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Product and process innovation patterns in Polish low and high technology systems

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Abstract

Research background: While the Sectoral Innovation System (SSI) anticipates technology-related similarities in innovation patterns in the same sectors across countries, the distance to the frontier suggests that there are important differences with respect to the level of national technological development. Most contemporary analyses of sectoral innovation systems are focused on well-developed economies. In contrast, the evidence from developing countries including new EU members are scared and lack dynamics.
Purpose of the article: The purpose of this paper is to identify and compare product and process innovation patterns in Polish low and high technology systems. The main assumption is that divergence and convergence in innovation patterns of low- and medium-low technology (LMT) and high technology (HT) systems evolve over time and are strongly influenced by the characteristics of firms, their linkages with other system participants, existing demand, and institutional conditions.
Methods: According to the third edition of the Oslo Manual (OECD, 2005), we employ a harmonized questionnaire and methodology to collect unique micro data on innovation. The survey concerns 5252 firms including 873 firms from HT sector. The scope of the research relates to product and process innovation at least new to the firm.
Findings & value added: Our results show that although the intensity of product and process innovation is higher in HT system, both business support institutions and public financial instruments better support firms in LMT sectors. On the other hand, existing demand and market structure favor the emergence of new innovations at the firm level (imitations), but with more emphasis on LMT. The key source of innovation is suppliers, with foreign suppliers in HT and national

ones in LMT. In contrast to leading economies, LMT plays a key role in long term economic growth in Poland.

Introduction

The increasing number of innovation studies recognizes the importance of innovation in low- and medium technology firms[1] (LMT) (Galindo-Rueda & Verger, 2016, p. 5) in terms of supporting high technology industries, output, employment and aggregate growth (Frenz & Lambert, 2009, pp. 69–110; Hirsch-Kreinsen, 2008, pp. 19–43; Mendonça, 2009, pp. 470–482). Innovation in LMT is the result of incremental product development, customer-oriented innovations or the optimization of process technologies and it often involves the serial incorporation of high technology (HT) components into existing products and production processes (Robertson *et al.*, 2003, pp. 457–474). Other studies reveal the importance of informal linkages (Chen, 2009, pp. 527–535) and external sources of information (Grimpe & Sofka, 2009, pp. 495–506).

The empirical results show that LMT manufacturing firms are behind their HT equivalents in terms of product innovation, but in some respects appear to perform better in terms of process innovation (Kirner *et al*., 2009, pp. 447–458). The important role in this process play the diffusion of technologies developed by HT firms (Robertson & Patel, 2007, pp. 708–721; Roger, 1995). Due to the globalization and growing competition many LMT firms have been relocated from highly industrialized economies to low-wage countries what makes the renewal and transformation of those industries inevitable (Robertson *et al*., 2009, pp. 441–446).

In an evolutionary perspective, different patterns of structural change (sectoral dynamics) can be associated with specific technological dimensions (Cattani & Malerba, 2021, pp. 265–289; Dosi & Nelson, 2010, pp. 51–127; Dosi, 1988, pp. 1120–1171; Malerba, 2002, pp. 247–264). However, most contemporary analyses of innovation systems are based on well-developed economies including the USA, Japan, South Korea, and western European economies. In contrast, the evidence from the newly industrialized countries including Poland are scare and lack dynamics. Furthermore, the main goal of most European Union innovation polices is to increase innovativeness of European Union to meet global challenges. Due to existing technology gap, high share of low technology firms and post-

[1] According to the R&D intensity indicator which refers to the ratio of *R&D expenditure* to an output measure, usually gross value added (ISIC Rev. 3).

communism social structure, this approach is relatively successful in the case of those economies.

By using micro data collected during two studies (2009–11 and 2014–16) it was possible to examine the impact of demand, market structure and institutional support in two groups representing low- and medium-low firms (4379) and high and medium-high technology firms (873) in Poland. The analysis includes four out of sixteen of Polish NUT-2 voivodships (Wielkopolska, Łodzkie, Kujawsko-Pomorskie, Pomorskie). The original contribution of the study comprises not only sectoral dynamics of both product and process innovation in technology groups, but also describes the significance and impact of both private and public support instruments in comparison with classical elements of market structure as well as demand and cost expectations of firms. The research question focuses on dynamics of innovation in LMT industries in contrast to HT industries in a country with traditional industry structure like Poland. It is hoped that the results provided in this paper will facilitate comparison and establish differences in innovation patterns with the technologically leading countries. The overall objective of this paper is to find the main principles governing the differences in innovation patterns between two industry segments (HT and LMT) in a country with a catching-up economy.

This paper consists of section 2, which provides a brief review of the literature. Section 3 introduces the methodological aspects of the empirical study, the data, the measures of the variables and the econometric specifications. Section 4 shows the results, and Section 5 & 6 offer discussion and conclusions.

Literature review

Innovation conceptual framework

Schumpeter (1934) portrays innovation as "new combinations" of existing knowledge and resources. According to this perspective, innovation relates to the notion of creative destruction with technological ease of entry and a major role played by entrepreneurs and new firms what leads to dramatic economic changes of existing structures. On the contrary, Schumpeter (1942) discusses the relevance of the industrial research and development (R&D) laboratory lead by large firms for incremental, mainly technological innovation. Lundvall (1988, pp. 349–369) contends that innovation is a non-linear, complex, collaborative and multi-level process which is embedded in innovation systems. Malerba (1992, pp. 845–859) assumes that at the roots of technical change in industry lies learning by firms including learning-by-doing (Arrow, 1962, pp. 155–173), learning-by-using (Rosenberg, 1982), learning-by-interacting, learning-by-producing and learning-by-searching (Lundvall & Johnson, 1994, pp. 23–42). Edquist (1997, pp. 1–35) links innovation to complex mechanisms of knowledge distribution with two modes of innovation. The first, labeled The Science, Technology and Innovation (STI), refers to production and use of codified and technical knowledge, while the latter labeled the Doing, Using and Interacting (DUI) relies more on processes and experience-based know-how (Alhusen *et al.*, 2021, pp. 104–114; Bennat, 2022, pp. 1666–1691). Pavitt (1984, pp. 343–373) explains the existing differences in innovation patterns based on inter-sectoral contrasts. His taxonomy of innovation comprises four sectors classified as supplier-dominated with weak in-house R&D, but strong links with external technology suppliers to produce as cheap as possible, or a design-intensive product, production-intensive sectors including scale-intensive based on the coordination and organization of complex production processes and specialized equipment suppliers who transfer their knowledge in the form of machinery and installations. The last sector consists of science-based firms dominated by entrepreneurial regimes. However, many empirical studies suggest considerable variety of association across Pavitt's taxonomy and innovation type (Freel, 2003, pp. 751–770; Leiponen & Drejer, 2007, pp. 1221–1238).

Inspired by Cohen and Levin (1989, pp. 1059–1107); Nelson and Winter (1982) and Winter (1984, pp. 287–320), Malerba and Orsenigo (1997, pp. 83–118) demonstrate the importance of technological regimes in innovation patterns. The innovation regime called 'Schumpeter Mark I' represents a widening pattern of innovation and includes mechanical technologies and traditional sectors with the innovative function of the entrepreneur while the latter entitled 'Schumpeter Mark II' represents a deepening pattern of innovation and comprises R&D based industries (Fontana *et al.*, 2021, pp. 1977–2011).

Diversity of R&D intensity and technological advance depends on the strength and sources of technological opportunities, while technological regimes characterize the learning processes that are involved in innovative activitie (Klevorick *et al.*, 1995, pp. 185–205).

Another important context for innovation provides the stage of the life cycle of the industry in which a firm operates (Klepper, 1996, pp. 562–583, 1997, pp. 145–182). The sectoral system of innovation and production (SSI) provides a multidimensional, integrated and dynamic for examining factors that affect innovation in sectors and it integrates knowledge and technologies, actors and networks (Castellacci, 2008, pp. 978–994;

Malerba, 2005, pp. 63–82). Majority of empirical studies focus on high technology sectors in developed countries and ignore most traditional sectors due to low degrees of opportunity, appropriability and cumulativeness (Malerba, 2004), while

the distance to the frontier suggests that there are important differences with respect to the level of national technological development (Fassio, 2015, pp. 102–125).

Current empirical studies on patterns of innovation in LMT and HT

Notwithstanding the growth of research, no definition of success, concerning innovation in low and medium technology sectors (LMT) exists (Hirsch-Kreinsen *et al*., 2006, pp. 3–21).

Nouman *et al*. (2022) criticize the lack of scholarly attention to LMT industries in innovation research. Although products and production processes of LMT may be highly complex and capital intensive and LMT firms are major customer of HT sectors, their innovativeness is ignored (Robertson *et al.*, 2003, pp. 457–474). Robertson and Patel, (2007, pp. 708–721) demonstrate the reciprocal connections between the patterns of innovation in LMT and HT industries and show that both sectors are symbiotic. Robertson *et al*. (2009, pp. 441–446) suggest that innovation in LMT is significant due to the place of LMT sectors in modern industrialized economies, the diffusion of innovation to LMT firms; and the roles played by LMT firms and industries in adapting new technologies to fit into existing technological frameworks.

According to Radicic and Pinto (2019) the embodied knowledge in LMT industries is generally transferred from suppliers through marketing, design and process optimization. On the other hand, thanks to high strategic flexibility, LMT firms can develop innovations in the face of market competition (Sakka *et al*., 2019).

Due to the innovation processes of non-R&D intensive companies are less formalized, LMT firms can spread their capabilities across different divisions and compete innovatively on a global scale without incurring high R&D costs (Mattes *et al.*, 2015, pp. 165–197). On the other hand, numerous case studies confirm that firms representing SMEs in LMT sector can continuously adapt and innovate to maintain a measure of growth and profitability (Kastelli *et al*., 2018, pp. 882–900).

LMT manufacturing industries are more active in process innovations that are customer- or market-driven (Santamaría *et al*., 2009, pp. 507–517) or derive from relevant regulatory incentives or requirements (McKelvey &

Ljungberg, 2017, pp. 534–544). Only innovation in product is explained by R&D expenditures (Hervas-Oliver *et al.*, 2011, pp. 427–446).

The innovation process in LTM sectors is often less formal and more related to adaptation and learning by doing, based on design and process optimization (Zheng *et al.*, 2016), rather than formal R&D (Hansen & Lema, 2019, pp. 241–257). Firms can make incremental changes to product and process relying on firm interaction and shared experiences (Trott & Simms, 2017, pp. 605–623), engineering knowledge (Grimpe & Sofka, 2009, pp. 495–506), reverse engineering (Connolly, 2003, pp. 31–55) or adopt innovations developed by users (von Hippel, 1988, 2007, pp. 293–315).

Firms in LMT induce to search external related knowledge to foster innovation what suggests that LMT firms need an industrial environment that encourage cooperation, communication and interactions among firms (Wu & Wang, 2017, pp. 488–502). Accordingly, not only too little, but also too much proximity may be detrimental to interactive learning and innovation (Boschma, 2005, pp. 61–74). While HT industries are more likely to benefit from related variety, LMT industries tend to benefit more from specialization (Liang & Goetz, 2018, pp. 1990–1995).

In the low-technology sector, the combination of training investments and innovation is positively associated with revenue growth (Muñoz *et al.*, 2022). However, the impact of different types of partners on technological innovation depends on a firm's internal R&D investment (Kuen-Hung & Wang, 2009, pp. 518–526). In contrast, no substantial differences emerge with regard to the exploitation of these sources (Segarra-Ciprés *et al.*, 2012, pp. 203–217). Firms in LMT can successfully innovate when they develop and apply relevant set of capabilities (Reichert *et al.*, 2016, pp. 5437–5441).

Although research literature about innovation patterns in LMT and HT is vast, there is a lack of empirical evidence from catching up economies in Central and East part of Europe. To fill this research gap, we will present our research methodology, which is based on micro data collected in Poland.

Research methods

The analysis involves original unique micro data based on commercial database called Teleadreson. The dataset includes information about 22812 companies from 4 Polish voivodships (NUTS-2 regions): Wielkopolska, Lodzki, Kujawsko-Pomorski and Pomorski. Following the third edition of Oslo Manual (OECD, 2005) a harmonized questionnaire and methodology is used to collect information about innovation activity over the period 2009–2011 in 2012 and 2014–16 in 2017. The research procedure combines emails send directly to owners and general managers, a call conversation and finally a meeting with a company representative (only in some cases). The scope of the research relates to product and process innovation at least new to the firm. The response rate was 11%. The LMT & HT relates to the OECD taxonomy of economic activities technology based on R&D intensity including ISIC Rev. 3 and ISIC Rev. 4 (Galindo-Rueda & Verger, 2016). The overall number of firms in the analysis is 5252 including 4379 firms from LMT sector and 873 firms from HT sector. The sample of LMT firms comprises 2237 firms surveyed in 2012 and 2142 firms researched in 2017. The sample of HT firms consists of 436 firms surveyed in 2012 and 437 researched in 2017, respectively. The population of LMT (HT) firms in four surveyed regions is 63918 (10119), whereas the population for Poland[2] is 212234 (37002), respectively. Table 1 includes distribution of LMT & HT firms by economic activity.

The main hypothesis is that divergence and convergence in innovation patterns of LMT and HT systems evolve over time and are strongly influenced by the characteristics of firms, their linkages with other system participants, existing demand, and institutional conditions.

The following sub-hypotheses were used in the verification of the main hypothesis:

H1: *Lack of contacts with competitors, suppliers and customers has a negative impact on innovation implementation.*

H2: *Decreasing distance from a competitor, supplier and customer has a positive influence on innovation implementation.*

H3: *Business support institutions equally support LMT and HT firms.*

In this study, we define a list of possible factors that have bearing on innovation (Cassiman & Veugelers, 2006, pp. 68–82). Explained variables represent implementations of new or improved products or technological processes, including production methods, nonproduction systems, and support systems. In turn, explanatory variables consist of firm size (micro, small, medium, large), ownership of capital (national, foreign, mix), revenues in the last three years (increase, stagnation and decrease), sales range (local, regional, national, international), primary directions of the sale (ag-

[2] National Official Business Register (REGON).

glomeration, peripheries, intermediate territories), primary customer sectors, geographical proximity to competitor, supplier and customer (local, regional, national, international), type of relationships with competitor, supplier and customer (no contacts, cooperation, hostile, neighborly), employee qualifications (high comparing to the average in the sector=1), private and public instruments supporting entrepreneurship and innovation (technology parks, technology incubators, university incubators, technology transfer centers, business angels networks, local or regional loan schemes, guarantee schemes and business consulting centers).

All variables in our study are binary, which calls for logit modeling. Thus, all models are based on multinomial logistic regression, which estimates the effects of explanatory variables on a dependent variable with unordered response categories (Lemeshow & Sturdivant, 2013).

The econometric specification of the model is as follows (definition of the variables is given in table 2):

$$\begin{aligned} &NewProd_i/NewProc_i/NewProcMet_i/NewProcNon_i/\ NewProcSup_i = \\ &= \alpha_0 + \alpha_1 StaffC_i + \alpha_2 CusAgr_i + \alpha_3 CusInd_i + \alpha_4 CusEne_i + \alpha_5 CusCon_i + \\ &+ \alpha_6 CusTrade_i + \alpha_7 CusFood_i + \alpha_8 CusFinIns_i + \alpha_9 CusPub_i + \\ &+ \alpha_{10} CusHealth_i + \alpha_{11} CusEdu_i + \alpha_{12} CusEnt_i + \alpha_{13} CusRet_i + \\ &+ \alpha_{14} ComLoc_i + \alpha_{15} ComReg_i + \alpha_{16} ComNat_i + \alpha_{17} ComInt_i + \\ &+ \alpha_{18} RelComNo_i + \alpha_{19} RelComClose_i + \alpha_{20} RelComHost_i + \\ &+ \alpha_{21} RelComGNe_i + \alpha_{22} SupLoc_i + \alpha_{23} SupReg_i + \alpha_{24} SupNat_i + \\ &+ \alpha_{25} SupInt_i + \alpha_{26} RelSupSimple_i + \alpha_{27} RelSupClose_i + \\ &+ \alpha_{28} RelSupHost_i + \alpha_{29} RelSupGNe_i + \alpha_{30} CusLoc_i + \alpha_{31} CusReg_i + \\ &+ \alpha_{32} CusNat_i + \alpha_{33} CusInt_i + \alpha_{34} RelCusNo_i + \alpha_{35} RelCusClose_i + \\ &+ \alpha_{36} RelCusHost_i + \alpha_{37} RelCusGNe_i + \alpha_{38} TechPark_i + \alpha_{39} IncTech_i + \\ &+ \alpha_{40} IncUni_i + \alpha_{41} TechCent_i + \alpha_{42} BAngels_i + \alpha_{43} CredFund_i + \\ &+ \alpha_{44} LoanGuart_i + \alpha_{45} TranCon_i + Control\ Variables \end{aligned} \quad (1)$$

We use the Wald test to test the significance. In order to verify the significance of the whole model, the likelihood-ratio chi-squared test is applied. The level of statistical significance is $p < 0.05$. All calculations are performed in Statistica Software. In order to determine the direction and magnitude of changes occurring over time between the periods, we calculate the absolute margin according to the following key:

$$Gap = t_{2014\text{-}16} - t_{2009\text{-}11} \quad (2)$$

Furthermore, to track changes in the strength and direction of determinants over the five years between surveys, a dichotomous auxiliary variable called period (2014–2016) was defined. It takes the value 1 for the 2014–2016 period. Finally, the divergence indicator was introduced described by the following equations:

$$\begin{gathered} D_{2009\text{-}11} = Zm(LMT)_{2009\text{-}11} - Zm(HT)_{2009\text{-}11} \\ D_{2014\text{-}16} = Zm(LMT)_{2014\text{-}16} - Zm(HT)_{2014\text{-}16} \\ Divergence\ (convergence) = |D_{2014\text{-}16}| - |D_{2009\text{-}11}|, \end{gathered} \tag{3}$$

where Zm(LMT)/(HT) indicates the value of independent variable describing LMT/HT and $|D_{2014\text{-}16}|$ is an absolute value of distinction for one of two periods.

Results

Descriptive results

As the indicator of innovation effort, we use the fact that the firm developed and launched any product innovation or process innovation in 3-year period (2009–11 or 2014–16). Three types of process innovation include production methods, non-production systems and support systems (see Table 3). In contrast to developed countries the highest values relate to process innovation. In the case of HT system the gap between periods increased in product innovation, support and non-production systems, while in LMT system the disparity increased in production methods and support systems.

It is worth noting, that the overall innovation activity decreased between periods in both systems. The Table 4 shows how product and process innovation gap fluctuate over the five-year period. The process of divergence includes product innovation, non-production and support systems. On the other hand, both systems converge with each other in terms of process innovation and production methods.

Technological variations concern innovation-related external linkages are well established (see Table 5). Industrial sectors vary in terms of the sources, paces and rates of technological change , so one may expect that specific sectors use specific internal and external resources in order to innovate successfully (Wang *et al*., 2014, pp. 484–514). Table 5 shows that the HT sector generally tends to cooperate more with science and technology institutions and business angels networks what is consistent with other results (Grimpe & Sofka, 2009, pp. 495–506). However, both sectors constitute the most significant innovative cooperation with suppliers, customers, local or regional loan schemes, guarantee schemes and business consulting centers. The effect of the cooperation with external agents on innovation has been extensively examined in the literature. The greater importance of cooperation with industrial agents suggest for supplier-dominated firms (Pavitt, 1984, pp. 343–373).

Regression analysis

Table 6 includes four logistic regression models. Model 1 and Model 2 concern implementations of new products in LMT and HT respectively while Model 3 and Model 4 consider implementations of new processes in LMT and HT.

For LMT, the drivers of new product and process innovations are firm size and qualified personnel. Exports favor product innovations (see Model 1), while national sales enhance the implementation of process innovations (see Model 3). Existing demand from industry, energy sector, construction, trade, public sector, and entertainment sector favor process innovation (see Model 3). In contrast, demand generated by the public sector and trade support product innovation (see Model 1). Competitors and customers have little impact. Conversely, nationwide suppliers foster both types of innovation. Nevertheless, having only basic relationships with them has a negative effect. Supporting infrastructure has a positive impact except for business angels and incubators.

In the case of HT, export and sales in intermediate territories are factors that favor new product innovations (see model 2) whereas medium firm size and qualified personnel positively influence the implementation of process innovations (see Model 4). Existing demand from the healthcare and retail sectors promote product innovation (see Model 2), while demand generated by industry, construction, and the public sector support product innovation (see Model 4). Lack of contact with competitors limits implementations in both areas. In the contrary, cooperation with suppliers has a positive effect. In contrast to LMT, only selected business supporting institutions (technological centers and business consulting centers) foster both product and process innovation.

Table 7 includes six logistic regression models. Model 5 and Model 6 concern implementations of new methods in LMT and HT respectively. Model 7 and Model 8 consider implementations of non-production systems. Finally, Model 9 and 10 relate to implementations of support systems.

In the case of LMT, an increase in company size positively influences the implementation of a new production method, a nonproduction system, or a support system. On the other hand, revenue stagnation and exports favor the emergence of new methods (see Models 5 and 7), and high staff competence supports both production methods and non-system implementations (see Models 5 and 7).

In contrast, sales to the periphery and intermediate territories limit the implementation of new production methods and the introduction of support systems (see Model 5 and 9). Demand from industry, trade and the public sector positively supports all types of implementations. Close relationships with competitors and the presence of key competitors abroad negatively affect the implementation of new production methods (see Model 5). Close or good neighborly relationships with suppliers boost the implementation of support systems (Model 9). In contrast, the influence of customers is low. Supporting infrastructure has a positive impact except for business angels and incubators.

In the case of HT, the number of new process implementations increases as firm size increases (see Models 6, 8, and 10). Existing demand from the energy, trade, and healthcare sectors favors the introduction of new production methods (see Model 6), while demand generated by the public sector supports non production systems (see model 8), and industry, trade, and retail positively influence the introduction of supporting systems (see model 10). The impact of competitors is negligible, while cooperation with suppliers stimulates the implementation of new production methods and support systems (see Models 6 and 10). In contrast to LMTs, technology parks, technology transfer centers, local and regional loan funds and business support centers positively support the studied areas (see model 6, 8 and 10).

Discussion

This study identifies key factors which shape product and process innovation in LMT and HT firms. It shows the moderating effect of firm size on product and process innovations in LMT what complies with findings support the idea that large firms possess innovative advantages over smaller ones (Choi & Lee, 2017, pp. 459–481). However, our results do not support this assumption in HT as only medium firms are innovative significantly.

On the other hand, our analysis is consistent with the study Caerteling *et al*. (2009, pp. 1211–1221) indicating the importance of public sector in LMT product innovation. In our models the existing market demand impacts more LMT, but innovation in HT depends also on the relationships with LMT sectors what is in line with Hirsh-Kreinsen *et al*. (2006, pp. 3–21). The findings show that firms in LMT sector recognize the importance role of employing highly qualified staff what is consistent with Thornhill (2006, pp. 687–703) who accent the benefits from investments in competent staff.

The importance of export in innovation fostering is consistent with studies that highlight the role of innovation in the process of internationalization (Nowiński & Rialp, 2013, pp. 191–231; Andersson *et al.*, 2014, pp. 390–405). Although, many studies concerning product innovation in HT sector emphasize the role of cooperation with customers (Candi *et al.*, 2016, pp. 418–434; Cui & Wu, 2015, pp. 516–538), we show that close cooperation with suppliers involves product and process innovation in HT. It suggests imitative character of innovations and is an accurate representation of several studies that confirm the importance of suppliers in both developed and developing countries (Chung & Kim, 2003, pp. 587–603; Johnsen, 2009, pp. 187–197).

Hostile relationships with competitors lead to less product innovation, whereas simple relationships with suppliers and no relationships with customers result in decrease product as well as process innovations what supports the findings about the role of competitors and suppliers in LMT system (Trott & Simms, 2017, pp. 605–623). However, this result contrasts with the empirical evidence found on a “U inverted” relationship (Pavitt *et al.*, 1987, pp. 297–316), but it is consistent with the thesis that innovation is demand-push and firms innovate less in less developed markets than in markets where demand grows or is stable (Schmookler, 1966).

The low number of relationships between high tech and non-high tech sectors suggest low health of analyzed high tech firms what is consistent with Robertson and Patel (2007, pp. 708–721). Many other pieces of evidence illustrate the fact that those firms which do not cooperate and which do not formally or informally exchange knowledge limit their knowledge base in a long term (Hauknes & Knell, 2009, pp. 459–469). In our case, cooperation with suppliers concern HT sector in relation to implementation of new production methods and support systems, which is consistent with the view presented by Chamberlin and Doutriaux (2010, pp. 487–510).

Furthermore, our analysis proves the importance of business support infrastructure what is consistent with Pittaway *et al.* (2004, pp. 137–168) who accent the importance of network relations and intermediaries.

Finally, our results prove that business support infrastructure more frequently foster innovations in LMT firms what is consistent with a study where cooperation with consultants, commercial laboratories, and R&D private institutes is more valued in activities with low innovation capacity, where the propensity for innovation is also reduced (Huang *et al.*, 2010, p. 63).

Conclusions

The study demonstrates that innovation patterns are relatively stable in time and are strongly influenced by the characteristics of firms, their relationships with suppliers, competitors and customers, existing demand, and business support institutions. The results prove H1 sub-hypothesis that no contacts with external partners have a negative impact on innovation implementation. However, it is only relevance to 3 cases: (1) competitors and process innovation in HT, (2) customers and process innovation in LMT, and customers and implementation of new production methods and support systems in LMT. H2 hypothesis turns out to be false as there are no significant relationships to prove it. Moreover, there are evidence that both nationwide competitors and suppliers, and customers from abroad support innovations in LMT as well as HT whereas local partners tend to limit them. Lastly, H3 hypothesis is so false as more business support institutions facilitate innovations in LMT firms. The extended view on the process innovation including production methods, non-production systems and support systems confirm that larger firms innovate more in both sectors, but HT sector is more vulnerable in terms of stagnation in revenues and demand including regional customers. In contrast, LMT sector depends on more diversified customers including variety sectors and international customers.

The research confirms domination of process innovations in both sectors due to the low level of R&D investments and dominance of imitations development that involve innovative activities that do not require R&D, such as the purchase of advanced machinery, computer hardware and software, the acquisition of patents and licenses, investment in training, and other procedures such as design and production engineering. This suggests reorienting analyses of the determinants of innovative performance in developing countries including both sectors away from R&D and towards combinations of other capabilities that can support innovation.

Considering different modes of innovation, the interdependent nature of innovation processes and their embeddedness in innovation systems, innovation can be assumed to be a diverse phenomenon. The development experience of most countries indicates that the catching up process is associated with the emergence and growth of some leading sectors that in turn contribute, both directly and indirectly, towards the development process. However, sectors vary in terms of the context in which such changes take place. Thus, while a sectoral system in developing countries might broadly adhere to the different dimensions including knowledge, technological domain, boundaries, agents, interaction and networks, and institutions, there are significant differences with respect to each of these dimensions for sectors operating in a developing country as compared their counterparts in the developed world. The existence of that variety leads to the need of policy differentiation especially in developing countries. However, caution should be exercised when generalizing results. The final solutions depend partly on the technical decisions.

The next step for this research is to consider conducting representative research backed by a qualitative analysis to bring a more in-depth discussion of the achieved results. The research has got some limitations. The key limitation is the nature of analyzed innovations as it focuses on innovation new for firms. The lack of information about R&D investments and cooperation with university institutions is also a limit.

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Annex

Table 1. Distribution of LMT & HT firms by economic activity

LMT Economic Activity (PKD 2007)	%	HT Economic Activity (PKD 2007)	%
10: Food products	13.82	20: Chemicals and chemical products	12.60
11: Beverages	0.80	21: Pharmaceuticals	4.47
12: Tobacco products	0.16	26: Computer. electronic and optical products	8.02
13: Textiles	6.65	27: Electrical equipment	16.95
14: Wearing apparel	8.77	28: Machinery and equipment. n.e.c.	43.18
15: Leather and related products	1.21	29: Motor vehicles. trailers and semi-trailers	6.41
16: Wood and products of wood and cork	7.51	303: Air and spacecraft and related machinery	0.46
17: Paper and paper products	2.69	30X: Railroad. military vehicles and transport n.e.c. (ISIC 302. 304 and 309)	3.67
18: Printing and reproduction of recorded media	10.09	325: Medical and dental instruments	4.24
19: Coke and refined petroleum products	0.30	Total	100.00
22: Rubber and plastic products	7.47		
23: Other non-metallic mineral products	7.47		
24: Basic metals	2.83		
25X: Fabricated metal products except weapons and ammunition (ISIC 25 less 252)	11.35		
31: Furniture	9.04		
32X: Other manufacturing except medical and dental instruments (ISIC 32 less 325)	8.65		
301: Building of ships and boats	1.19		
Total	100.00		

Table 2. Definition of the variables

Variables	Description
Dependent Variable	
NewProd	Binary variable; 1: new product innovation implementation; 0: otherwise
NewProc	Binary variable; 1: new process innovation implementation; 0: otherwise
NewProcMet	Binary variable; 1: new production methods implementation; 0: otherwise
NewProcNon	Binary variable; 1: new nonproduction systems implementation; 0: otherwise
NewProcSup	Binary variable; 1: new support systems implementation; 0: otherwise

Table 2. Continued

Variables	Description
Independent Variables	
StaffC	Binary variable; 1: staff competence high in comparison to average in a sector; 0: otherwise
CusAgr	Binary variable; 1: customers represent agriculture; 0: otherwise
CusInd	Binary variable; 1: customers represent industry; 0: otherwise
CusEne	Binary variable; 1: customers represent energy sector; 0: otherwise
CusCon	Binary variable; 1: customers represent construction; 0: otherwise
CusTrade	Binary variable; 1: customers represent trade; 0: otherwise
CusFood	Binary variable; 1: customers represent food industry; 0: otherwise
CusFinIns	Binary variable; 1: customers represent finance or insurance sectors; 0: otherwise
CusPub	Binary variable; 1: customers represent public sector; 0: otherwise
CusHealth	Binary variable; 1: customers represent heath sector: 0: otherwise
CusEdu	Binary variable; 1: customers represent education; 0: otherwise
CusEnt	Binary variable; 1: customers represent entertainment; 0: otherwise
CusRet	Binary variable; 1: customers represent retail sector; 0: otherwise
ComLoc	Binary variable; 1: key competitors are locally; 0: otherwise
ComReg	Binary variable; 1: key competitors are in a region; 0: otherwise
ComNat	Binary variable; 1: key competitors are in a country; 0: otherwise
ComInt	Binary variable; 1: key competitors are abroad; 0: otherwise
RelComNo	Binary variable; 1: no relationships with competitors; 0: otherwise
RelComClose	Binary variable; 1: close relationships with competitors; 0: otherwise
RelComHost	Binary variable; 1: hostile relationships with competitors; 0: otherwise
RelComGNe	Binary variable; 1: good neighbour relationships with competitors; 0: otherwise
SupLoc	Binary variable; 1: key suppliers are locally; 0: otherwise
SupReg	Binary variable; 1: key suppliers are in a region; 0: otherwise
SupNat	Binary variable; 1: key suppliers are in a country; 0: otherwise
SupInt	Binary variable; 1: key suppliers are from abroad; 0: otherwise
RelSupSimple	Binary variable; 1: simple relationships with suppliers; 0: otherwise
RelSupClose	Binary variable; 1: close relationships with suppliers; 0: otherwise
RelSupGNe	Binary variable; 1: good neighbour relationships with suppliers; 0: otherwise
CusLoc	Binary variable; 1: key customers are locally; 0: otherwise
CusReg	Binary variable; 1: key customers are in a region; 0: otherwise
CusNat	Binary variable; 1: key customers are in a country; 0: otherwise
CusInt	Binary variable; 1: key customers are from abroad; 0: otherwise
RelCusNo	Binary variable; 1: no relationships with customers; 0: otherwise

Table 2. Continued

Variables	Description
RelComClose	Binary variable; 1: close relationships with competitors; 0: otherwise
RelComHost	Binary variable; 1: hostile relationships with competitors; 0: otherwise
RelComGNe	Binary variable; 1: good neighbour relationships with competitors; 0: otherwise
SupLoc	Binary variable; 1: key suppliers are locally; 0: otherwise
SupReg	Binary variable; 1: key suppliers are in a region; 0: otherwise
SupNat	Binary variable; 1: key suppliers are in a country; 0: otherwise
SupInt	Binary variable; 1: key suppliers are from abroad; 0: otherwise
RelSupSimple	Binary variable; 1: simple relationships with suppliers; 0: otherwise
RelSupClose	Binary variable; 1: close relationships with suppliers; 0: otherwise
RelSupGNe	Binary variable; 1: good neighbour relationships with suppliers; 0: otherwise
CusLoc	Binary variable; 1: key customers are locally; 0: otherwise
CusReg	Binary variable; 1: key customers are in a region; 0: otherwise
CusNat	Binary variable; 1: key customers are in a country; 0: otherwise
CusInt	Binary variable; 1: key customers are from abroad; 0: otherwise
RelCusNo	Binary variable; 1: no relationships with customers; 0: otherwise
RelCusClose	Binary variable; 1: close relationships with customers; 0: otherwise
RelCusHost	Binary variable; 1: hostile relationships with customers; 0: otherwise
RelCusGNe	Binary variable; 1: good neighbour relationships with customers; 0: otherwise
TechPark	Binary variable; 1: collaboration with technology park; 0: otherwise
IncTech	Binary variable; 1: collaboration with technology incubator; 0: otherwise
IncUni	Binary variable; 1: collaboration with university incubator; 0: otherwise
TechCent	Binary variable; 1: collaboration with technology transfer centre 0: otherwise
BAngels	Binary variable; 1: collaboration with business angels; 0: otherwise
CredFund	Binary variable; 1: collaboration with credit guarantee fund; 0: otherwise
LoanGuart	Binary variable; 1: collaboration with local or regional loan firm; 0: otherwise
TranCon	Binary variable; 1: collaboration with training and consulting centre; 0: otherwise
Control Variables	
Period	Binary variable; 1: 2014-16 survey; 0: otherwise
SmallF	Binary variable; 1: small firm; 0: otherwise
MediumF	Binary variable; 1: medium firm 0: otherwise
LargeF	Binary variable; 1: large firm; 0: otherwise
ForeignC	Binary variable; 1: foreign capital firm; 0: otherwise
RevDec	Binary variable; 1: revenues decrease; 0: otherwise

Table 2. Continued

Variables	Description
RevStag	Binary variable; 1: revenues stagnation; 0: otherwise
SaleScopeNat	Binary variable; 1: national sales range; 0: otherwise
SaleScopeIntr	Binary variable; 1: international sales range; 0: otherwise
SaleDirPer	Binary variable; 1: selling on the periphery; 0: otherwise
SaleDirTer	Binary variable; 1: selling on intermediate territories; 0: otherwise

Source: own study based on Oslo methodology.

Table 3. Product and process innovation in LMT & HT systems

R&D Intensity	Period	Product Innovation	Process Innovation	Production Methods	Non Production Systems	Support Systems
LMT	2009-11	63.1	70.7	44.2	30.2	21.0
	2014-16	62.1	67.7	49.0	25.2	22.1
	Gap	-1.0	-3.0	+4.8	-5.0	+1.1
HT	2009-11	69.3	77.8	49.3	35.1	29.4
	2014-16	72.1	73.9	49.4	37.5	33.6
	Gap	+2.8	-3.9	+0.1	+2.4	+4.2

Table 4. Product and process innovation gap between LMT and HT systems

Period	Product Innovation	Process Innovation	Production Methods	Non Production Systems	Support Systems
2009-11	-6.2	-7.1	-5.1	-4.9	-8.4
2014-16	-10.0	-6.2	-0.4	-12.4	-11.6
|2009-11| - |2014-16|	-3.8	+0.9	+4.7	-7.4	-3.1

Table 5. Innovation-related external linkages in LMT and HT systems

Partner	LMT			HT		
	2009-11	2014-16	Gap	2009-11	2014-16	Gap
competitors	5.6	3.8	-1.8	5.5	4.6	-0.9
suppliers	25.2	30.4	+5.2	27.5	35.5	+8.0
customers	20.0	20.9	+0.9	23.6	24.7	+1.1
Polish Academy Units	0.3	0.8	+0.5	2.1	1.8	-0.3
universities	3.1	4.1	+1.0	6.7	8.5	+1.8
national research units	6.5	1.7	-4.8	14.5	4.8	-9.7

Table 5. Continued

Partner	LMT			HT		
	2009-11	2014-16	Gap	2009-11	2014-16	Gap
foreign research units	1.3	0.8	-0.5	3.4	0.7	-2.7
technology parks	8.3	5.7	-2.6	13.1	13.5	+0.4
technology incubators	3.5	1.8	-1.7	4.4	4.8	+0.4
academic incubators	1.6	1.4	-0.2	1.8	3.4	+1.6
technology transfer centers	5.8	3.0	-2.8	14.4	7.6	-6.8
business angels networks	2.1	1.8	-0.3	3.0	3.2	+0.2
local or regional loan schemes	20.6	22.4	+1.8	17.0	19.5	+2.5
guarantee schemes	17.1	21.3	+4.2	14.9	18.8	+3.9
business consulting centers	25.0	28.6	+3.6	35.8	35.0	-0.8

Table 6. Logit models for products and process innovation in LMT & HT systems

	Logistic regression models (Odds ratio in parentheses)			
	LMT Model 1 (NewProd)	HT Model 2 (NewProd)	LMT Model 3 (NewProc)	HT Model 4 (NewProc)
SmallF	0,17 (1,42)	-	0,29 (1,80)	-
MediumF	0,26 (1,69)	-	0,43 (2,39)	0,49 (2,67)
LargeF	0,34 (1,97)	-	0,69 (3,93)	-
RevStag	-	-0,39 (0,45)	0,15 (1,23)	-0,34 (0,50)
StaffC	0,21 (1,53)	-	0,10 (1,22)	0,45 (2,47)
SaleScopeNat	-	-	0,07 (1,16)	-
SaleScopeIntr	0,21 (1,54)	0,38 (2,14)	-	-
SaleDirPer	-0,24 (0,60)	-0,24 (0,61)	-	-
SaleDirTer	-0,09 (0,83)	0,27 (1,74)	-	-
CusInd	-	-	0,11 (1,26)	-
CusEne	-	-	0,24 (1,64)	0,28 (1,75)
CusCon	-	-	0,12 (1,28)	-
CusTrade	0,13 (1,30)	-	0,11 (1,25)	0,47 (2,59)
CusFinIns	-	-0,41 (0,43)	-	-0,50 (0,36)
CusPub	0,16 (1,39)	-	0,14 (1,34)	-
CusHealth	-	0,29 (1,80)	-	0,25 (1,65)
CusEnt	-	-	0,24 (1,63)	-
CusRet	-	0,18 (1,44)	-	-
ComLoc	-	-	-	-0,28 (0,56)
ComNat	-	0,17 (1,43)	-	-
RelComNo	-	-0,30 (0,54)	-	-0,27 (0,57)
RelComHostile	-0,21 (0,65)	-0,48 (0,38)	-	-
RelComGNe	0,11 (1,25)	-	-	-
SupNat	0,10 (1,22)	-	0,09 (1,21)	-
SupInt	-	-	0,19 (1,47)	-
RelSupSimple	-0,13 (0,75)	-	-0,09 (0,83)	-
RelSupClose	-	0,33 (1,93)	-	0,41 (2,28)

Table 6. Continued

Logistic regression models (Odds ratio in parentheses)				
	LMT Model 1 (NewProd)	HT Model 2 (NewProd)	LMT Model 3 (NewProc)	HT Model 4 (NewProc)
CusReg	-	-0,16 (0,71)	-	-
RelCusNo	-	-	-0,12 (0,78)	-
TechPark	0,35 (2,02)	-	0,65 (3,70)	0,40 (2,26)
IncTech	0,31 (1,87)	0,43 (2,37)	0,33 (1,94)	-
TechCent	0,38 (2,17)	0,42 (2,31)	0,60 (3,34)	0,86 (5,63)
BAngels	-	-	-	0,83 (5,28)
CrediFund	0,20 (1,50)	-	0,37 (2,12)	-
LoanGuar	0,21 (1,52)	-	0,48 (2,61)	0,75 (4,50)
TranCentr	0,30 (1,82)	0,31 (1,88)	0,59 (3,25)	0,51 (2,80)
Constants	-2,19	-1,02	-4,96	-3,62
Sample	4379	873	4379	873
Likelihood ratio	-2604	-458	-2269	-372
chi-square	566,64	138,378	852,12	219,803
R2 Coxa-Snell	0,121	0,147	0,177	0,222
R2 Nagelkerke	0,165	0,209	0,250	0,332
Hosmer-Lemeshow Test	6,884	5,575	10,146	8,596
Hosmer-Lemeshow p-value	0,549	0,695	0,255	0,377

Table 7. Logit models for process innovation including production methods, non-production systems and support systems in LMT & HT

	Logistic regression models (Odds ratio in parentheses)					
	LMT Model 5 (NewProcMet)	HT Model 6 (NewProcMet)	LMT Model 7 (NewProcNon)	HT Model 8 (NewProcNon)	LMT Model 9 (NewProcSup)	HT Model 10 (NewProcSup)
Period	-	-	-0,21 (0,65)	-	-	0,13 (1,32)
SmallF	0,16 (1,39)	0,21 (1,54)	0,26 (1,70)	-	0,15 (1,36)	-
MediumF	0,17 (1,43)	0,22 (1,55)	0,47 (2,56)	0,37 (2,11)	0,32 (1,90)	0,23 (1,58)
LargeF	0,38 (2,16)	-	0,63 (3,54)	0,55 (3,00)	0,44 (2,41)	0,39 (2,20)
ForeignC	-	-	-0,12 (0,78)	-	-	-
RevDec	-0,10 (0,80)	-	-	-	-	-
RevStag	0,07 (1,15)	-0,25 (0,60)	0,07 (1,16)	-	-	-
StaffQ	0,09 (1,20)	-	-	-	0,16 (1,37)	-
SaleScopeReg	-	-	-	-	-	0,25 (1,64)
SaleScopeNat	-	-	0,08 (1,17)	-	-	-
SaleScopeIntr	0,13 (1,31)	0,21 (1,53)	0,13 (1,29)	-	-	-
SaleDirPer	-0,15 (0,73)	-0,20 (0,66)	-	-	-0,10 (0,80) (*)	-
SaleDirTer	-0,10 (0,81)	-	-	-	-0,14 (0,74)	-
CusAgr	0,16 (1,39)	-	-	-	-	-
CusInd	0,10 (1,23)	-	0,09 (1,19)	-	0,11 (1,26)	0,27 (1,73)
CusEne	0,16 (1,39) (*)	0,19 (1,47)	-	-	0,16 (1,39) (*)	-
CusCon	-	-	0,14 (1,33)	-	-	-0,17 (0,70)
CusTrade	0,06 (1,13) (*)	0,23 (1,60)	0,11 (1,25)	-	0,12 (1,27)	0,26 (1,69)
CusFood	-	-	0,18 (1,44)	-	-0,10 (0,81) (*)	-
CusFinIns	-	-	-0,26 (0,59)	-	-	-
CusPub	0,10 (1,24)	-	0,08 (1,19)	0,19 (1,47)	0,17 (1,40)	-
CusEdu	-0,16 (0,72)	-0,45 (0,40)	-	-	0,15 (1,37)	-
CusHealth	-	0,26 (1,68)	-	-	0,18 (1,46)	-
CusEnrt	-	-	0,09 (1,21)	-	0,18 (1,43)	-
CusRet	-	-	0,10 (1,23)	-	0,11 (1,25)	0,23 (1,59)
ComInt	-0,24 (0,60)	-	-	-	-	-
RelComClose	-0,10 (0,81)	-	-	-	-	-

Table 7. Continued

	Logistic regression models (Odds ratio in parentheses)					
	LMT Model 5 (NewProcMet)	HT Model 6 (NewProcMet)	LMT Model 7 (NewProcNon)	HT Model 8 (NewProcNon)	LMT Model 9 (NewProcSup)	HT Model 10 (NewProcSup)
SupReg	-	-	-	-	-0,08 (0,83)	-
SupInt	-	-	0,25 (1,66)	-	-	-
RelSupSimple	-	-	-	-0,33 (0,51)	-	-
RelSupClose	-	0,16 (1,40)	-	-	0,16 (1,39)	0,28 (1,76)
RelSupGNe	-	-	-	-	0,24 (1,63)	-
CusReg	-	-	-	-	-	-0,23 (0,62)
CusIntr	-	-	-	0,22 (1,58)	-	-
RelCusNo	-0,12 (0,77)	-	-	-	-	-
RelCusGNe	-	-	-	-	-0,13 (0,75)	-
TechPark	0,26 (1,70)	0,21 (1,52)	0,44 (2,41)	0,30 (1,85)	0,16 (1,38)	0,23 (1,60)
IncTech	-	-	0,22 (1,57)	-	0,26 (1,69)	-
IncUni	-	-	-	-	0,26 (1,69)	-
TechCent	0,14 (1,34) (*)	0,45 (2,45)	0,24 (1,64)	0,12 (0,27)	0,22 (1,55)	0,41 (2,26)
BAngels	-	-	0,30 (1,84)	-	-	-
CrediFund	0,23 (1,61)	-	0,18 (1,44)	-	0,15 (1,37)	-
LoanGuar	0,21 (1,52)	0,28 (1,76)	0,21 (1,53)	0,37 (2,13)	0,32 (1,91)	0,29 (1,80)
TranCentr	0,31 (1,86)	0,29 (1,79)	0,26 (1,69)	0,30 (1,84)	0,32 (1,92)	0,33 (1,94)
Constants	-0,94	-0,66	-1,76	-0,84	-1,00	-0,24
Sample	4379	873	4379	873	4379	873
Likelihood ratio	-2793	-542	-2290	-505	-2019	-468
chi-square	445,752	123,785	579,388	132,034	514,543	149,201
R2 Coxa-Snell	0,097	0,132	0,124	0,141	0,111	0,157
R2 Nagelkerke	0,129	0,176	0,179	0,192	0,171	0,221
Hosmer-Lemeshow Test	7,971	4,018	11,231	9,08	13,043	4,886
Hosmer-Lemeshow p-value	0,436	0,855	0,188	0,169	0,110	0,769

Note: (*) – significance at a level of 10%.