Dynamics of innovation in low and medium-low technology (LMT) and high and medium-high technology (HT) sectors in Poland

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Agenda

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Introduction 1/2

- The increasing number of innovation studies recognizes the importance of innovation in low- and medium technology firms and industries (LMT) (Galindo-Rueda & Verger, 2016; Hatzichronoglou, 1997) in terms of *supporting high technology industries, output*, *employment* and *aggregate growth* (Frenz & Lambert, 2009; Hirsch-Kreinsen, 2008; Mendonça, 2009; Rothgang, Peistrup, & Lageman, 2011; Sandven, Smith, & Kaloudis, 2005; von Tunzelmann & Acha, 2006).

- Innovation in LMT firms and industries:
  - is the result of *incremental product development*, *customer-oriented innovations* or *the optimization of process technologies* .
  - involves the serial incorporation of high technology (HT) components into existing products and production processes (Hirsch-Kreinsen, 2008; Robertson et al., 2003).
  - concerns informal linkages (Chen, 2009) and external sources of information (Grimpe & Sofka, 2009).

- LMT manufacturing firms lag behind their HT counterparts regarding product innovation performance, but they in some respects seem to perform better at process innovation (Kirner, Kinkel, & Jaeger, 2009).

- 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 & Patel, 2007; Robertson, Smith, & von Tunzelmann, 2009).

Introduction 2/2

- Different patterns of structural change (sectoral dynamics) can be associated with specific technological dimensions (Breschi & Malerba, 1997; Dosi & Nelson, 2010; Dosi, 1982, 1988b; Malerba, 1992, 2002).
- Due to existing technology gap, a high share of low technology firms and post-communism social structure, the evidence from the newly industrialized countries, including Poland is scare and lack dynamics.
- This paper fills this gap as it includes a longitudinal study that involves two periods: 2009-11 and 2014-16 in two technology groups representing low- and medium-low firms (4379) and high and medium-high technology firms (873) in Poland.
- The original contribution of the study comprises sectoral dynamics of innovation in technology groups and 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 the dynamics of innovation in LMT industries in contrast to HT industries in a country with traditional industry structure.
- The research results support:
  - the comparison and establish differences in innovation patterns with the technologically leading countries,
  - implications for both the European Union as well as Polish innovation policies.
- The presentation is organized as follows: first section provides a brief review of the literature. Next part describes the methodological aspects of the empirical study, the data, the measures of the variables, and the econometric specifications. Section 4 presents the results, and Section 5 offers some conclusions from the study.

Modes of innovation in literature

- Creative destruction with technological ease of entry and a significant role played by entrepreneurs (Schumpeter, 1934)
- Incremental, mainly technological innovation based on research and development (R&D) laboratory lead by large firms (Schumpeter,1942)
- A non-linear, complex, collaborative, and multi-level process which is embedded in innovation systems (Lundvall 1988, 1992).
- Technical change based on learning-by-doing (Arrow, 1962), learning-by-using (Rosenberg, 1982), learning-by-interacting, learning-by-producing and learning-by-searching (Malerba, 1992)
- Edquist (1997) links innovation to complex mechanisms of knowledge distribution with two modes of innovation. The first labeled The Science, Technology, and Innovation (STI), refers to the 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 (Jensen, Johnson, Lorenz, & Lundvall, 2007).
- Pavitt (1984) explains the existing differences in innovation patterns based on inter-sectoral contrasts.
- Breschi, Malerba, & Orsenigo (2000) 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 (Malerba & Orsenigo, 1996).
- Another critical context for innovation provides the stage of the life cycle of the industry in which a firm operates (Agarwal & Gort, 1996; Klepper, 1996, 1997; Utterback & Abernathy, 1975).
- 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; Malerba, 2002, 2005).

Innovation in LMT

- While the SSI predicts the existence of technology-related similarities in innovative patterns in the same sectors across countries, the Distance-to-the Frontier suggests the existence of relevant differences related with the level of technological development of each sector (Fassio, 2015).
- Notwithstanding the growth of research, no definition of success, concerning innovation in low and medium technology sectors (LMT), exists (Hirsch-Kreinsen, Jacobson, & Laestadius, 2005; Hirsch-Kreinsen, Jacobson, & Robertson, 2006).
- Von Tunzelmann and Acha (2005) criticize the lack of scholarly attention to LMT industries in innovation research.
- Robertson & Patel (2007) demonstrate the reciprocal connections between the patterns of innovation in LMT and HT industries and show that both sectors are symbiotic.
- Robertson, Smith, & von Tunzelmann (2009) 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 adopting new technologies to fit into existing technological frameworks.
- According to Huang, Arundel, & Hollanders (2010), the embodied knowledge in LMT industries is generally transferred from suppliers through marketing, design, and process optimization.
- LMT firms can develop innovative products, processes and organizational methods in the face of market competition (Hirsch-Kreinsen, 2015; Kirner et al., 2009).
- 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, Zanker, & Som, 2015).
- Firms representing SMEs in LMT sector can continuously adapt and innovate to maintain a measure of growth and profitability in this way provide learning opportunities within the sector as a whole (Dooley & O'Sullivan, 2017; Karagouni, 2018; Kastelli, Tsakanikas, & Caloghirou, 2018).
- LMT are more active in process innovations that are customer- or market-driven (Grimpe & Sofka, 2009; Santamaría, Nieto, & Barge-Gil, 2009) or derive from relevant regulatory incentives or requirements (Caerteling, Halman, Song, & Dorée, 2009; McKelvey & Ljungberg, 2017; Rothgang et al., 2011; Spencer, Murtha, & Lenway, 2005).

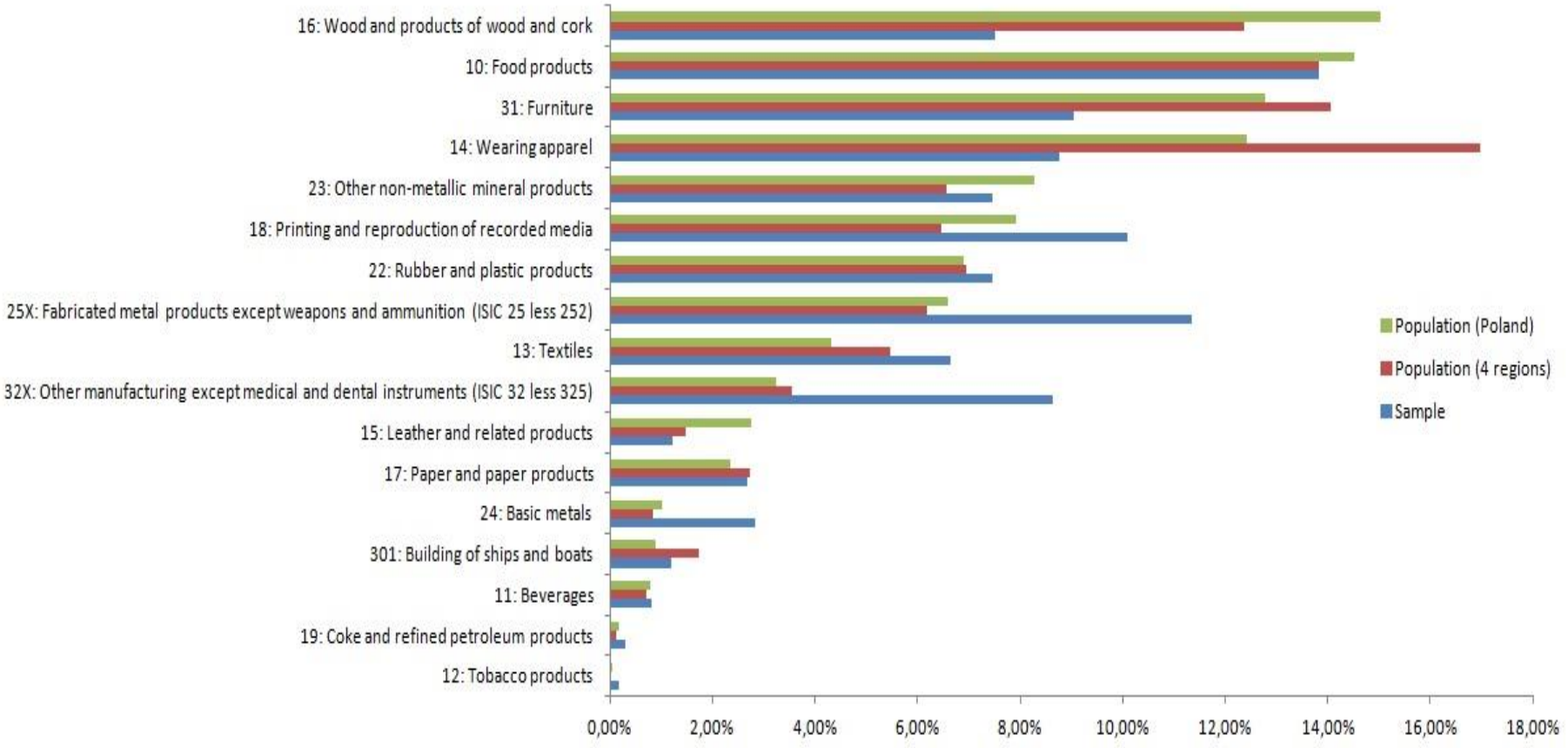
Innovation in LMT

- Less formal and more related to adaptation and learning by doing, based on design and process optimization (Chen, 2009; Zheng, Guo, & Wang, 2016), rather than formal R&D (Hansen & Serin, 1997; Hansen & Lema, 2019).
- Firms make incremental changes to product and process relying on firm interaction and shared experiences (Trott & Simms, 2017), engineering knowledge (Grimpe & Sofka, 2009), reverse engineering (Connolly, 2003) or adopt innovations developed by users (von Hippel, 1988, 2007).
- Compared to HT sectors, LMT firms and industries are inclined to search external related knowledge to facilitate innovation what suggests that LMT firms need an industrial environment that favors cooperation, communication, and interactions among firms (Wu & Wang, 2017).
- Accordingly, not only too little but also too much proximity may be detrimental to interactive learning and innovation (Boschma, 2005).
- LMT industries tend to benefit more from specialization (Liang & Goetz, 2018).
- The combination of training investments and innovation is positively associated with revenue growth (Thornhill, 2006).
- The impact of different types of partners on technological innovation depends on a firm's internal R&D investment (Kuen-Hung & Wang, 2009).
- No substantial differences emerge concerning the exploitation of these sources (Chamberlin & Doutriaux, 2010; Segarra-Ciprés, Bou-Llusar, & Roca-Puig, 2012).
- Firms develop and use an appropriate set of capabilities (Reichert, Torugsa, Zawislak, & Arundel, 2016).

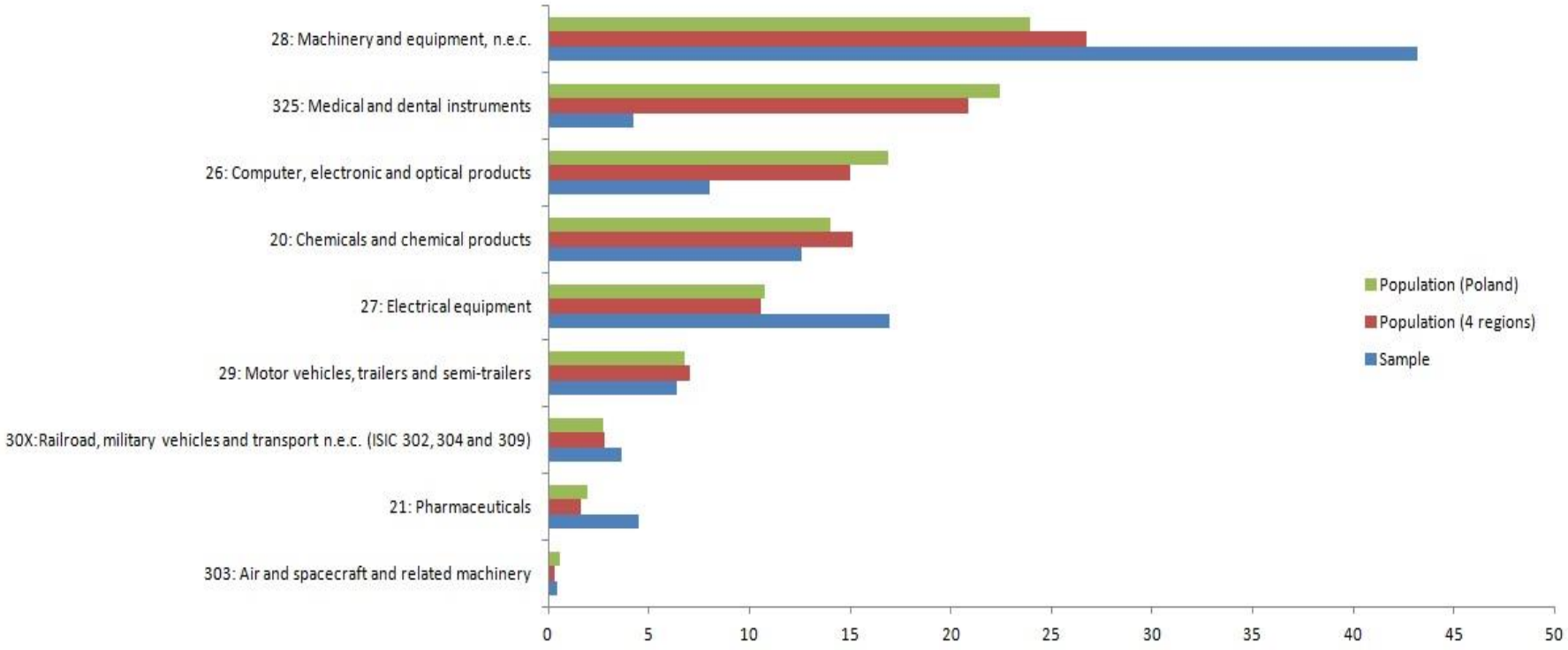
Data and methodology

- Following the third edition of Oslo Manual (OECD, 2005), a questionnaire and methodology is used to collect information about innovation activity over the period 2009-2011 in 2012 and 2014-16 in 2017.
- The scope of the research relates to product & process innovation new to the firm. The response rate is 11%.
- The research refers to four out of sixteen Polish regions: Wielkopolska, Lodzki, Kujawsko-Pomorski, and Pomorski.
- Those regions are moderate innovative, and the structure of an industry is a good match for the domestic structure of the industry .
- 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 while 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 is 212234 (37002) .

Distribution of LMT firms by economic activity and sectoral classification



Distribution of HT firms
by economic activity and sectoral classification



Variables

- Explained variables represent implementations of new or improved products or technological processes, including production methods, nonproduction systems, and support systems.
- 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 (agglomeration, 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).
- Our goal is to find factors that have a significant impact on innovation and show how these influence changes.
- All variables in our study are binary, which calls for multinomial logistic regression modeling (Aldrich & Nelson, 1984; Lemeshow & Sturdivant, 2013; Liao, 1994). The Wald test tests the significance of the independent variable coefficients. The level of statistical significance is $p < 0.05$.
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- The econometric specification of the model is as follows:
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- $$\text{PRODUCT (PROCESS) INNOVATION}_i = \alpha_{0+}\alpha_1\text{FIRM\_SIZE}_i + \alpha_2\text{CAPITAL}_i + \alpha_3\text{REVENUES}_i + \alpha_4\text{SALES\_RANGE}_i + \alpha_5\text{SALE\_DIRECTION}_i + \alpha_6\text{CUSTOMER\_SECTOR}_i + \alpha_7\text{COMPETITOR\_PROXIMITY}_i + \alpha_8\text{SUPPLIER\_PROXIMITY}_i + \alpha_9\text{CUSTOMER\_PROXIMITY}_i + \alpha_{10}\text{COMPETITOR\_RELATIONS}_i + \alpha_{11}\text{SUPPLIER\_RELATIONS}_i + \alpha_{12}\text{CUSTOMER\_RELATIONS}_i + \alpha_{13}\text{EMPLOY\_QUALIFICATIONS}_i + \alpha_{14}\text{BUSINESS\_SUPPORT\_INSTRUMENTS}_i$$
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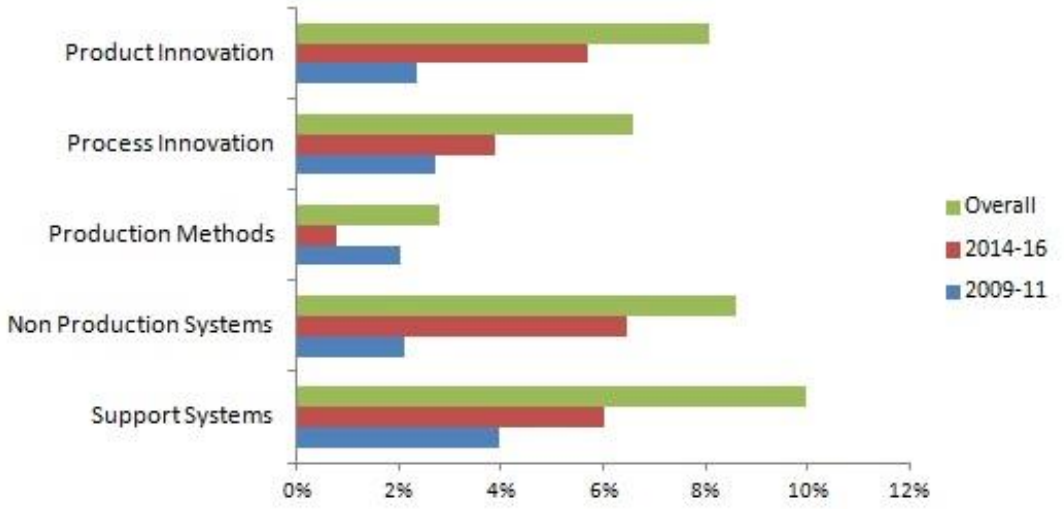
Innovation gap between HT and LMT sectors (%)

Innovation in LMT & HT sectors (%)

R&D Intensity	Period	Product Innovation	Process Innovation	Production Methods	Non Production Systems	Support Systems
LMT	2009-11	32,22	36,13	22,59	15,41	10,71
	2014-16	30,37	33,11	23,98	12,31	10,80
	Overall	62,59	69,24	46,57	27,72	21,51
HT	2009-11	34,59	38,83	24,63	17,53	14,66
	2014-16	36,08	37,00	24,74	18,79	16,84
	Overall	70,68	75,83	49,37	36,31	31,50

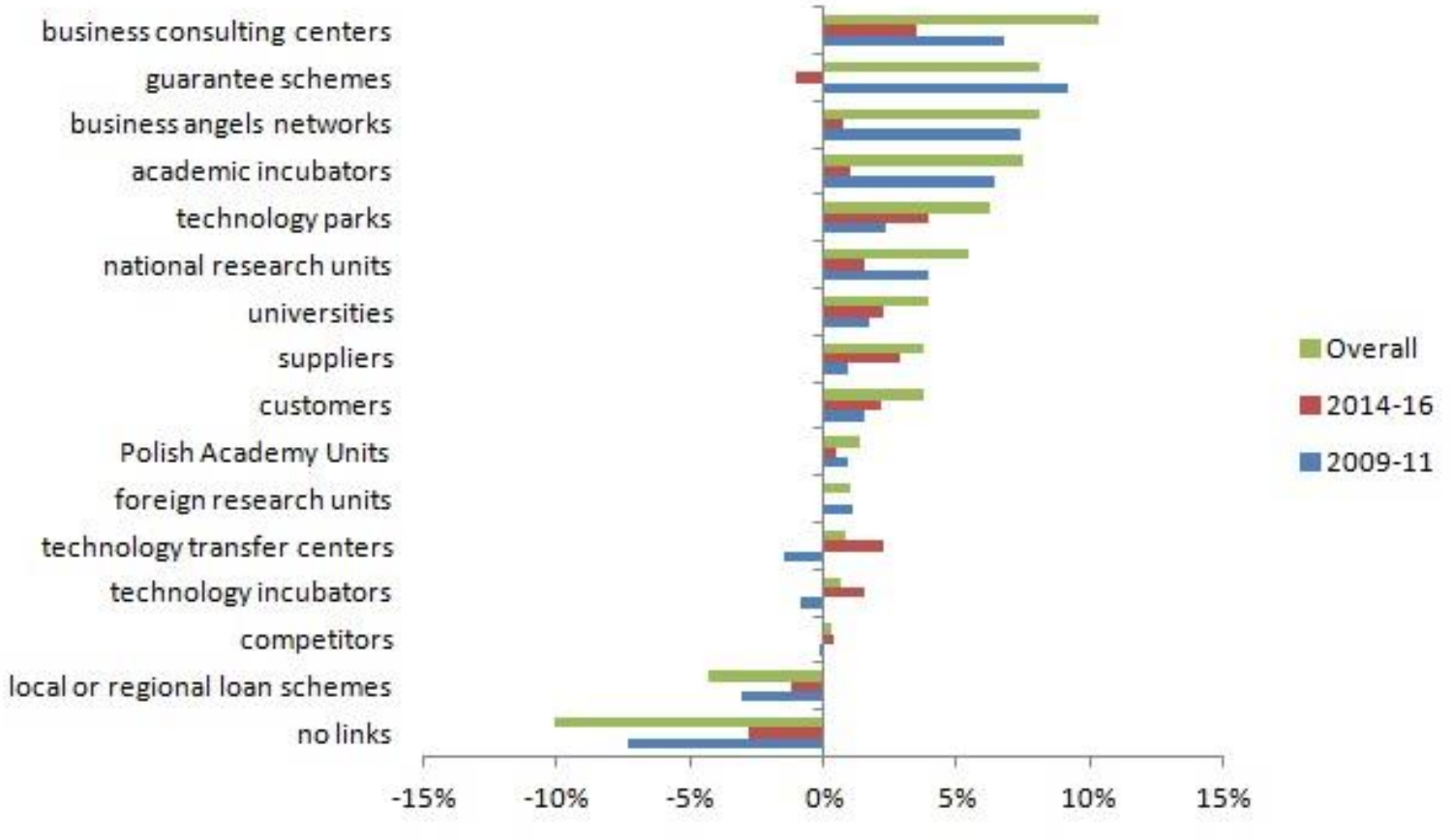
Innovation gap between HT and LMT sectors (%)



Innovation-related external linkages (%)

Partner	LMT			HT		
	2009-11	2014-16	Overall	2009-11	2014-16	Overall
competitors	2,85	1,87	4,72	2,75	2,29	5,04
suppliers	12,86	14,87	27,73	13,75	17,75	31,50
customers	10,21	10,23	20,44	11,80	12,37	24,17
Polish Academy Units	0,14	0,41	0,55	1,03	0,92	1,95
universities	1,58	1,99	3,57	3,32	4,24	7,56
national research units	3,31	0,82	4,13	7,22	2,41	9,63
foreign research units	0,64	0,41	1,05	1,72	0,34	2,06
no links	30,94	28,77	59,71	23,60	26,00	49,60
technology parks	4,22	2,79	7,01	6,53	6,76	13,29
technology incubators	1,78	0,89	2,67	0,92	2,41	3,32
academic incubators	0,80	0,66	1,46	7,22	1,72	8,93
technology transfer centers	2,95	1,48	4,43	1,49	3,78	5,27
business angels networks	1,10	0,87	1,96	8,48	1,60	10,08
local or regional loan schemes	10,50	10,96	21,47	7,45	9,74	17,18
guarantee schemes	8,72	10,41	19,14	17,87	9,39	27,26
business consulting centers	12,79	14,00	26,79	19,59	17,53	37,11

Gap of innovation-related external linkages between HT and LMT sectors (%)



Logistic models of the probability of introducing new products and processes in LMT & HT sectors

Variable	Product Innovation		Process Innovation	
	LMT	HT	LMT	HT
period 2014-16	1,033	-	-	-
micro firm (0-9)	-0,300	-	-	-
small firm (10-49)	-	-	0,496	-
medium firm (50-249)	-	-	0,755	1,027
large firm (>249)	-	-	1,240	-
national ownership of capital	0,986	-	-	-
foreign ownership of capital	1,069	-	-	-
mix ownership of capital	1,131	-	-	-
inrease in revenues (in the last three years)	1,295	-	1,031	-
decrease in revenues (in the last three years)	0,733	-	0,593	-
stagnation in revenues (in the last three years)	0,681	-0,748	0,685	-0,667
highly qualified staff compared to the industry average	0,353	-	-	0,863
local sales range	-	-	-0,323	-
international sales range	0,407	0,821	-	-
sales in the agglomeration	0,148	-	-	-
sales on the periphery	-0,288	-0,524	-	-
primary customers from industry	-	-	0,257	-
primary customers from energy sector	-	-	0,508	-
primary customers from construction sector	-	-	0,250	-
primary customers from trade sector	0,331	0,507	0,218	0,904
primary customers from public administration	0,252	-	0,279	-
primary customers from healthcare	-	0,602	-	-
primary customers from entertainment and recreation sector	-	-	0,444	-
local competitors	-	-	-	-0,536
national suppliers	0,211	-	-	-
no relationships with competitors	-	-	-	-0,548
cooperation with competitors	-	0,744	-	-
hostile relationships with competitors	-0,452	-	-	-
neighbourly relationships with competitors	0,265	0,442	0,170	-
necessary relationships with suppliers	-0,234	-	-	-0,836
cooperation with suppliers	-	0,629	-	-
neighbourly relationships with suppliers	-	-	-	-0,802
no relationships with customers	-	-	-0,262	-
cooperation with technology parks	0,641	-	1,283	0,932
cooperation with technology incubators	0,560	-	-	-
cooperation with technology transfer centers	0,718	0,890	1,157	1,706
cooperation with local or regional loan funds	0,404	-	0,732	-
cooperation with credit guarantee funds	0,442	-	0,960	1,396
cooperation with training and consulting centers	0,623	0,728	1,166	0,992
Chi2	645,95	121,89	895,88	208,86
Observations	4379	873	4379	873

Logistic models of the probability of introducing new production methods, nonproduction systems, and support systems in LMT & HT

Variable	Production Methods		Non Production Systems		Support Systems	
	LMT	HT	LMT	HT	LMT	HT
micro firm (0-9)	-0,692	-0,603	-0,483	-0,738	-0,299	-
small firm (10-49 osob)	-0,385	-	-	-0,918	-	-
medium firm (50-249 osob)	-0,393	-	0,378	-	0,337	0,414
large firm (>249)	-	-	0,660	-	0,546	0,746
inrease in revenues (in the last three years)	0,508	-	0,608	-	-	-
decrease in revenues (in the last three years)	-	-	0,464	-	-	-
stagnation in revenues (in the last three years)	0,360	-0,526	0,424	-	-	-0,630
highly qualified staff compared to the industry average	0,166	-	-	-	0,328	-
local sales range	-	-	-0,264	-	-	-
regional sales range	-	-	-	-	-	0,500
international sales range	0,246	0,434	0,217	-	-	-
sales in the agglomeration	-	-	-	-	0,279	-
primary customers from agriculture and fisheries	0,312	-	-	-	-	-
primary customers from industry	0,212	-	-	-	0,255	0,527
primary customers from energy sector	0,369	-	-	-	-	
primary customers from construction sector	-	-	0,278	-	-	-
primary customers from trade sector	0,141	0,448	0,231	-	0,229	0,506
primary customers from gastronomy sector	-	-	0,343	-	-	-
primary customers from public administration	0,227	-	-	0,365	0,353	-
primary customers from education sector	-0,317	-0,831	-	-	0,353	-
primary customers from healthcare	-	0,508	-	-	-	-
primary customers from entertainment and recreation sectors	-	-	-	-	0,347	-
primary customers representing end users	-	-	0,196	-	0,221	0,455
primary suppliers in region	-	-	-	-	-0,181	-
primary suppliers abroad	-	-	0,515	-	-	-
primary customers in region	-	-	-	-	-	-0,511
primary customers abroad	-	-	-	0,501	-	-
necessary relationships with suppliers	-	-	-	-	-0,350	-
cooperation with suppliers	-	-	-	0,489	-	0,560
neighbourly relationships with customers	-	-	-	-	-0,230	-
cooperation with technology parks	0,557	-	0,885	0,667	0,383	0,487
cooperation with technology incubators	-	-	0,426	-	0,524	-
cooperation with technology transfer centers	-	0,939	0,487	0,554	0,451	0,741
cooperation with business angels	-	-	0,618	-	-	-
cooperation with local or regional loan funds	0,498	-	0,395	-	0,311	-
cooperation with credit guarantee funds	0,417	0,522	0,449	0,764	0,651	0,606
cooperation with training and consulting centers	0,633	0,571	0,538	0,600	0,649	0,673
Chi2	444,23	111,91	590,12	128,46	500,52	142,48

Conclusions

- The study demonstrates that both product and process innovation is higher in HT sector.
- Process innovation takes higher levels in LMT as well as HT sector, but product innovation is increasing more vibrant.
- Both sectors prefer cooperation with industrial agents what suggest for supplier-dominated firms.
- HT sector cooperates more including science and technology and business support institutions except for local or regional loan schemes.
- The LMT sector tends to innovate no matter of ownership and revenue and depends on external partners more while HT sector is more vulnerable on business cycles, demand and cooperate less.
- The propensity to implement product innovation in LMT sector increased in 2014-16 (2017) compared to 2009-11 (2012).
- The expansive view on the process innovation including production methods, nonproduction 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.
- LMT sector depends on more diversified customers, including various sectors and international customers.
- Due to the low level of R&D spending in Poland (0,9% of GDP in 2017) process innovation dominates in both sectors as it often involves 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 what 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.
- 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 (Malerba, 2002).
- The 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 concerning 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 that were made.
- 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.

- Thank you ☺.