the same time, firm-level and regional innovation drivers are reinforcing themselves (still not too much), strengthening this mechanism should be beneficial to companies (and regions) in terms of creating innovative potential. This leads to implications for further research – meaning the development of a framework (within the S3 concept) of more effective interdependence between the internal (companies) and regional innovation potential in less-developed regions.

In most cases, the obtained results confirm the conclusions from other studies devoted to the analysis of determinants of firm-level innovativeness of Polish enterprises (Arendt & Grabowski, 2017, 2018; Szczygielski & Grabowski, 2014; Szczygielski et al., 2017; Lewandowska & Kowalski, 2015; Lewandowska, 2016). Moreover, the results are consistent with the conclusions from studies devoted to regional differences in innovativeness (Golejewska, 2018). It should be stressed that the conclusions from this paper significantly expand the existing knowledge concerning firm-level and regional-level determinants of innovativeness. The novelty of the approach presented in this paper relies on combining, within one framework, firm-level data with meso data describing the innovative potential of the regional environment, and using multilevel random-effects models to test the hypothesis about the relevance of firm-level and regional drivers of SMEs' innovativeness. Thanks to the use of such an approach, we can evaluate interregional differences in the impact of consecutive factors on the probability of introducing different types of innovation. These conclusions should be treated as an original contribution in comparison with the results of other studies. Moreover, we were able to evaluate the relative significance of firm-level and regional factors on innovativeness, and the former turned out to be more important.

However, this study has some limitations. The most important one is related to the mode of firm-level data collection – survey research is not easily replicable. Moreover, as our data contains information about the innovation behavior of enterprises covering only one year before the survey, there is no possibility to use dynamic models or to analyze companies' innovation patterns in time. In addition, as the survey covered only SMEs, which are relatively advanced in ICT utilization, the results might differ if other, less ICT-ready SMEs had been surveyed as well.

Appendix - Summary statistics of dependent variables and regressors

Table A.1. Summary statistics of the dependent variable and regressors

	Binary variables
Variable	**Percentage of "ones" (%)**
INNOV_PROD	28
INNOV_PROC	16
INNOV_ORG	20
INNOV_MARKET	16
RD	23
UNIV_MAN	74
UNIV_WORK	26

Binary variables				
Variable	Percentage of “ones” (%)			
ICT_SKILLS	28			
ICT_TUT	40			
INVEST_ICT	50			
MOT_PAY	62			
INT_COV	63			
MANUFACTURING	15			
CONSTRUCTION	11			
SERVICES	31			
MTF	21			
Non-binary variables				
Variable	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
ICT_USE	0.36	0.27	1	0
ORG	0.34	0.48	1	0
Size	38.93	53.54	249	2

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Abstrakt

Artykuł podejmuje problematykę innowacyjności małych i średnich przedsiębiorstw w ujęciu regionalnym w gospodarce, która przeszłą proces transformacji systemowej. Analiza empiryczna bazuje na danych zgromadzonych w 820 polskich MŚP, które aktywnie wykorzystują ICT w swojej działalności. Celem głównym badania była identyfikacja wewnętrznych (na poziomie przedsiębiorstwa) i zewnętrznych (regionalnych) determinant innowacyjności małych i średnich przedsiębiorstw. Oryginalnym elementem badania było zastosowanie podejścia, w którym sięgnięto równocześnie po dane mikro i mezo opisujące potencjał innowacyjny firm i regionów, i użycie wielopoziomowego modelu efektów losowych do określenia, które z czynników – wewnętrzne czy regionalne – mają istotniejszy wpływ na innowacyjność MŚP. Dzięki wykorzystaniu regionalnych efektów losowych oceniono, w sposób pośredni, skuteczność polityki innowacyjnej prowadzonej w polskich województwach w ramach strategii RIS oraz inteligentnych specjalizacji. Nieoczekiwanie, hipoteza badawcza mówiąca o tym, że czynniki regionalne mają większy wpływ na innowacyjność MŚP niż wewnętrze (firmowe) determinanty, nie została potwierdzona. Badanie wykazało, że dla innowacyjności MŚP ze słabiej rozwiniętych regionów kraju, który przeszedł transformację systemową gospodarki, bardziej istotny jest potencjał wewnętrzny przedsiębiorstwa niż potencjał innowacyjny regionu. Sugeruje to, że strategia inteligentnych specjalizacji w słabiej rozwiniętych regionach powinna koncentrować się w większym zakresie na kreowaniu efektu synergii między czynnikami wewnętrznymi i regionalnymi systemami innowacji w celu zwiększenia zdolności innowacyjnych przedsiębiorstw.

Słowa kluczowe: *MŚP, innowacje, słabo rozwinięte regiony, wielopoziomowy model probitowy*

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