JAGODA KASZOWSKA-MOJSA*

Innovation Strategies of Polish Manufacturing Companies through the Business Cycle[1]

Introduction

The aim of the study was to analyse and compare the differences in the innovation activities and strategies of Polish manufacturing companies during the economic expansions (2004–2008 and 2013–2014) and slowdowns (2009–2013) of Polish economy. I assumed that supply factors play a key role in the innovation activities and strategies of firms. However, because the aim was to analyse the impact of changes in the macroeconomic conditions on the innovation strategies of firms, I had to consider the role of the demand factors as well, including their influence on the innovation activities and the use of innovation resources. During an economic slowdown, market demand decreases, which emphasises the gap in competences between firms and may bring further incentives for introducing innovations. In other words, a slowdown or recession may cause changes in a firm's innovation strategy. A preliminary analysis of the innovation activities of manufacturing companies indicated that there is heterogeneity in the manner and timing of this type of activity. Some companies undertake innovative activities in a procyclical way and some in an anticyclical way. It was important to the answer to the question which factors influence a company's innovation activity during an economic slowdown or expansion. It was also relevant to analyse the behaviour of individual companies and the groups of firms that carry out similar business activities (firms that belong to the same subsectors of a manufacturing sector according to the Statistical Classification of Economic Activities in the European Community (NACE rev. 2), and to determine whether their behaviour in the aggregate is procyclical or countercyclical.

* Jagoda Kaszowska-Mojsa, Ph.D. – Institute of Economics, Polish Academy of Sciences; e-mail: jagoda.kaszowska@inepan.waw.pl

[1] The article presents the results of a research grant no. 2015/17/B/HS4/02742, which was funded by the National Science Center. This was a collective research project managed by Prof. Wziątek-Kubiak as the project leader, but the article has been written individually by the author. The statistical data used in the calculations originate from the Statistical Office in Szczecin, which assumes no responsibility for the conclusions reached in the paper.

1. Literature review and research hypotheses

Literature review

The problem of the differentiation of innovation strategies is a key element of the discussion between mainstream researchers and those that represent an evolutionary tradition. Evolutionary approaches, strategic management and the Austrian business cycle theory focus on the differentiation of sources, factors and the forms in which knowledge is accumulated among firms and in time, which shape the innovation strategies of the firms and their behavior on the market (Mintzberg 1988). The evolutionary perspective focuses primarily on the supply side of innovation. However, in our study, we not only adopted the supply-side approach, but also the demand one. The impact of the changes in demand has been somewhat neglected in the literature. The objective of this study is to fill the gap in the literature and to provide insights on the differentiation of a firm's innovation strategies during different phases of the business cycle, which goes far beyond the current state-of-the-art. On the one hand, an external shock, such as a decrease in market demand during an economic slowdown, can make the introduction of innovation harder even with a higher knowledge accumulation of a firm. Therefore, an external shock may cause a change in a firm's innovation strategy. On the other hand, following the Schumpeterian approach, we can assume that the crisis can mobilize companies that already have some innovation facilities and a history of introducing innovations to the market.

Although the diversity of a firm's innovation strategy constitutes one of the three pillars of the evolutionary perspective, an empirical analysis of this problem has only recently been undertaken. Its main directions reflect two approaches: a sectoral or a micro-economic approach. Within the sectoral approach, two streams of research have emerged. Both of these posit that the innovation strategy of a firm is determined by the characteristics of its sector. Pavitt's (1984) taxonomy of industries paved the way for the first stream (Peneder 2003, de Jong et al. 2006, Leiponen and Drejer 2007, Castellaci 2008). In the second one – the OECD classified industries according to their technological intensity.

Subsequent studies (e.g. Srholec and Verspagen 2008) undermined the conclusion that the differences in the innovation strategies among the sectors were greater than those among firms. A subsequent micro-economic research showed the differentiation of the firms' innovation strategies in some EU countries (Wziątek-Kubiak et al. 2013). In the empirical literature, there are two main approaches that deal with this issue. Both are extensions of the evolutionary approaches. The first one (Llerena and Oltra 2002, Damanpour and Wischnevsky 2006, Jensen et al. 2007) focuses on the internal and external sources of innovation. The second one (Leiponen and Dreijer 2007, Srholec and Verspagen 2008, Peneder 2003, Som et al. 2010; for an overview of some studies on innovation modes, see Frenz and Lambert 2010) uses a cluster analysis to select different

innovation strategies. Most of them are based on the data from the Community Innovation Survey (CIS). This pool of research differs with respect to the period of the analysis, a company's activities (manufacturing and/or services) and the variables that are used. These analyses have raised the issue of innovation persistence, which was analysed in certain countries. The non-availability of the micro-data for Polish firms implied that the issue of innovation persistence could not be studied for Polish firms.

The literature on the impact of a crisis or economic slowdown on the innovation behavior of the firms is surprisingly scarce. Despite the Schumpeterian origin of the evolutionary perspective, the above-mentioned topic was rarely undertaken (Antonioli et al. 2011). To date, research on the relationship between the innovation behavior of the firms and changes in the business cycle has shown (Archibugi and Filippetti 2011, 2012; Archibugi et al. 2013a, 2013b; Correa and Iootty 2010; Wziątek Kubiak and Pęczkowski 2013) a very strong sensitivity of the innovation activities of the firms in the EU new member states to an external shock such as an economic slowdown. This suggests that the level of knowledge accumulation influences the sensitivity of the innovation activities of the firms to changes in the business cycle. In addition, the recent publications of Wziątek-Kubiak (2019) and Kaszowska-Mojsa (2020) showed that the demand effect was visible and that the crisis decreased the likelihood of innovating while the entire sample of firms (innovative and non-innovative firms) was considered.

The remaining open question is how the conclusions would change if we restricted the sample to the firms which had innovation facilities and a history of introducing innovations to the market. This problem is closely related to the issue of innovation persistency. There are firms which are highly or moderate-persistent and which have a successful history of implementing innovations. However, there are also firms that have scarce experience in innovation development and introduce them only occasionally.

Another problem which will be tackled in this paper is the problem of aggregation bias. The Schumpeterian opportunity cost hypothesis predict that firms concentrate innovative activities in recessions. Firms shift resources toward "productivity-enhancing activities such as training, reorganization or software, and away from productivity activities in recessionary times, when the opportunity cost of doing so is lower" (Fabrizio and Tsolmon 2014, Hall 1991, Saint-Paul 1993, Aghion and Saint-Paul 1998). As it was pointed out by Fabrizio and Tsolmon (2014), "theory proposes that firms shift R&D investments and innovation from recessions to booms to maximize returns by capturing high-demand periods before imitators compete away rents". However, empirical evidence (carried out mostly on aggregates) suggests that innovative activities are procyclical (Berlevy 2007, Comin and Gerler 2006, Fatas 2000, Geroski and Walters 1995, Griliches 1990). Nonetheless, the results of analyses conducted on the disaggregated data suggest a strong heterogeneity of firms' innovation activities and strategies. Moreover, the studies on the procyclicality of R&D and innova-

tion activity are not concluding. In my paper, I attempt to answer the question to what extent the procyclicality of innovation activity in Polish manufacturing sector may be the result of aggregation bias. I also show how productivity-enhancing activities, such as training, R&D or purchase of software, were carried out in different phases of business cycle by different firms classified by the degree of innovation activity persistence (highly persistent innovators, moderate-persistent innovators, low-persistent innovators, occasional innovators or challengers).

Research hypotheses

Based on the presented literature research, I identified a number of issues that require further research and verification of the established hypotheses. In this article, I verify four main hypotheses.

H1: The procyclicality of innovation activities in the manufacturing sector is primarily the result of an aggregation bias.

H2: Changes in the macroeconomic environment result in changes in the typology of innovative firms in terms of their persistence in innovation and innovation strategies.

The following groups of innovators can be identified: persistent innovators, occasional innovators and challengers. The first group of firms undertakes innovation repetitively in the long term. The firms from the second group only introduce innovation occasionally, primarily during a period of upswing. Finally, challengers introduce innovation irrespective of the slowdowns.

H3: Changes in the macroeconomic environment are accompanied by a differentiation in innovation strategies among and within the three types of innovators.

For example, the innovation strategies of persistent innovators change in an upturn compared to a slowdown and differ from the innovation strategies of the other groups of innovators.

H4: The probability of the commercialisation of an innovation is primarily determined by internal and external funding, the size of the company, the investment in R&D and macroeconomic (demand-side) factors.

2. Innovative companies in the sample

We based our analysis on the Central Statistical Office's survey on the innovation activities of the Polish manufacturing companies (so-called PNT-02), which partly overlaps with the Community Innovation Survey (CIS). In the project, we used the data for the period from 2004 to 2014. Therefore, five databases were

used for the following periods: 2004–2006, 2006–2008, 2008–2010, 2010–2012 and 2012–2014. We constructed a panel of 3691 manufacturing firms that had reported in all five periods. We then studied the activities and strategies of the firms that were not taken into account when constructing the panel. Some companies were not included in all of the surveys because they had gone bankrupt or had ceased to report data to the Central Statistical Office (CSO).

Definitions of innovative firms

The exact number of innovative firms in the sample depended on the definition. We adopted three different definitions for an innovative firm based on different questions in the PNT-02 survey, all of which were consistent with the definition of innovation that is presented in the Oslo Manual (2005). The Manual distinguishes innovation in four areas: product, process, marketing and organisational innovations and so does the PNT-02 survey. A common feature of an innovation is that it must have been implemented, that is, a new or improved product must have been introduced on the market. New process, marketing methods or organisational methods are implemented when they are brought into actual use in a firm's operations.

We constructed three subsamples that corresponded to the three definitions of an innovative firm, which differed in how restrictive the subject of company innovation is approached.

According to the first definition, an innovative firm is one that declares the introduction of new and/or significantly improved products, services, methods of manufacturing products and services, methods in the field of logistics and/or methods for the delivery and distribution of supplies, products and services, new methods (systems) that support the processes, such as the maintenance systems or operating systems connected with accounting or computational systems at least once in the period 2004–2014. The adoption of the first criterion enabled us to answer the question of how many companies were able to commercialise an innovative product at least once in the decade. This was the most general group from which we could extract the companies that were able to introduce more than one innovation in different phases of the business cycle (their persistence was moderate or high).

The second definition assumed that a firm was innovative only if it declared the introduction of new or significantly improved products, services or methods in at least three of the five periods (at least three times in the decade). In this way, we examined to what extent the innovative activity of a company had positive results more frequently (not only occasionally). In this subsample, companies might have introduced all three innovations in the expansionary phase of a cycle, but none during the slowdown. This may have been an indication of the procyclicality of innovation activities (more innovations during an expansion and fewer during a slowdown).

The last definition implied that a firm had introduced innovations at least three of the five periods, but that one had been introduced during a slowdown. In this way, we identify the companies who were able to innovate in both the expansion phase of the cycle and during an economic downturn. To test the persistence of innovation activities, we also analysed the differences in the continuity of the innovation activities and strategies of the firms through the business cycle.

The samples of innovative firms

First of all, we constructed a panel of all of the companies that conducted business throughout the period from 2004 to 2014. In the sample of 3691 firms, we grouped the firms according to the codes in the classification of business activities in Poland (PKD 2007, which is compatible with NACE rev. 2). We distinguished ten groups: I – codes: 10,11,12, II – 13,14,15, III – 16, IV – 17,18, V – 19,20, 21, VI – 22, 23, VII – 24, 25, VIII – 26, 27, IX – 28, 29, 30, 33 and X – 31, 32. Table 1 presents the percentage of the total number of firms that operated in specific groups of manufacturing companies.

Table 1

The percentage of firms that operated in specific groups of manufacturing companies

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	17.53	17.53	17.39	17.50	17.50
II	8.67	8.67	8.83	8.91	8.86
III	4.09	4.06	4.06	4.15	4.20
IV	4.58	4.61	4.63	4.63	4.69
V	5.17	5.17	5.12	5.09	5.09
VI	12.84	12.79	12.79	12.79	12.79
VII	14.85	14.82	15.47	15.42	15.44
VIII	6.83	6.85	6.64	6.50	6.45
IX	18.83	18.83	18.21	18.34	18.34
X	6.61	6.66	6.80	6.66	6.64
Sum	100 (3691)	100	100	100	100

Source: own elaboration based on PNT-02 data.

The percentage of the firms in each of the NACE subgroups was relatively stable; only small number of firms changed groups (see Table 1).

The percentages of innovative firms that operated in a specific group in a given period, according to one of the three criteria, are presented in the following tables below.

Table 2

The percentage of innovative firms according to first criterion in specific groups of manufacturing companies (the impact of firms changing groups – NACE codes)

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	15.96	15.96	15.84	15.92	15.92
II	5.76	5.76	6.02	6.02	5.98
III	3.18	3.15	3.15	3.22	3.30
IV	4.27	4.27	4.31	4.31	4.39
V	6.76	6.76	6.68	6.64	6.60
VI	13.90	13.90	13.86	13.90	13.86
VII	15.22	15.22	15.84	15.77	15.84
VIII	7.96	8.00	7.84	7.65	7.53
IX	20.43	20.39	19.73	19.84	19.88
X	6.56	6.60	6.72	6.72	6.68
Sum	100 (2575)	100	100	100	100

Source: own elaboration based on PNT-02 data.

Table 2 presents the percentage of companies that were innovative in the total number of companies from a given group. Based on the presented data, it can be seen that the percentage of innovative companies from a given group remained at a similar level, i.e. the effect of changing the industry of the innovative companies was negligible. Thus, the impact of an industry change by innovative companies had little impact on the behaviour of the aggregates for the individual groups. Therefore, it can be concluded that the analysed effects will be affected by the structural changes of the databases to a very limited extent.

Table 3 presents the number of innovations that were introduced by companies classified as innovative according to the first criterion in a given period. The largest percentage of innovations in the aggregate were commercialised in the expansive phases of the business cycle, while definitely fewer were commercialised during the crisis and economic weakness (2009–2013).An aggregate analysis, therefore, suggests the procyclicality of innovation activities and the commercialisation of innovations. The behaviour of the sub-aggregates for groups I–IV and VI–X replicated the aggregate for the whole sample. However, procyclicality was not observed in the case of groups V–VI. The most innovative firms were those from the groups nine, one, seven and six. The companies from the groups five, eight and ten were moderately innovative. The companies from the groups two, three and four were less innovative (see Tables 3 and 4).

In aggregate, the most innovations were commercialised in the period 2004–2006, i.e. 1875 innovations were introduced by the 2575 innovative firms

Table 3

The number of innovations introduced by the firms defined as innovative according to first criterion in specific groups of manufacturing companies

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	308	240	220	212	222
II	95	80	68	61	76
III	52	45	44	35	42
IV	77	59	55	58	65
V	144	132	136	133	128
VI	256	239	214	213	212
VII	273	262	236	215	241
VIII	171	167	151	142	145
IX	385	383	328	334	343
X	114	107	97	102	107
No. of innovations out of 2575 firms	1875	1714	1549	1505	1581

Source: own elaboration based on PNT-02 data.

Table 4

Percentage of the innovative firms in a specific group of industries that actually implemented innovations in a given period

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	11.96	9.32	8.54	8.23	8.62
II	3.69	3.11	2.64	2.37	2.95
III	2.02	1.75	1.71	1.36	1.63
IV	2.99	2.29	2.14	2.25	2.52
V	5.59	5.13	5.28	5.17	4.97
VI	9.94	9.28	8.31	8.27	8.23
VII	10.60	10.17	9.17	8.32	9.36
VIII	6.64	6.49	5.86	5.51	5.63
IX	14.95	14.87	12.74	12.97	13.32
X	4.43	4.16	3.77	3.96	4.16
Percentage of innovative firms	72.82	66.56	60.16	58.45	61.40

Source: own elaboration based on PNT-02 data.

Table 5

Percentage change in the number of innovative firms in a specific group of industries that actually implemented innovations in a given period (with respect to the previous period)

No. group	2006–2008	2008–2010	2010–2012	2012–2014
I	–2.64	–0.78	–0.31	0.39
II	–0.58	–0.47	–0.27	0.58
III	–0.27	–0.04	–0.35	0.27
IV	–0.70	–0.16	0.12	0.27
V	–0.47	0.16	–0.12	–0.19
VI	–0.66	–0.97	–0.04	–0.04
VII	–0.43	–0.01	–0.82	1.01
VIII	–0.16	–0.62	–0.35	0.12
IX	–0.08	–2.14	0.23	0.35
X	–0.27	–0.39	0.19	0.19

Source: own elaboration based on PNT-02 data.

according to the first criterion in that period. This can also be interpreted in the following way: 72.82% of the innovative firms implemented innovations in 2004–2006 (see Table 4.). In the next period under study, a lower percentage of the innovative firms introduced innovations (66.56% of the innovative firms). During the global crisis and the period of an economic slowdown in Poland (2009–2013), an even lower percentage of innovation was introduced by the innovative firms according to the first criterion (60.16% in 2008–2010 and 58.45% in 2010–2012). In the last period under study, which corresponded to the expansionary phase of the business cycle, 61.40% of the innovative firms introduced innovations.

Table 5 presents the percentage change in the innovative firms that operated in a specific group of industries, which actually implemented innovations in a given period (with respect to the previous period).

Based on the data presented in Table 5, we can observe in which periods the percentage of introduced innovations fell in relation to the previous period. Only in the last period, 2012–2014, there was an increase in the number of introduced innovations compared to the previous period (2010–2012) in most groups.

Table 6 presents the percentage change in the innovative firms operating in a specific group of industries that actually implemented innovations in a given period (with respect to the base period 2004–2006). This presents a rather pessimistic picture of innovative activities in the manufacturing sector in Poland. Although we observed the procyclicality of innovative activity and innovation in the aggregate, it should be noted that in each period, the number of innovations that were introduced by the innovative companies (according to the first criterion) was lower than in the base period (2004–2006).

Table 6

Percentage change in the number of innovative firms in a specific group of industries that actually implemented innovations in a given period (with respect to the base period 2004–2006)

No. group	2006–2008	2008–2010	2010–2012	2012–2014
I	–2.64	–3.43	–3.74	–3.34
II	–0.58	–1.05	–1.32	–0.74
III	–0.27	–0.31	–0.66	–0.39
IV	–0.70	–0.85	–0.74	–0.47
V	–0.47	–0.31	–0.43	–0.62
VI	–0.66	–1.63	–1.67	–1.71
VII	–0.43	–1.44	–2.25	–1.24
VIII	–0.16	–0.78	–1.13	–1.01
IX	–0.08	–2.21	–1.98	–1.63
X	–0.27	–0.66	–0.47	–0.27

Source: own elaboration based on PNT-02 data.

Table 7

Percentage of the innovative firms in the specific groups of manufacturing companies according to the second criterion

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	14.10	14.10	14.03	14.10	14.10
II	4.06	4.06	4.25	4.25	4.25
III	2.35	2.29	2.22	2.35	2.48
IV	3.94	3.94	3.94	3.94	4.00
V	8.51	8.51	8.44	8.44	8.38
VI	13.78	13.78	13.97	13.90	13.84
VII	14.67	14.67	15.37	15.24	15.37
VIII	10.16	10.22	10.22	9.90	9.78
IX	22.29	22.22	21.21	21.59	21.59
X	6.16	6.22	6.35	6.29	6.22
Sum	100 (1237)	100	100	100	100

Source: own elaboration based on PNT-02 data.

Table 7 presents data on a more restrictive approach to company innovation by industry (NACE groups). In subsample of 3691, there were 1237 innovative companies that introduced new or significantly improved products, services or

methods in at least three of the five periods (at least three times in the decade). The most innovative companies according to the second criterion were from groups IX, VII, I, VI and VIII, while the companies from groups V, II, IV, X and III were moderately innovative.

Table 8

Percentage of the innovative firms in the specific groups of manufacturing companies according to the third criterion

No. group	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014
I	14.21	14.21	14.14	14.21	4.21
II	3.73	3.73	3.95	3.95	3.95
III	2.44	2.37	2.30	2.44	2.58
IV	3.45	3.45	3.37	3.37	3.45
V	9.05	9.05	8.97	8.90	8.83
VI	13.35	13.35	13.64	13.64	13.64
VII	14.36	14.36	15.29	15.36	15.36
VIII	10.34	10.41	10.34	9.98	9.83
IX	23.04	22.97	21.90	22.11	22.18
X	6.03	6.10	6.10	6.03	5.96
Sum	100 (1100)	100	100	100	100

Source: own elaboration based on PNT-02 data.

Table 8 presents the data on the percentage of innovative firms according to the third criterion in specific groups of manufacturing companies. There were 1100 innovative companies in the database according to the third criterion, i.e. those that introduced at least three innovations in the five periods under study including at least one in the period of economic slowdown. The highest percentage of such companies was in groups IX, VII, I and VI and VIII, respectively.

However, the differentiation of companies does not have to be closely connected with the groups of industries in which the companies operate. In the next part of the article, we will focus on the enterprise groups in relation to their innovative activity rather than the activities in specific industries (NACE groups I–X).

3. Heterogeneous behaviour of firms: persistent innovators, occasional innovators and challengers

The analyses that were conducted on the aggregates indicated the procyclicality of the innovation activity of companies in Poland. However, a 'pure' procyclical behaviour was only observed for 42 of 3691 firms in the sample. These compa-

nies introduced three innovations in the periods that corresponded with the expansionary phase of the business cycle in 2004–2006, 2006–2008 and 2012–2014, respectively, and did not introduce any innovation during the global crisis (2008–2010) or during the recovery phase (2010–2012). This corresponded to only 1.1% of the companies in the panel of 3691 companies and 1.7% of the innovative companies according to the first criterion, i.e. those that had introduced an innovation at least once in the decade. On the other hand, only 28 companies behaved in a purely countercyclical manner (0.7% of companies in the panel of 3691 companies and 1.1% of the innovative companies according to the first criterion). It is, therefore, worth noting that the behaviour of the companies and their innovation activity was definitely more complex and diverse than was suggested by the studies carried out using aggregate data.

It is worth noting that in the panel, 55.44% of the observations of the variable describing the commercialisation of an innovation by firm i at time t (*Innovit*) were equal to zero and that 44.56% of the observations were equal to one (if the innovation was introduced in that period). There was a considerable persistence from period to period under study. There were 85.65% of firms that did not innovate in one year (one period) and also did not implement an innovation in the next year (the next reporting period), while 78.04% of those who did innovate in one year also innovated in the next. However, it was also observed that 21.96% of the firms in the panel that innovated in the first period did not do so in the following period. Only 14.35% of the firms that did not innovate were able to implement an innovation in the following period.

However, the companies in the sample differed in the degree of persistence. The strongest persistence was demonstrated by 859 companies that had introduced one innovation in each of the five analysed periods (23.27% of 3691 firms in the panel and 33.36% of the innovative firms). In addition, 345 companies introduced innovations in four of the five periods (9.35% of 3691 firms in the panel and 13.40% of the innovative firms), of which 52 did not innovate in the period 2008–2010 and 56 did not innovate in the period 2010–2012 (1.41% and 1.52% of 3691 firms in the panel, respectively). 371 companies (10.05% of 3691 firms in the panel) introduced innovations in three periods of the five (with 42 companies – 1.14% of the total number of all firms in the panel – that did not introduce any innovations in 2008–2010 and 2010–2012).

A lower level of persistence was observed in the case of 436 companies that introduced innovations in two of the five periods (11.81% of the firms in the panel). Of these, 158 companies introduced two innovations in a row in the growth phase (2004–2006 and 2006–2008) and 47 companies introduced two innovations in a row during the slowdowns (2006–2008 and 2008–2010). In the case of these companies, there was no strict cyclical pattern. 28 companies introduced innovations in a purely countercyclical manner during the global crisis, that is, in the periods 2008–2010 and 2010–2012; 84 firms in the phase of recovery from the crisis and in the expansionary phase of the business cycle (in 2010–2012 and 2012–2014, respectively).

It was also possible to distinguish the 'challengers' – companies that introduced one innovation during the decade but only during the global crisis or economic slowdown. There were 86 such companies in the database, which corresponded to 2.33% of the panel of companies and 3.34% among the innovative firms according to the first criterion. The occasional innovators that implemented innovations only during the expansionary phases of the business cycle accounted for 12.95% of the firms in the panel and 18.56% of the innovative firms according to the first criterion (478 firms). A total of 564 firms were occasional innovators (irrespective of the phase of the business cycle phase), that is, 15.3% of the firms in the panel and 21.9 % of the innovative firms according to the first criterion.
We also analysed the specific PNT-02 data for each of the groups.[2] In the first group of the most persistent innovators, enterprises undertook a large number of projects, some of which have not yet been completed or were discontinued. The percentages of uncompleted or discontinued projects are much higher than in the case of any other group of firms under study, which may suggest a lower risk aversion in undertaking innovation activities. In each period, more than half of the companies in this group incurred expenses for research and development. The percentage of these companies did not decrease during the global financial crisis or economic weakness. After the crisis, the role of the companies that conducted this type of research on a continuous basis increased (the percentage of companies that conducted research on an occasional basis decreased accordingly). The percentage of persistent innovators who outsourced R&D tasks did not change radically with the business cycle phase. The average percentage of expenditure on internal research and development in the total expenditures gradually increased over the decade after 2004.

In the group of persistent innovators, more innovation activity and more attempts to develop and implement innovations were undertaken in all of years. At the same time, the percentage of uncompleted or abandoned projects was also higher. Unlike the group of the most persistent innovators, in this group, the effect of the crisis on the percentage of companies that did not complete or interrupted innovative projects was visible. Companies abandoned projects that had a greater chance of failure. However, they did not stop research and development altogether. Nonetheless, the percentage of firms that outsourced R&D tasks was lower in this group compared to the group of highly persistent innovators. Like in the first group, the percentage of persistent innovators that outsourced R&D tasks was not specifically affected by changing macroeconomic conditions. Although the percentage of firms that outsourced R&D tasks was slightly lower during the crisis, the average percentage of outlays for the purchase of knowledge from external sources was higher after 2008 than prior to the crisis.

In the group of moderate-persistent innovators, the percentage of projects that had not been completed decreased in 2008–2010. However, it increased sig-

[2] The numerical results of this disaggregated part of the analysis, in the form of 17 additional statistical tables, are available with the author and can be rendered electronically on request.

nificantly during the slowdown of 2010–2012. The analysis of the percentage of companies that incurred expenditures on R&D over time might have suggested procyclicality. However, the share of expenditures on R&D in total expenditures increased during the crisis and economic slowdown (in a countercyclical manner).

During the crisis, the percentage of low-persistent innovators that abandoned or did not complete innovative projects fell (only 1.61% of the companies). It should be noted, however, that this was partly due to the fact that the percentage of attempts to introduce innovative projects decreased during the crisis. After 2010, the percentage of companies that had undertaken new innovative projects in this group increased and some of them were discontinued. However, their number did not reach the pre-crisis levels. The percentage of the firms that performed R&D internally was significantly lower than in the case of the highly and moderate-persistent innovators. Unlike in the case of the previous group of firms, the percentage of firms that carried out R&D tasks on occasional basis was higher. The average share of the expenditures for internal R&D dropped significantly during the global crisis of 2008–2010.

There was no cyclical pattern in the expenditures for machinery and technical equipment in the first group of companies. The percentage of highly persistent innovators that incurred these types of expenses increased in the two periods prior to the global crisis, but gradually decreased after the crisis. The average percentage share of expenditure on machinery and technical equipment, means of transport, tools, instruments, mobility and equipment in this group of enterprises in the total expenditures also significantly decreased after 2004. Similar pattern was observed in case of persistent innovators. The percentage of persistent innovators that had expenditures for the purchase of machinery and technical equipment, tools, instruments and movable property was also relatively lower than in the group of the highly persistent innovators. There was no evidence of a procyclical character of the expenditures on machinery and equipment or fixed assets. In case of moderate persistent innovators, the percentage of firms that incurred expenditures for machinery has been decreasing gradually since 2004. However, the highest average percentage share of expenditure on machinery and technical equipment was observed during the crisis (2008–2010). The percentage of occasional innovators that incurred such expenses decreased significantly during the crisis and the slowdown. Nonetheless, there is no strict cyclical pattern in the average share of expenditure on machinery. The highest value was observed during the crisis (2008–2010), while the lowest value was observed in the subsequent period (the economic slowdown of 2010–2012).

The average percentage shares of outlays on fixed assets and on buildings, premises, civil engineering and land in the groups of highly persistent and persistent enterprises increased in 2004–2008 and then gradually decreased. They have been decreasing since 2004 in case of groups of moderate persistent innovators and low-persistent innovators. In case of occasional innovators, the average percentages shares were significantly lower after 2010.

A higher percentage of companies which incurred expenses for the software connected with the introduction of the innovations was observed in the groups

of highly persistent, moderate persistent and persistent innovators as compared with the groups of low-persistent or occasional innovators. After the onset of the crisis, the highly persistent firms reduced the costs that were connected with the purchase of new software. The percentages of persistent innovators which incurred expenses for software were lower compared to the first group. The average percentage of expenditures on software in this group of enterprises was higher than in the first group in all of the periods under study. These companies reallocated expenditures for implementing innovation support software. In the case of the group of the most persistent innovators, we can assume that this software had already been implemented in the past. Expenditures on software during the crisis turned out to be a relatively worse strategy of allocating funds (spending).

The purchase of technology from external sources in this form during the crisis was intensified in the group of the most innovative and the most persistent companies. Companies from these groups tried to combat the effects of the economic slowdown in Poland and the global crisis. However, the average percentage of outlays for the purchase of knowledge from external sources in this group of enterprises was moderate. The levels of the average percentage of outlays for the purchase of knowledge form external sources in the groups of moderate persistent and low-persistent innovators were comparable to the levels that had been reported in the case of the second group, although they were more volatile.

At the same time, a larger percentage of most persistent companies incurred additional expenses for employee training. Firstly, this concerned the period immediately before the onset of the crisis (2006–2008). It is worth noting, however, that even during and after the crisis, a larger percentage of companies decided to prepare employees for the new market conditions and that there was higher level of innovation activity than had been reported in the period 2004–2006. This was connected with both the aforementioned proactive attitude of the companies and increased resources from the EU funds that were received by the Polish firms. However, the average percentage share of expenditures for employee training that was connected with the introduction of innovations in the first group was comparable or lower than in case of other groups.

Similar to the costs that were incurred for employee training, the highest percentage of companies that incurred expenses for marketing connected with the introduction of innovations was observed in 2006–2008. In the subsequent years, the percentage of companies that incurred these expenses decreased. However, the average percentage share of the expenditure on marketing associated with the introduction of new or significantly improved products in the total expenditures was higher after the crisis than before 2008–2010. In most general terms, the higher the average percentage share of the expenditure on marketing, the most persistent was the firm in innovation process.

Finally, the survey also provides information on other expenses connected with introducing innovations to the market. Apart from the first period, a very high percentage of the companies from the first group incurred additional expenses connected with the introduction of innovations in all of the periods. On

average, the percentage share of other outlays connected with the introduction of new or significantly improved products in the total outlays was relatively higher during the crisis than prior to 2008. Such expenses were incurred by most persistent innovators in a countercyclical manner. This countercyclicality in this aspect was not observed in case of other groups.

In the context of the costs that were incurred for introducing innovations, a key issue was the use of a company's own financial resources and obtaining additional external financing. In the group of highly persistent innovators, the average percentage share of a company's own funds in its total expenditures was high in all of the periods under study. These companies also benefited from stable public funding. After 2008, the role of non-returnable funds received from abroad increased. The impact of the crisis on the possibilities of obtaining additional funds from loans was relatively high. However, the decline in lending negatively affected, above all, the companies that financed their innovative projects with external funds. In the highly persistent innovators group, however, the average share of a company's own funds in financing the implementation of innovations was high, which enabled the implementation of innovations despite the economic slowdown. Like in the case of the most innovative and persistent companies, the percentage share of a company's own funds in the total expenditure on innovation activities in the remaining groups of enterprises was also high. In the case of companies from the low persistent innovators' group, the greater part of the financial resources came from bank credit, which was partially limited in 2008–2010.The low-persistent innovators were much more dependent on external funding in the form of loans, the number of which decreased during the crisis.

Because of the great diversity of innovation activities and commercialisation strategies among the companies, it was worth analysing what we know about the individual groups based on the data from the national CIS data ('PNT-02'). In particular, we paid attention to a company's own funds and external financing and the expenditure of these funds in the context of innovation activities. The conclusions of this type of analysis are useful for formulating recommendations for policies to support innovations. In the next part of the article, we explore what factors influenced the probability of introducing innovations by companies.

4. The role of funding and expenditures of firms in innovation commercialization: random effects logistic regression model

The logit RE model

Although we used in this research the random effects logistic regression model like in Kaszowska-Mojsa (2020), it was applied to a different sample. We focused on short panels in which a consistent estimation of the fixed effects models is not possible in some standard nonlinear models such as binary logit. Following Cameron and Trivedi (2009), we considered a nonlinear panel model for the sca-

lar-dependent variable y_{it} with the regressors x_{it}, where i denotes the individual firm and t denotes time. As in Cameron and Trivedi (2009), we could specify a fully parametric model with the conditional density:

$$f\left(y_{it} \mid \alpha_i, x_{it}\right) = f\left(y_{it}, \alpha_i + x_{it}'\beta, \gamma\right), \quad t = 1, ..., T_i, \quad i = 1, ..., N, \tag{1}$$

where γ denotes any additional model parameter such as the variance parameters and α_i is an individual effect. In the random effects (RE) model, the individual-specific effect α_i is treated as an unobserved random variable with a specific distribution $g(\alpha_i \mid \gamma)$. Then, α_i is eliminated by integrating over this distribution. The unconditional density for the ith observation is

$$f\left(y_{it} ... y_{iT_i} \mid x_{it} ... x_{iT_i}, \beta, \gamma, \eta\right) = \int \left\{ \sum_{t=1}^{T_i} f\left(y_{it} \mid x_{it}, \alpha_i, \beta, \gamma\right) \right\} g\left(a_i \mid \eta\right) d\alpha_i. \tag{2}$$

Usually, this integral has no analytical solution because of the nonlinearity of the model; however, numerical integration can be used. The logit individual effects model specifies that

$$\Pr\left(y_{it} = 1 \mid x_{it}, \beta, \alpha_i\right) = \Lambda\left(\alpha_i + x_{it}'\beta\right), \tag{3}$$

where α_i is RE in our case.

The logit RE model specifies that $\alpha_i \sim N(0, \sigma_\alpha^2)$. Then, the joint density for the ith observation, after integrating out α_i, is

$$f\left(y_{it}, ..., y_{iT_i}\right) = \int \left[\prod_{t=1}^{T} \Lambda\left(\alpha_i + x_{it}'\beta\right)^{y_{it}} \left\{1 - \Lambda\left(\alpha_i + x_{it}'\beta\right)\right\}^{1-y_{it}} \right] g\left(\alpha_i \mid \sigma^2\right) d\alpha_i, \tag{4}$$

where $g(\alpha_i \mid \sigma^2)$ is the $N(0, \sigma_\alpha^2)$ density. Usually, the numerical method is used to obtain the solution to the integral. The standard default method that is frequently used is an adaptive 12-point Gauss-Hermite quadrature. For a discussion of this and alternative methods see Mulkay (2015). The standard deviation of the RE is given in the output of a statistical program as sigma_u, and therefore it is estimated that $\alpha_i \sim N(0, \sigma_\alpha^2)$.

The logit RE model can be motivated as coming from a latent-variable model with $y_{it} = 1$ if $y_{it}^* = x_{it}' + \alpha_i + \varepsilon_{it} > 0$, where ε_{it} is logistically distributed with a variance of $\sigma_\varepsilon^2 = \pi^2/3$. The intraclass error correlation in the latent-variable model is $\rho = \sigma_\alpha^2/(\sigma_\alpha^2 + \sigma_\varepsilon^2)$ and the quantity is reported as rho. The interpretation of the odd-ratio and marginal (partial) effects for logit models is applicable.

Results of econometric study

In this section, I would like to present the individual factors that influenced the probability that an innovation would be introduced the most. We constructed a balanced panel of 2575 firms that had reported values in all five editions of the PNT-02 survey and that had introduced at least one innovation over the decade (2004–2014) (firms that were innovative according to the first criterion previously described). The dependent variable was a binary variable $Innov_{it}$, which is equal to one for the innovations and is zero otherwise. Table 9 summarises the variables

Table 9

The variables tested in order to determine whether they were significant when estimating the RE logistic regression model

Variable	Name
$Innov_{it}$	Innovations of firm *i* at time *t*
$Group_{it}$	NACE group which firm *i* belongs to at time *t*
$Size_{it}$	Size of firm *i* at time *t*
$R\&D_{it-1}$	Percentage of expenditures allocated for internal R&D in total expenditures of firm *i* at time *t*–1
$ExtKnowl_{it}$	Percentage of expenditures on the purchase of knowledge from external sources of firm *i* at time *t*
$Softw_{it}$	Percentage of expenditures on software of firm *i* at time *t*
$FixAssets_{it}$	Percentage share of outlays on fixed assets of firm *i* at time *t*
$Bulid_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm *i* at time *t*
$MachEq_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of expenditures on machinery and technical equipment of firm *i* at time *t*
$Trainings_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of expenditures on staff training directly related to the introduction of innovations of firm *i* at time *t*
$Marketing_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of expenditures on marketing related to the introduction of innovations of firm *i* at time *t*
$OtherExp_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of other outlays related to introduction of innovations of firm *i* at time *t*
$OwnFunds_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of own funds received from the state budget in total expenditure on innovation activities of firm *i* at time *t*
$StateFunds_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of funds received from the state budget in total expenditure on innovation activities of firm *i* at time *t*
$ForeingFunds_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of funds obtained from abroad (non-returnable) in total expenditure on innovation activities of firm *i* at time *t*, including EU funds
$Loans_{it}$	Percentage share of expenditures on buildings, premises, civil engineering facilities and land of firm share of funds obtained from bank loans in total expenditure on innovation activities of firm *i* at time *t*
$GlobalCrisis_t$	Global financial crisis in 2008–2010 (dummy)
$Slowdown_t$	Slowdown in Poland 2008–2012 (dummy)

Source: own elaboration.

that were tested in order to determine whether they were significant (in different models) when estimating the random effects logistic regression model.

The results of estimating the logistic regression models with random effects clearly showed that the probability of implementing innovations by the innovative companies was affected by both supply side and demand side factors. Unlike other studies, our analysis captured the occurrence of the global financial crisis in 2008–2010. The results of the model estimation showed that the variable $GlobalCrisis_{it}$ was significant. Therefore, the likelihood of introducing an innovation by an enterprise is also influenced by the demand factor.

In Kaszowska-Mojsa (2020) it was proved that a negative external shock decreased the likelihood of introducing an innovation in the sample of 3691 innovative and non-innovative firms. According to this study, this effect is visible for all of the enterprises that operated in the manufacturing sector. The likelihood of introducing innovations increased with the size of the company, a higher expenditure on research and development within the institution and more external funds to carry out research and development. This study covered all of the companies (innovative and non-innovative) in the panel. However, in our project we also tried to answer the question of which factors influenced the probability of introducing innovations by the firms that had already implemented at least one innovation over the decade (a subsample of 2575 firms).

Table 10 presents the results of the estimation of the logistic regression model with random effects. The probability of innovation was higher when the size of a company was larger; it also increased with a higher percentage of expenditure allocated for internal R&D, a higher percentage share of the expenditure on software in total expenditures, a higher percentage share of the expenditure on trainings, a higher percentage share of the expenditure on marketing and the other expenses connected with the introduction of innovations. The probability of innovation increased with a higher percentage share of a company's own funds in its total expenditures for innovation activities, with a higher percentage share of the funds obtained from abroad (non-returnable) in the total expenditures for innovation activities (including EU funds), and with a higher percentage share of the funds obtained from bank loans in total expenditures for innovation activities. The effect of the crisis of 2008–2010 on innovative companies was also positive. In Kaszowska-Mojsa (2020), it was showed that although the negative demand effect was visible, a decrease in the likelihood of innovating was limited. The economic slowdown decreased the possibility of introducing innovation by 1.96 percentage points compared to that of the upswing. However, an in-depth analysis shows that, in fact, when we limit the database to the companies that had been innovative (i.e. had introduced at least one innovation during the decade), the crisis had a less obvious impact on the likelihood of these companies introducing innovations in the future. A crisis can mobilise companies that already have some innovation facilities and a history of introducing innovations to the market. This is much more pro-Schumpeterian approach, which, however, finds support in the results of the estimation.

Table 10

The estimation results of the logistic regression model with random effects (integration method: mvaghermite, pts: 12)

Random effects $u_i \sim Gaussian$ Prob > χ^2 = 0.000					
Variable	Coefficient	Std. Error	$P > \|z\|$	95% confidence interval	
Size	0.3112748				
2	0.5217252	0.1524739	0.041	0.124315	0.6101181
3	0.11659	0.1636769	0.001	0.2009244	0.842526
Rdlag	0.0430144	0.0015759	0.000	0.0085704	0.0147476
Softw	0.0864972	0.0781157	0.000	0.276958	0.0583329
Training	0.1241624	0.0398896	0.030	0.0083151	0.1646792
Marketing	0.212101	0.0303636	0.000	0.646507	0.183674
Oexp	0.0473117	0.0064437	0.001	0.0085807	0.338395
OwnFunds	0.036805	0.0012321	0.000	0.0448969	0.0497265
StateFunds	0.036805	0.0058497	0.000	0.0448969	0.0482702
ForeignFunds	0.0389415	0.0046944	0.000	0.0253398	0.0481423
Loans	0.0487566	0.0033068	0.000	0.0422754	0.0552377
GlobalCrisis	0.4664729	0.0701985	0.000	0.3288865	0.6040594
Const	–1.550109	0.1492496	0.000	–1.842632	–1.257585
lnsig2u	–0.3404769	0.1404754		–0.6158036	–0.0651503
σ_u	0.8434637	0.0592429		0.7349875	0.9679497
ρ	0.1778	0.0205357		0.1410434	0.2216636
				Prob >= chibar2 = 0.000	

Source: own elaboration based on PNT-02, estimation in STATA.

The most innovative companies increased their share in their expenditures on the key aspects of their business and innovation activity, including primarily internal research and development, trainings, marketing and software. They also changed the combinations of funding sources (adjusting them to the appropriate phase of the cycle). This is an interesting result because despite research on a full statistical sample, we can conclude that the crisis had a negative impact on the innovation of the companies in the Polish manufacturing sector and the likelihood of their introducing innovations in the future, but it would seem that this is only part of the truth. In fact, we found a relatively large group of companies that never innovate, regardless of the phase of the business cycle, as well as a diverse group of innovative companies (persistent innovators, challengers and occasional innovators) for which the impact of the crisis on their innovation activities was also diverse. This impact on innovation activity was small in the case of the persistent innovators or negative in the case of the selected occasional

innovators. However, for the whole group of innovative companies (the aggregate), the impact of the crisis on the probability of innovation was positive. The results that were obtained are interesting for many reasons because they dispel the widespread beliefs that:

Table 11
Conditional marginal effects

Model VCE: OIM No of obs: 12,871					
Expression	Pr (innov =1)	Predict (pr)			
1. size =	0.0454510 (mean)				
2. size =	0.6628079 (mean)				
3. size =	0.2917411 (mean)				
Rdlag =	11.6798740 (mean)				
Softw =	3.2106400 (mean)				
Training =	0.8419253 (mean)				
Marketing =	2.6214730 (mean)				
Oexp =	1.8642530 (mean)				
OwnFunds =	42.9853300 (mean)				
StateFunds =	1.2094220 (mean)				
ForeignFunds =	1.9770750 (mean)				
Loans =	4.4495380 (mean)				
Crisis =	0.1999845 (mean)				
Variable	*dx*/*dy*	Delta-method	$P > \|z\|$	95% confidence interval	
Size					
2	0.4027050	0.0213165	0.059	–0.0015092	0.0820501
3	0.0636478	0.0223028	0.004	0.0199352	0.1073604
Rdlag	0.0013413	0.0001927	0.000	0.0009636	0.0017190
Softw	0.0049486	0.0009001	0.000	0.0031844	0.0067128
Training	0.0099511	0.0045146	0.028	0.0011026	0.0187996
Marketing	0.0142843	0.0029498	0.000	0.0085028	0.0200659
Oexp	0.0024401	0.0007101	0.001	0.0009752	0.0039050
OwnFunds	0.0054430	0.0002937	0.000	0.0048673	0.0060187
StateFunds	0.0042342	0.0007101	0.000	0.0028425	0.0056260
ForeignFunds	0.0044800	0.0005917	0.000	0.0033204	0.0056397
Loans	0.0056092	0.0004698	0.000	0.0046884	0.0065300
GlobalCrisis	0.0536656	0.0087017	0.000	0.0366105	0.0707207

Source: own elaboration based on PNT-02, estimation in STATA.

1) in the aggregate the behaviour of companies in the field of innovative activity is purely procyclical or purely countercyclical;
2) the impact of a crisis on the innovation activity of all manufacturing sector companies is negative, and therefore the crisis clearly negatively affects the possibility (probability) of their innovations in the future.

This may also suggest the need for a change in innovation policy, which will also require further research *via* specific econometric and simulation research on the impact of the policies that support innovations for specific groups of enterprises.

Table 12
Average marginal effects

Model VCE: *OIM* No of obs. = 18,455 Expression: Pr (innov=1) Predict (pr)					
Variable	*dx/dy*	Delta-method	$P > \|z\|$	95% Conf. Interval	
Size					
2	0.0294887	0.0140625	0.036	0.0019267	0.0570508
3	0.0504403	0.0153584	0.001	0.0203383	0.0805422
Rdlag	0.0011376	0.0001520	0.000	0.0008397	0.0014355
Softw	0.0041971	0.0075930	0.000	0.0027090	0.0056853
Training	0.0084400	0.0038891	0.030	0.0008175	0.0160625
Marketing	0.0121152	0.0029586	0.000	0.0063164	0.0179140
Oexp	0.0020696	0.0006279	0.001	0.0008389	0.0033002
OwnFunds	0.0046165	0.0000827	0.000	0.0044543	0.0047786
StateFunds	0.0035913	0.0005660	0.000	0.0024819	0.0047006
ForeignFunds	0.0037997	0.0004504	0.000	0.0029169	0.0046826
Loans	0.0047574	0.0003099	0.000	0.0041500	0.0053649
GlobalCrisis	0.0455163	0.0067693	0.000	0.0322488	0.0587838

Source: own elaboration based on PNT-02, estimation in STATA.

Conclusions

The aim of our study and project was to analyse and compare the differences in the innovation activities and strategies of Polish manufacturing companies during a period of the economic expansion (2004–2008) and slowdown (2009–2013) of the Polish economy. The problem of differentiating innovations is important from both a theoretical and empirical point of view. It has been the key element of discussions between mainstream researchers and those that represent the evolutionary tradition. In our study, we used the evolutionary perspective, i.e. various evolutionary theories (research-based theory, resource-advantage theory, relational-based view and knowledge-based view), its modern extensions, the Austrian theory of busi-

ness cycle, and the strategic management approach. The evolutionary perspective focuses more on the supply side of innovations. However, neither the evolutionary nor strategic management perspective explicitly considers how firms use their competences flexibly when the environment suddenly changes or what the impact of a crisis on the competences of firms is. In our opinion, the evolutionary approach still underestimates the impact of changes in the demand for the accumulation of knowledge and the innovation behaviour of firms. Therefore, we proposed a wider approach to the differentiation of the innovation strategy of firms than the one that has been used in the evolutionary tradition to date. We aimed to analyse the impact of the supply-side factors and changes in the macro environment on the innovation strategies of firms. During an economic slowdown, market demand decreases, which emphasises the gap in competences between firms and may bring incentives to introduce innovations. In other words, a slowdown or recession may cause a change in a firm's innovation strategy. It was important to determine the innovation activities of which manufacturing companies in Poland are procyclical or countercyclical and which are acyclical. It was also relevant to determine the behaviour of individual companies (or their groups according to similar business activities) and whether their behaviour in the aggregate is procyclical or countercyclical. As we proved, procyclicality is mostly the effect of the aggregation bias. We could distinguish between the groups of highly persistent innovators, moderate-persistent innovators, low-persistent innovators and occasional innovators. We also identified the group of challengers, who only introduce innovations during a period of economic slowdown or crisis. We proved that there is direct link between the research and development that is performed internally by companies and the probability of the commercialisation of their innovations. While the probability of introducing innovations is also affected by the demand-side factors, this effect is moderate. Nonetheless, the companies that were more dependent on external funding in the form of bank loans were less likely to introduce innovations during a slowdown. In previous studies, the author showed that although the demand effect was visible, a decrease in the likelihood of innovating was limited. However, when we limit the database to the companies that had been innovative, we observed that the crisis mobilised companies that already have some innovation facilities and a history of introducing innovations to the market. This is in accordance with a Schumpeterian approach, which finds support in the results of our estimation.

Received: 11 February 2020
Revised version: 8 November 2020

Bibliography

Aghion P., Saint-Paul G. (1988), *On the Virtue of Bad Times*, "Macroeconomic Dynamics", no. 2, pp. 322–344.

Antonioli D., Mazzanti M., Pini P. (2011), *Innovation, industrial relations and employee outcome. Evidence from Italy*, "Journal of Economic Studies", no. 38, pp. 66–90.

Archibugi D., Filippetti A. (2011), *Is the Economic Crisis Impairing Convergence in Innovation Performance across Europe?* "JCMS-Journal of Common Market Studies", no. 49(6), pp. 1153–1182.

Archibugi D., Filippetti A., Frenz M. (2013a), *The impact of the Economic Crisis on Innovation: Evidence from Europe*, "Technological Forecasting and Social Change", no. 80(7), pp. 1247–1260.

Archibugi D., Filippetti A., Frenz M. (2013b), *Who Innovates Out of the Crisis?*, "The European Business Review", (n.d.), pp. 58–60.

Berlevy G. (2007), *On the Cyclicality of Research and Development*, "American Economic Review" no. 97, pp. 1131–1164.

Cameron C., Trivedi P. (2010), *Microeconometrics using STATA*, Taylor & Francis, Milton Park.

Castellaci F. (2008), *Technological paradigms, regimes and trajectorie: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation*, "Research Policy", no. 37, pp. 978–994.

Correa P., Iotty M. (2010), *Will the Crisis Affect the Economic Recovery in Eastern European Countries? Evidence from Firm Level Data*, The World Bank Policy Working Paper, no. 5278.

Comin D., Gertler M. (2006), *Medium-Term Business Cycles*, "American Economic Review", no. 96, pp. 523–551.

Damanpour F., Wischnevsky J.D. (2006), *Research on innovation in organizations: Distinguishing innovation-generating from innovation-adopting organizations*, "Journal of Engineering and Technology Management", no. 23(4), pp. 269–291.

de Jong J.P.J., Marsili O. (2006), *The fruit flies of innovations: A taxonomy of innovative small firms*, "Research Policy", no. 35, pp. 213–229.

Fabrizio K., Tsolmon U. (2014), *An Empirical Examination of the Procyclicality of R&D Investment and Innovation,* "The Review of Economics and Statistics", no. 94(4), pp. 662–675.

Fates A. (2000), *Do Business Cycle Cast Long Shadows? Short-Run Persistence and Economic Growth*, "Journal of Economic Growth", no. 5, pp. 147–162.

Geroski P., Walter C. (1995), *Innovative Activity over the Business Cycle*, "Economic Journal", no. 105(431), pp. 916–928.

Griliches Z. (1990), *Patent Statistics as Economic Indicators: A Survey*, "Journal of Economic Literature", no. 28, pp. 1661–1707.

Hall R. (1991), *Recessions as Reorganizations*, in: O. Blanchard, S. Fisher (eds.), *NBER Macro Annual*, NBER, Cambridge, MA, pp. [?????]

Jensen M.B. et al. (2007), *Forms of Knowledge and Modes of Innovation*, "Research Policy", no. 36(5), pp. 680–693.

Kaszowska-Mojsa J. (2020), *Innovation activities of Manufacturing Companies during Expansions and Slowdowns*, "Entrepreneurial Business and Economic Review", no. 8(4) (in press).

Leiponen A., Drejer I. (2007), *What exactly are technological regimes? Intra-industry heterogeneity in the organization innovation activities*, "Research Policy", no. 36(8), pp. 1221–1238.

Llerene P., Oltra V. (2002), *Diversity of Innovative Strategy as a Source of Technological Performance,* "Structural Change and Economic Dynamics", no. 13(2), pp. 179–201.

Mazzucato M. (2013), *Financing innovation: creative destruction vs. Destructive creation*, "Industrial and Corporate Change", no. 22(4), pp. 851–867.

Mintzberg H. (1988), *Generic strategies: Towards a comprehensive framework*, "Advance in Strategic Management" 1988, no. 5, 1–16.

Mulkay B. (2017), *Bivariate probit estimation for panel data: A two-step Gauss–Hermite quadrature approach with an application to product and process innovations for France*, Working paper, Universite de Montpellier, Faculte d'Economie, no. 2018.1.

Oslo Manual. The Measurement of Scientific and Technological Activities. Guidelines for Collecting and Interpreting Innovation Data (2005), OECD and Eurostat Joint Publication, Paris.

Pavitt K. (1984), *Sectoral patterns of technical change: towards a taxonomy and a theory*. "Research Policy", no. 13(6), pp. 343–373.

Peneder M. (2003), *Industry Classifications: Aim, Scope and Techniques*, "Journal of Industry, Competition and Trade", no. 3, pp. 109–12.

Saint Paul G. (1993), *Productivity Growth and the Structure of the Business Cycle*, "European Economic Review", no. 37, pp. 861–883.

Som O., Dreher C., Maloca S. (2010), *Innovation Patterns of Non-R&D Performing Firms in the German Manufacturing Industries. An Evolutionary Approach to Heterogeneity in Firms' Innovation Strategy*, Paper for the 13th Conference of the International Schumpeter Society, Aalborg University, Denmark, June 21–24 2010.

Srholec M., Versagen B. (2008), *The Voyage of the Beagle in Innovation System Land. Explorations on Sectors, Innovation, Heterogeneity and Selection*, Centre for Technology, Innovation and Culture, University of Oslo, Working Papers on Innovation Studies, no. 20080220.

Weresa M. (2011), *Działalność innowacyjna w gospodarce* światowej w warunkach *globalnego kryzysu*, "Ekonomia", no. 1(13), pp. 224–232.

Wziątek-Kubiak A., Balcerowicz E., Pęczkowski M. (2013), *Differentiation of Innovation Strategy of Manufacturing Firms in the New Member States. Cluster Analysis on Firm Level Data*, "Argumenta Oeconomica", no. 2(31), pp. 117–149.

Wziątek-Kubiak A., Pęczkowski M. (2013), Źródła *i bariery ciągłości wdrażania innowacji przez polskie przedsiębiorstwa*, in: J. Sokołowski, M. Rękas (eds.), *Ekonomia*, 1st ed., pp. 872– 883 (Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, no. 305).

Wziątek-Kubiak A. , Pęczkowski M. (2019), *Czynniki ciągłości komercjalizacji innowacji w okresie negatywnego szoku zewnętrznego. Przykład Polski*, "Bank i Kredyt", no. 50(1), pp. 21–44.

INNOVATION STRATEGIES OF POLISH MANUFACTURING COMPANIES THROUGH THE BUSINESS CYCLE

Summary

The paper analyses the differentiation of innovation activities and strategies of Polish manufacturing companies during economic expansions (2004–2008 and 2013–2014) and slowdowns (2009–2013) of the Polish economy. The research is based on the data from five databases of the Central Statistical Office, which overlap with the Community Innovation Survey (CIS). It is found that because companies are heterogeneous in their innovation resources, they also differ in the continuity of the innovation activities and

strategies that they introduce. Some of them – persistent innovators – innovate continuously, while others – occasional innovators – innovate from time to time, most often during an economic upswing. There is also a group of challengers that initiate innovation activities irrespective of a slowdown.

Although existing theories propose that research and development and, in more general terms, innovation activities are concentrated when output is low, aggregate data for many developed economies repeatedly show their procyclicality. In the paper, the author shows that it is possible to distinguish subgroups of Polish manufacturing companies whose innovation activity is procyclical and those in which this activity is countercyclical. Expenditures on R&D, machinery and technical equipment, technology and marketing as well as the commercialisation of innovations also differ across groups. Due to strong heterogeneity of the whole sample, the results of aggregate analyses may be misleading. The policies that support innovation in Poland should take this heterogeneity into account. It is also highly recommended that the needs of persistent innovators, occasional innovators and challengers be reassessed.

Keywords: innovations, innovation activity, manufacturing firms, Poland, aggregation bias

JEL: O31, O32

STRATEGIE INNOWACYJNE POLSKICH PRZEDSIĘBIORSTW PRZEMYSŁU PRZETWÓRCZEGO W PRZEBIEGU CYKLU KONIUNKTURALNEGO

Streszczenie

W artykule przeanalizowano zróżnicowanie aktywności innowacyjnej i strategii innowacyjnych polskich przedsiębiorstw przetwórstwa przemysłowego w okresach ekspansji gospodarczej (2004–2008 i 2013–2014) oraz spowolnienia polskiej gospodarki (2009–2013). W badaniu wykorzystano dane udostępnione przez Główny Urząd Statystyczny, gromadzone według kwestionariusza stosowanego w programie badań działalności innowacyjnej UE (Community Innovation Survey – CIS). W artykule wykazano, że ponieważ przedsiębiorstwa są heterogeniczne pod względem zasobów innowacyjnych, różnią się one także pod względem ciągłości aktywności innowacyjnej i strategii wdrażania innowacji. Niektóre z nich – tzw. wytrwali innowatorzy – wprowadzają innowacje w sposób ciągły, podczas gdy „okazjonalni innowatorzy" wprowadzają innowacje rzadziej, głównie w okresie ożywienia gospodarczego. Wyróżniono również grupę przedsiębiorstw, które wprowadzają innowacje pomimo spowolnienia gospodarczego.

Chociaż istniejące teorie sugerują, że badania i rozwój oraz, bardziej ogólnie, aktywność innowacyjna przedsiębiorstwa powinny być większe w okresach spowolnienia gospodarczego, wyniki badań dla gospodarek rozwiniętych przeprowadzonych na danych agregatowych wielokrotnie wykazały ich procykliczność. W artykule wykazano, że możliwe jest wyróżnienie podgrup polskich przedsiębiorstw przetwórstwa przemysłowego, których aktywność innowacyjna miała charakter procykliczny, oraz takich, których aktywność innowacyjna była antycykliczna. Wykazano również zróżnicowanie wydatków na badania i rozwój, maszyny i wyposażenie techniczne, nową technologię i marketing między grupami oraz znaczące różnice w komercjalizacji innowacji. Ze względu na dużą heterogeniczność całej próby wnioski z badań na danych agregatowych mogą być mylące. Polityka wspierania innowacji w Polsce powinna uwzględniać to zróżnicowanie. W szcze-

gólności zasadne wydaje się ponowne przeanalizowanie potrzeb „wytrwałych innowatorów", „okazjonalnych innowatorów" oraz przedsiębiorstw, które wprowadzają innowacje pomimo spowolnienia gospodarczego w kraju.

Słowa kluczowe: innowacje, aktywność innowacyjna, przedsiębiorstwa przemysłu przetwórczego, Polska, błąd agregacji

JEL: O31, O32

ИННОВАЦИОННЫЕ СТРАТЕГИИ ПОЛЬСКИХ ПРЕДПРИЯТИЙ ПЕРЕРАБАТЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ В ХОДЕ КОНЪЮНКТУРНОГО ЦИКЛА

Резюме

В статье проведен анализ дифференциации инновационной активности и инновационных стратегий польских предприятий промышленной переработки в период экономической экспансии (2004–2008) и (2013–2014), а также в период замедления польской экономики (2009–2013). В исследовании были использованы данные, предоставленные Главным статистическим управлением. Они были накоплены на основании опросника, используемого в программе исследований инновационной деятельности ЕС (Community Innovation Survey – CIS). В статье доказывается, что как так предприятия в плане инновационных ресурсов являются гетерогенными, то они различаются в таких областях как непрерывность инновационной активности и стратегии внедрения инноваций. Некоторые из них – так называемые «стойкие новаторы» – вводят инновации постоянно, тогда как «случайные новаторы» вводят инновации реже, главным образом в период экономического оживления. Была выделена также группа предприятий, которые вводят инновации несмотря на экономическое замедление.

Согласно существующим теориям, затраты на НИОКР и вообще на инновационную активность, должны увеличиваться в периоды экономического замедления, Исследования развитых экономик, проведенных на агрегатных данных, многократно доказали их проциклический характер. В статье высказывается мнение, что возможно выделение подгрупп польских предприятий промышленной переработки, инновационная активность которых имела проциклический характер, а также таких, инновационная активность которых являлась антицикличной. Автор указывает также на дифференциацию расходов на исследования и развитие, машины и техническое оборудование, новую технологию и маркетинг между группами, а также значительные различия в коммерциализации инноваций. Ввиду большой гетерогеничности всей пробы, результаты агрегатных исследований могут вводить в заблуждение. Политика поощрения инновации в Польше должна учитывать эту дифференциацию. Особенно обоснованным кажется проведение анализа потребностей «стойких новаторов», «случайных новаторов». а также предприятий, которые вводят инновации несмотря на экономическое замедление в стране.

Ключевые слова: инновации, инновационная активность, предприятия промышленной переработки, Польша, ошибка агрегации

JEL: O31, O32