SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2019
ORGANIZATION AND MANAGEMENT SERIES NO. 139

MANAGEMENT OF INNOVATIVE RESOURCES IN AN UNSTABLE ENVIRONMENT AND SELECTION OF INNOVATIVE FIRMS

Anna WZIĄTEK-KUBIAK

Institute of Economics, the Polish Academy of Sciences, Warsaw; hkubiak@inepan.waw.pl,
ORCID: 0000-0003-0516-1391

Abstract: Innovative resources and their management are of key importance for innovation performance and thus for achieving competitive advantages, especially in an unstable period. To a large extent, it results from the risky nature of innovative activities and translates into innovation performance and the processes of selecting companies on the market. The purpose of this paper is to analyse changes in the knowledge resource management, innovation performance and their diversification across Polish manufacturing firms in unstable environment, i.e., during the period of world financial crisis. We study changes in the use of knowledge resources, innovation performance and selection of innovative firms that have introduced innovations within three out of five Polish Community Innovation Survey waves (2004-2014). We analysed 32 types of knowledge resources used by innovative firms. The paper shows that the changes in the use of knowledge resource by innovative firms accompanies changes in their innovation performance and results in a selection process between innovative firms on the regional and macroeconomic level. The strong drop in the use of innovation resources and innovation performance of competing firms accompanied the improvement in innovation performance of the newcomers.

Keywords: management of knowledge resources, innovation performance, selection of innovative firms, unstable environment and crisis.

1. Introduction

Innovation has become a crucial component of firms' strategies and growth (Bartolacci et al., 2016). The empirical evidence confirms that innovative firms outperform non-innovative ones across different dimension (see Cohen, 2010 for a survey). In the strategic management literature, innovation is considered to be a fundamental tool for firm competitiveness in which changes in the economic environment play a role (Nelson, 1991, p. 347). In evolutionary perspective it is viewed as an ongoing, evolutionary (continuous, heterogenous and selective) learning process in which firms exploiting and transforming resources accumulate knowledge.

As long as the firm moves forward with its innovation activities, its continuity stimulates learning process, knowledge accumulation, development and expansion.

Research on innovation and the management of its resources focus on changes in expansion phase of the business cycle. Few studies take into account changing market conditions, not only as a result of cyclical changes, but also turbulences, rapid and unforeseen changes in the economy. Loosely defined economic turbulences are an unexpected exogenous disturbance that have a significant impact on the economic system or its part(s). The term is largely used for phenomenon that have an adverse impact on the economy, although some of shocks may have a positive impact (e.g. technological breakthroughs). There are many types of turbulences like domestic and external ones, country specific and global, concerning demand and supply, technology and price shocks, etc. Turbulences in one area are shifting to and impact other areas, especially those that are risky and sensitive to external shocks. Similarly, turbulence in one country spreads to other countries through capital and trade links. Psychological factors also play a role. Some areas and countries are more strongly hit and others may hardly feel the effects of external or even global turbulences. Singapore is one of such countries (referred to in the literature as "Singapore paradox"), in which – in the conditions of the global crisis of 2008-2010 and significant economic difficulties of neighbouring countries – no deterioration of macroeconomic conditions was noted. The Polish case which was quite similar was unnoticed.

Empirical studies show the strong diversity of innovative firms' behaviour under the influence of macroeconomic changes, especially business crises. Selected pro-cyclical, counter-cyclical and neutral behaviours show the difference in the response of innovative activities of various firms to the economic crisis (Galbreath, 2005). The latter is a kind of overwhelming shock, turbulence that firms must struggle with. The all-encompassing nature of the crisis distinguishes it from turbulence or shock, which usually affects some parts of the business. Not all businesses crisis accompanies shocks. Similarly, the frequency, mechanism and effects of crises are not always the same as in the case of shocks and turbulences. The latter also take place in the expansion phase of the business cycle. Hence, the study of the impact of various types of turbulences on the economy, its areas of activities or entities deserves attention.

In the study we analyse the management of innovative resources of Polish manufacturing firms during the global economic crisis (2008-2012), whose impact on the Polish economy was an external shock. Although in this period the Polish economy experienced only a short-term slowdown in growth dynamics, its various areas were affected to a different extent. This impact was particularly strongly felt by innovative activities: extremely risky and sensitive to external changes type of economic activity. The basis of innovation is the accumulation of knowledge, which – during production process – is used by firms. The inhibition of innovative activity that accompanies turbulences decreases the use of innovative resources and inhibits the accumulation of knowledge. And this reduces the possibilities of continuity in innovation in the future and affects economic development. Hence, the issue of managing innovative resources in turbulence is crucial to the continuity of innovation and maintaining competitive advantages

in the long run. Innovative resources management is also a key element of the firm's development strategy, which is affected by changes in the environment. Turbulences in the economy causes changes in development strategies, that is also in resource management. This, in turn, affects innovation performance, and thus also the competitive advantages and expansion of firms on the market. Hence, research into changes in resource management under dramatic changes in environment has important theoretical and empirical significance.

The purpose of the paper is to show changes in the management of innovative resources by various Polish manufacturing innovative firms during economic turbulence. These firms have been selected on the basis of the frequency of introducing innovations to the market in years 2004-2014. Therefore, we deal with manufacturing firms that before the examined period (2008-2012) had developed innovation capacity. Most of them introduced innovations to the market and accumulated knowledge with varying frequency. Therefore, it is a distinct segment of manufacturing firms that through links with other firms stimulate their innovative activity and development.

The legitimacy of taking up this topic results firstly from the importance of managing innovative resources for innovation, competitive performance of firms, the knowledge accumulation and learning which determine the possibilities of further introduction of innovation on the market. Secondly, from risky nature and sensitivity of innovation activity to turbulence in the economy and its environment, but also the high frequency of different types of turbulences in the economy.

One might think that the analysis carried out herein is therefore historical. However, in our opinion, the analysis carried out in this paper as well as the examined period have important substantive significance. It has a direct reference, firstly to the regularity and continuity of innovation activities, which is not always noticed and appreciated, secondly, to resources management strategies in specific conditions and thirdly to public policy, especially in relation to the future. The analysis proves an excellent laboratory for yielding insights into how large external negative shock affects innovation process of manufacturing firms in a developing country.

The paper consists of several parts. In the first one we show changes of innovation activities and performance of Polish manufacturing firms in the last ten years. In the second part we describe the theoretical background of the paper. The third part presents methodology and statistical data. In the fourth part, we analyse heterogeneity in management of innovative resources, activities and performance across innovative firms and their selection in the period of unstable environment. Summary wraps up the paper.

2. Divergence in economic and innovative activity of Polish manufacturing firms in unstable environment

The global financial and economic crisis of 2008-2010 was accompanied by a short-term slowdown in the economic growth in Poland in 2009 and 2012. This decrease mainly concerned investments. In 2009, 2012 and 2013 their absolute value decreased by 12.7%, 3.95 and 5.8% respectively. Although against the background of processes that took place in the global economy, the Polish economy was successful (in the meaning of high dynamics of economic growth), this process was accompanied by a kind of collapse in innovative activity. The largest decrease took place in 2008-2012 (see figure 1). A strong reduction of innovative activity concerned the introduction of all forms of innovation: product, process, organizational and marketing ones. It also covered the vast majority of types of innovative resources (see section 3).

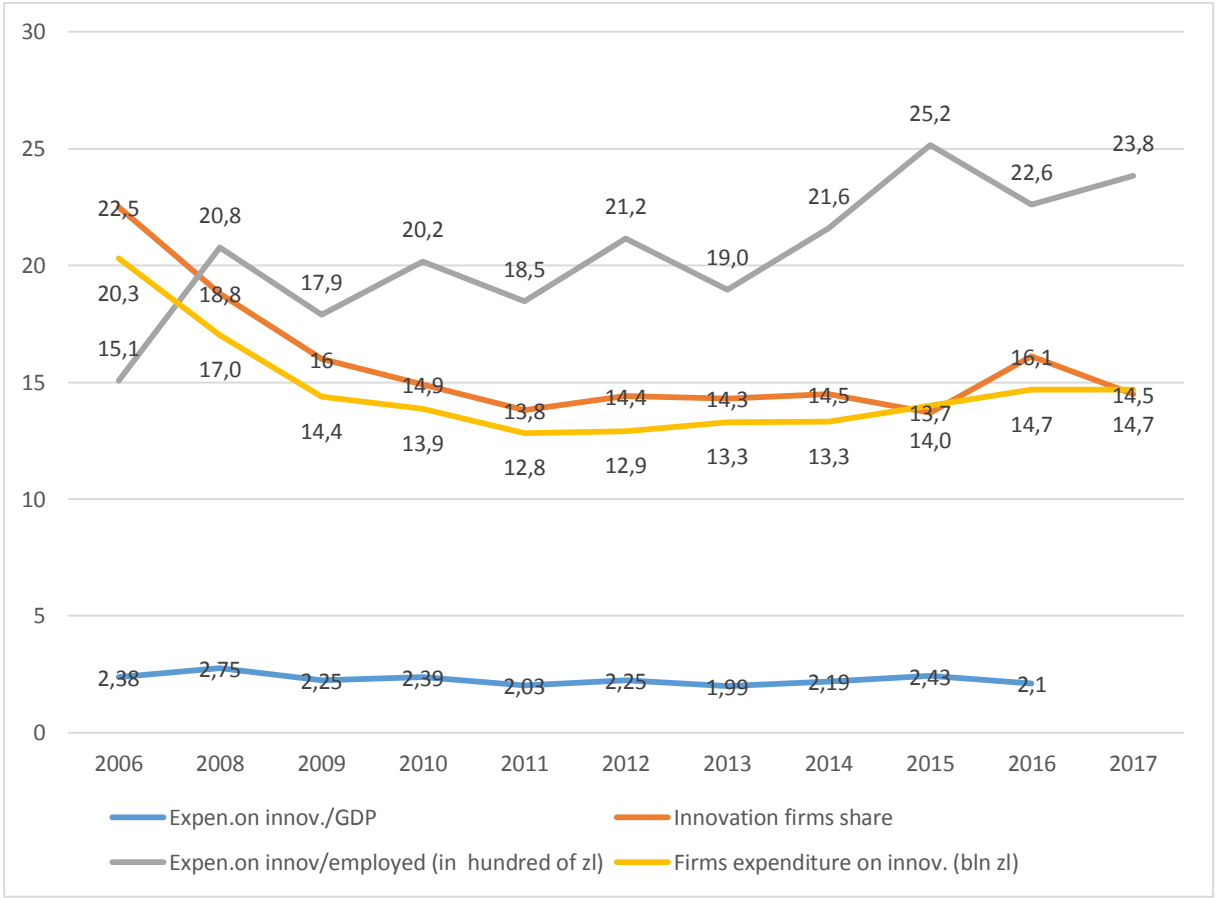

Figure 1. Innovation activity of Polish manufacturing firms in 2006-2017. Source: Based on Innovative activity of enterprises in the years 2015-2017, Statistics Poland, Warsaw, Statistical Office in Szczecin.

In the years 2008-2012, the share of expenditure on innovation in GDP in Poland decreased from 2.75% to 2.25% (in 2006 it was 2.38%) and until 2017 this level did not reach 2008's level. The share of innovative firms in the total number of industrial firms decreased from 18.8% to 14.4% (22.5% respectively). The fact that in 2012-2017 the innovative activity of

Polish firms has been increasing very slowly (figure 1) suggests that the global crisis has been reflected not only in the strong decrease in the innovative activity of Polish manufacturing firms, but in the change of its previous trend: from growth to stabilization (see figure 1). In 2017 the share of enterprises' expenditure on innovation in GDP, the share of innovative firms in the total number of firms and the value of expenditure on innovation were lower than 11 years before. This indicates that the innovation gap of Polish enterprises to the EU ones has been widening.

3. Theoretical background

We set the analysis within an evolutionary research perspective which is widely used by the strategic management literature. It opens up some theoretical approaches that explain the adjustment of innovation resources to the changes in the external environment: Generalized Darwinism, resource-based view, including resource constraints view, knowledge-based view and dynamic capacity view.

Three main principles of evolutionary perspectives: variation, retention and selection processes and interaction between them are based on the Generalized Darwinism (Coccia, 2018; Simmie, Martin, 2010). It introduces the analogies between evolution in the biological sense and evolution of technology (innovation). It underlines that organizations differ in terms of behaviours which are subsequently selectively retained. If a system covers variety of entities, then only those which fit the environment best will survive. It means that according to some criteria elements that fit best and their attributes are selected and will survive in the turbulent period, while non-surviving entities and their characteristics will die out. Evolutionary perspective examines the forces which change the characteristics of heterogenous population in the long run. They are used to explain the evolution of firms, their adaptation to change of environment over time and selection as reaction to changes in external environment and internal (within a firm) changes.

In resource-based view (RBV) the firm is seen as a historically determined collection of assets or resources. The ability of firms to adapt to different conditions is determined by their ability to create, develop and use functional resources and their bundles. Functionality of resources determines the way they are employed (Penrose, 1959). For example, innovation resources as dynamic ones, create new opportunities for businesses over time. As valuable, rare, inimitable, non-substitutable (Barney, 1991) they determine firm’s behaviour and should differ from the resources and their bundles of competitors. Resources and their bundles allow to create unique capabilities. The latter create value, are superior to competitors and allow to adapt to different conditions, stay in the market and outcompete competitors. Resources are the key

factor in explaining the process of diversification of firms and their selection, especially when environment changes.

The ability of firms to adapt to new conditions, to exploit their current strength and explore new opportunities is determined by their ability to use, create, develop and modify the bundles of resources. It suggests that value of resources and their impact on innovation performance should be evaluated in changing environment context in which the firm operates. Various resources, their characteristics and adjustment to changes in environment are the key factors in explaining continuous diversification of firms' performance and selection. However, the static nature of RBV resulted in the emergence of new approaches.

The extension of the RBV of the firm which can serve to explain the basis of continuity of innovation activities and performance in drastically changing environment is the dynamic capabilities view. Dynamic capabilities are seen as "the firm ability to integrate, build and reconfigure internal and external resources/competence to address and shape rapidly changing environment" which is "fast moving" (Teece, 2010, p. 690, 692). As dynamic capabilities have both external and internal dimension (p. 693), their transformation in new, rapidly changing circumstances play critical role. The ability to create a new configuration of assets, or dynamic capabilities makes them complementary in a new way and serves for newly created value. The firm's unique position, specific path and processes including recognizing, creating and exploiting complementarities makes that dynamic capabilities differ across firms (Teece et al., 1997, p. 517) and results in their selection.

In the knowledge-based view (NBV) which directly refers to innovation resources of firms and their adjustment to changes in environment, knowledge is the most important of the firm's resources. Its accumulation is based on both absorption of the existing and external – towards the firm - knowledge and creation and development of a new knowledge. Diversification of the types, quality, bundles and linkages of innovative resources results in a diversification in accumulation of knowledge across firms and adjustment to changing environment. It is also reflected in changes in strategies across firms and results in the selection process across firms.

Knowledge is cumulative and its cumulation results in innovation. Innovation takes the form of firm-specific learning in production by a process of cumulative and incremental problem-solving activity. Learning creates capability base of firms. Past learning which "represents a broader store of capabilities" (Vogus, and Sutcliffe, 2007, p. 3418) plays a role. In NBV persistence in innovation is seen as a combination of learning effects which stem from innovation activities and its interaction with the accumulation of knowledge. The creation of new knowledge by the firm impacts the knowledge stock which can be used in future innovation. The generation of new knowledge builds upon what has been learned in the past. Previous innovation activities extend the firm's level of knowledge stock, reduces resource constraints and increases probability of subsequent innovation (Antonioli, Montresor, 2018). As Amore (2015) shows, market success of innovation in previous crisis positively influences the success of innovation in subsequent crisis. The same concerns turbulences. Over time,

cumulative nature of the knowledge base and knowledge accumulation builds barriers to other firms' entry into the same type of innovation activities. So accumulated competencies of a firm constrain the future innovation performance of their competitors. Depreciation of accumulated knowledge leads to an increase in the gap in quantity and quality of knowledge stock between a firm and its competitors and diminishes the probability of the latter of introducing innovation to the market. It also means that suppression of innovation process of a firm results in a drop in knowledge accumulation, decreases the stock and quality of knowledge and potential to innovate. The firm must persistently accumulate knowledge that it creates, develops and acquires from the environment which creates both new opportunities and barriers in innovation activities. Successful innovation lifts the external financial restrictions and serves ongoing innovation activities (Le Bas, and Scellato, 2014). It results in increase of sales, profits and internal funding. To remain competitive a firm must persistently accumulate knowledge which it creates and also acquires from the environment. As "success breeds success", the results of innovation are determined by the previous conditions and activities (Antonelli, 2011).

However, we should keep in mind that changing environment can affect the role of previously used resources. Some resources, knowledge and their feedback accumulated in the past might not be suitable for the new, uncertain environment (Suarez, 2014; Antonioli, et al., 2011). Volatile conditions might reveal lack of innovative resilience of the firm. Drivers of innovation, sets of knowledge resources, capabilities and their feedbacks that were crucial for innovation in stable environment could be modified. Other resources can take their place (Nelson, and Winter, 1982). So past successes may be insufficient to achieve new successes and may not lead to new innovations.

Innovative activity is highly uncertain and risky. Only part of it translates into the commercialization of innovation (introduction to the market), and thus into the improvement of economic results. This particularly applies to the period of economic turbulence, when risk aversion is growing. There are also some other causes for stopping commercialization of innovation in situation when macroeconomic environment is unfavourable. These are, firstly, sunk costs generated by earlier investment in innovation and its commercialization (Máñez, et al., 2009). Firms always face the choice between investing and not investing in new innovation and their commercialization. As investments in innovation have a long-term character, they might induce a kind of state of dependence or inter-temporal stability in commercialization of innovation (Antoneli, et al., 2013). Secondly, there can be the demand-pull constraints where, due to changes in market condition, a firm may have more pessimistic perception of customers' demand. Due to firm's previous innovations there may be no need for further innovations. It may induce a firm to stop innovating and instead concentrate on exploiting its earlier innovations. If the current product demand develops unfavourably, a firm might decide to stop introducing its product innovation to the market and to continue the exploitation of earlier introduced product innovation. In this case a firm will focus on stimulating its demand or on searching for a new market by introducing marketing innovation

and improving the mix of target markets. This might be especially relevant for firms that offer only few products in markets characterized by rather long product cycles. Firm may be also afraid that introduction of innovation on the market will cannibalize rent from previously commercialized innovation.

4. Methodology and statistical data

The paper is based on statistical data of the Central Statistical Office of Poland (CSO). We use Polish Community Innovation Survey (CIS) data covering the ten-year period (2004-2014), i.e., data of all five waves of CIS of Poland. This is the widest survey of innovative firms in Poland, covering the majority of such firms operating in Poland. CIS is based on Oslo Manual (OECD/Eurostat, 2005) approach to innovation and definition. In the definition of innovation Oslo Manual uses the criterion of results, effects, not efforts or activity of innovative activities. According to the Oslo Manual an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method. This definition covers product, process and two methods – marketing and organization innovation. An innovation must be commercialized (introduced on the market) and implemented ("brought into actual use in the firm's operation") (Gault, 2018, p. 618).

In our paper, we used a new methodology to study innovative behaviour and management of innovative resources by companies during the innovation crisis. It reflects a different than used before way of perceiving innovative resources management by companies during the innovation crisis. This methodology is based on the theses of the theory of innovation, especially the resource-based view, the knowledge-based theory and the dynamic capabilities theory. They emphasize the role of knowledge accumulation, including its restructuring and quality changes under the influence of environmental changes in the introduction of innovation by companies.

Although we focus on the period of innovation crisis in Poland, we capture the innovative behaviour of companies in the long-term perspective, within 10, not just four years on which we focus. This is due to several reasons. First, one of the conditions for introducing innovation during the innovation crisis is the accumulation of knowledge in the pre-crisis period. Innovative resources are created and accumulated over a long period of time, not just during a crisis. In the last period these resources are being restructured. Having the potential for innovation is the basis for the innovative resilience of companies to the crisis. Thus, companies that introduced innovations to the market before the crisis also had extensive and differentiated across firms innovation potential during the crisis. So far, no methodology has been developed for testing the level of knowledge resources accumulated by companies. On the other hand, the mere accumulation of knowledge does not guarantee the continuity of innovative activity

in times of economic turbulence. This continuity depends on the characteristics and structure of knowledge resources and their changes under the influence of environmental changes, and thus also on the ability to manage resources. The research on innovative behaviour of companies that has been introduced so far during the crisis does not use the long-term perspective of researching the management of innovative resources in the period of the innovation crisis. In these studies, focusing mainly on the countries of Southern Europe, especially Italy, Spain, Portugal, but also Argentina, companies that were innovative only during the global crisis of 2008-2012 are analysed. Secondly, in preparing the said methodology for selecting companies, we took into account the features of the Polish sector of innovative companies, especially the low level of innovation of these companies. In the long term (2004-2014), the share of innovative companies in the total number of companies in Poland was one of the lowest in Europe. It was significantly lower than in the aforementioned southern European countries. A very small part of the companies introduced innovations in all CIS periods. Thirdly, as mentioned before, in the years 2008-2012 Poland did not go through an economic crisis, which by its nature is overwhelming. Despite this, the innovation crisis in Poland was much stronger than in the aforementioned southern European countries. And in Poland its effects were long-term (at least until 2016). The above-mentioned premises were the basis for introducing a different than commonly used in literature methodology for selecting companies and a method of examining the management of their resources.

The second new element of the methodology for testing the management of innovative resources of firms during the innovation crisis is the typology of innovative firms introduced (see section 4a). Although it is based on the innovative results of firms during the crisis, taking into account the long-term perspective, in connection with changes and the frequency of using innovative resources, it shows the basics of selecting innovative firms on the market of innovative products, especially the emerging perspective of "exiting" some firms and entering firms from recently innovative. Thus, it proves that the basis of persistence in innovation is not only accumulation of knowledge, but also the ability to adapt knowledge management to new conditions. Therefore, it confirms the thesis of the evolutionary trend that the ability to accumulate and manage knowledge is crucial in the innovation performance of firms and their selection on the market.

We start with building a panel of innovative manufacturing firms from statistical data of all five waves[1] of the CIS. This panel covers innovative manufacturing enterprises that – during the ten-year period – took part in the CIS of Poland conducted by US Szczecin. Although we focus on the turbulent period in Poland (2008-2012) we also consider two CIS waves covering periods before (in 2004-2006 and 2006-2008) and one wave after the turbulent period (in 2012-2014). Our panel's firms participated at least in three out of five CIS waves (in 2004-2014) and introduced innovations to the market at least once in 2008-2010 or 2010-2012. We did not

[1] In the years 2004-2006, 2006-2008, 2008-2010, 2010-2012, 2012-2014.

include firms that did not introduce product/and process innovations to the market in 2008-2012.

The CIS survey covers core questions and module which changes with each survey. It means that we were forced to use core questions and some additional questions included in both 2008-2010 and 2010-2012 surveys. We selected four forms of innovation: product, process, organizational and marketing innovation, and 32 types of resources, including some barriers of innovation, that show which resources a firm is short of.

a. Characteristics of the panel

The panel consists of 1533 Polish manufacturing firms that were innovative in at least three Polish CIS waves and also were innovative at least in 2008-20010 or/ 2010-2012. It means that we focus our analysis on innovative manufacturing firms which in long run have been developing innovation potential and were successful in introducing innovation to the market either in the first (2008-2010) or/and the second period of turbulence (2010-2012).

The panel was composed mostly of medium-sized (59.2%) and large firms (38.1%). The share of small firms was negligible (2.7%) as the data received from the CSO were not weighed. However, according to the official CSO data (covering weights), the share of small firms in expenditure on innovation and sales of innovative products was small (less than 8%). Innovative resources of small firms have little impact on the innovative resources of the panel.

Most the panel's firms operated in the medium – high (43.8%) and low technology[2] (38.7%) sectors. The share of high (5.3%) and medium – low (12.1%) technology sector's firms was much smaller. Most firms were private and over 40% belonged to a capital group. 74.4% panel's firms were private, while 5.6% - state-owned. About 70% panel's firms introduced product and process innovation and much less – organizational and marketing innovation (see Table 2).

The diversity of the innovation capacity of the surveyed firms is reflected in the diversity of export and sales of innovative products shares. Nearly 40% of the number of panel's firms did not export innovative products. On the other hand, in 38.2% of firms, the export of these products exceeded 20% of their total export, and in 15.8% of firms it was from 0.1% to 9.99%.

The share of sales of innovative products in total sales exceeded 20% in 34% of the panel's firms. The share of innovative products in sales ranged from 0.1% to 4.99% - in 28% of firms, share from 5% to 9.99% - in 21% of firms and from 10% to 19.99% - in 17% of firms.

The innovation intensity of export and sales was diversified across panel's firms. 54% of the firms did not export innovative products. However, in a significant part (29%) of firms, the share of export of innovative products in total export exceeded 20%. In 50% of the panel's firms the intensity of export of innovative products exceeded 10%, in 1/3 of firms it was over 20%.

[2] According to the 2008 classification of Eurostat and the European Research Center of the European Commission.

b. Changes in the use of innovation resources by innovative manufacturing firms

Since the literature lacks standardized nomenclature of resources, including innovation ones, different classifications of them are used. Galbreath (2005), referring to Hall's (1992, 1993) approach to resources and defining them as a firm level factors that have potential to contribute to economic benefit (p. 980), selects two types of resources. The first ones are assets (tangible, including financial and intangible) which show what the firm has. The second ones are skills (intangible resources) which show what the firms do. Chatterjee and Winnefeld (1991) identify three classes of resources: physical, intangible assets and financial ones. The last are most flexible, very useful for diversification of innovation activities and can be used to buy most innovative resources. Strong dependence of innovative activity on access to finance implies that the latter play a special role in adjustment to changes in external environment. Limited access to the external finance hampers innovative activities and increases their vulnerability to turbulence. For example, given the higher credit barriers, firms suffer in time of turbulence and they are less willing to invest in new innovation. However, the fact that a firm has, for example, resources, does not have to mean that they are sufficient for conducting innovative activity. Hence, the aforementioned divisions of innovative resources do not exhaust all the problems that result from the assessment of the company's equipment in these resources.

CIS formularies for years 2008-2010 and 2010-2012 cover question on the barriers to innovation. They suggest what is missing in the firm or what are their shortages and deficiencies (like lack of educated staff or financial resources) in the firm and what is the firms' perception of market and demand conditions. These questions are very relevant to the unstable period.

We explore different types of innovation resources, which reflect different types of knowledge. Our data (see Table 3 and Table 4) cover following types of innovative resources: tangible (like machinery and equipment, automation measures) and intangible (human capital); static (machinery) and dynamic (human capital); external (21 resources) and internal (12 resources); financial (four types) and non-financial, and resources which show what the firm has (like educated staff, internal sources of information) and what it does (develops and adapts product and process innovation, cooperates with different types of partners etc.). The binary form of the received data allows to indicate which resources were the most often used by the innovative manufacturing firms.

Our focus on innovative resources management in the period of dramatic changes in external environment suggests the legitimacy of using the division of resources into internal ones and those acquired from the environment. The changes in the use of the latter reflects not only the ability to use resources, i.e. absorption capacity, but also the impact of changes in the environment.

In both analysed periods (see Table 3-4) more than 55% of innovative manufacturing firms purchased machinery and equipment and acquired information from the suppliers and customers (see Table 4). More than 70% of firms used internal sources of information and

internal finance and over 60% - developed and adapted product by themselves. Other internal and external resources were used by the panel's firms much less frequently.

In 2008-2010 about four times more panel's firms used internal instead of external financial resources, including public support (Table 3 and 5). This may suggest their relatively small dependence on external financial resources, but also a low ability to obtain funds from public sources, especially EU ones, which were relatively easily available at that time. However, the fact that a significant number (41%) of firms suffers from a shortage of funds suggests the low absorption capacity of a significant part of innovative firms. Over 45% of firms developed product and process innovations themselves (without cooperation) and much less (18%) cooperated with other firms and scientific units, and 9% - cooperated with foreign firms and scientific institutions. Although a large part of the surveyed innovative firms often used information from the external environment, only few of them purchased licenses and consulting services. The weakness of financial standing of these firms and strong dependence on access to financial resources makes them often focus on the traditional sources of innovation such as the purchase of machinery and equipment.

In the years 2010-2012, despite a very strong (by over 40 percentage points) improvement in the perception of market and demand conditions, the number of firms that suffered a shortage of financial resources increased significantly (see Table 4). It was accompanied by an increase in the number of firms that reduced the use of innovative resources. There was a drop in the frequency of using almost all (except four) resources. These were public support, employment of employees with higher education, continuous in-house R&D and external expenditure on innovation. There was also a drop in the number of firms which developed product and process innovations themselves (without cooperation) and those that did it in cooperation with foreign firms and scientific institutions. However, in the opposition to it, there was an increase in the number of firms that increased the employment of people with higher education, benefited from public support in conducting innovative activities and - which may come as a surprise – conducted R&D on a continuous basis. The stronger drop in the frequency of using external instead of internal resources suggests further concentration on the use of internal resources. The inevitable effect of the above-mentioned processes was the deterioration of innovation performance. The number of firms that introduced product innovations dropped from 76% to 72%, in the case of process innovations from 69% to 65%, number of firms that reorganized dropped from 45% to 43% and introduced marketing innovations (from 42% to 41%). This was accompanied, on the one hand, by a decrease (see Table 5) in the number of firms for which the sale of innovative products was a source of income, but on the other - a very small increase in export of these products.

5. Heterogeneity in management of innovation resources, activities and performance across innovative firms in unstable environment

In respect to characteristics of firms, their innovative resources, activities and performance, our panel of innovation firms was heterogenous. Basing on firms' innovation performance in the long run (2004-2014) with a special consideration of the unstable period (2008-2012) we classify them into some groups.

a. Typology of innovative firms and their characteristics

We have distinguished two basic groups and some subgroups of firms (Table 1):

I. Resistant (to the turbulences): they introduced innovative products to the market in both analysed periods (2008-2010 and 2010-2012) and in one of other CIS waves. In this group, we have identified two subgroups of firms:
   1. Permanently innovating firms which introduced innovations in all five CIS waves.
   2. Impermanently innovating firms in the long run (10 years period) that introduced innovation at least in three out of five CIS waves and in both periods of 2008-2010 and 2010-2012. They were divided into two subgroups:
      a. Inexperienced innovating firms (newcomers) that did not introduce innovative products to the market before the unstable period (in 2004-2006).
      b. Experienced innovating firms which were selling innovative products before 2008 and have got some experiences in operating on innovation product market.

II. Fighting (in turbulent time) firms for introducing innovative products on the market: they introduced innovations in one of the two periods studied (in 2008-2010 or in 2010-2012) and in one CIS wave: before or after turbulent period (2008-2012).

Table 1.
Typology of innovative manufacturing firms

Classification of firms	Number of firms	% of the panel firms
I. Resistant to turbulences (REST)	1186	77.4
1. Permanent in innovation (PER)	859	56.1
2. Impermanent in innovation (IMPER)	327	21.3
2a. Inexperienced (INEX)**	(54)	(3.5)
2b. Experienced (EXP)**	(273)	(17.8)
II. Fighting* in the period of turbulence (FIGH)	347	22.6
Total	1533	100

*to be innovative in the Oslo Manual meaning.
** before the unstable period, in 2004-2008.

Source: calculation based on data of Statistic Poland and Statistical Office in Szczecin.

The rationale for classifying the impermanently innovating firms into two groups (experienced and inexperienced) is the fact that sale of innovative products is a source of gaining knowledge about the market and competitors. Expanding the size of accumulated knowledge stimulates the innovation activity and performance of firms.

The study did not include firms that did not introduce product innovations to the market during the turbulent period, although they did it before and after it.

Most (nearly 80%) panel firms introduced innovations (and in this sense were resistant to global crisis) during the period considered. However, in many respects they differed widely. Over half of the number of innovative companies have brought innovation in five CIS waves. They are the most stable segment of the innovation sector. However, on the other hand, as many as 1/5 of the number of companies had difficulty staying on the market of innovative products during the turbulence period, and many of them did not bring innovation to the market in 2012-2014. An interesting segment of the surveyed sector of innovative companies are inexperienced innovative companies, i.e. newcomers. Before 2008 they did not launch innovative products on the market but they actively launched these products both during the turbulence period and after 2014.

Table 2.
Characteristics of groups of innovative manufacturing firms in 2008-2012 (% of the panel firms)

Share of	2010						2012					
	Resistant				Fight (II)	Total	Resistant				Fight	Total
	Total (I)	Impermanent (2)		PER (1)			Total (I)	Impermanent (2)		PER		
		IN-EX (2a)	EXP (2b)					IN-EX (2a)	EXP (2b)			
Medium sized firm	58	80	68	53	65	59	57	78	67	53	68	60
Large firm	41	13	29	46	30	38	41	2	30	46	29	38
Medium and high level of technology	51	44	45	54	42	49	52	43	45	55	41	49
Private firms	74	91	74	73	76	88	72	82	72	71	72	72
Part of group	41	26	40	43	38	40	42	20	37	44	33	40

Abbreviations: see Table 1.

Source: see Table 1.

Among the distinguished groups, the most distinct were permanently innovating and inexperienced in commercialization of innovation firms. From the other groups of firms, permanently innovating firms were distinguished by a high share of large firms and high level of technology of production, while the inexperienced innovating firms – by high share of medium-sized, private and not belonging to capital groups firms.

b. Difference in the use of innovation resources across groups of innovative firms

The management of innovative resources of a firm includes both its internal knowledge resources and the ones available in the environment. To exploit external knowledge a firm has to acquire and transform external knowledge, i.e., it has to have absorptive capacity. It allows to "recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen, and Levinthal, 1990, p. 128). In a firm's absorptive capacity, a special role is

played by research and development (R&D) which "not only generates new information, but also enhances the firm's ability to assimilate and exploit existing information" (Cohen, and Levinthal, 1989, p. 569). In the innovative process, R&D plays double role: creative and absorptive.

In the analysed turbulent period, the use of most of external and internal knowledge resources of our panel firms diminished (see Table 3-4). However, the size of this decrease varies between selected groups of firms and knowledge resources considerably.

In terms of the level and changes in the use of internal innovative resources, the biggest differences existed between fighters and firms resistant to turbulences, especially permanently innovating firms (see Table 3). In the years 2008-2010 the use of internal innovative resources by the former group was very low and much lower than by impermanently innovating firms. Surprisingly, although a similar part of both groups of innovating firms used internal financial resources for innovation, the perception of their shortage by fighting firms was smaller. This is due to less involvement in innovative activities. Much less fighters developed product and process innovations by themselves, introduced marketing innovation, trained staff, financed innovation activities from internal resources, and conducted occasional R&D. In case of conducting continuous R&D, the differences between the two groups of firms were even greater. In the years 2010-2012, compared to 2008-2010, in both groups of innovating firms, the use of most of internal resources decreased (except for human capital and continuous R&D). However, this decline was much stronger in the fighting than impermanently innovating firms. Resistance of innovative activity to turbulences of the latter group was greater.

In the first years of world financial crisis, innovative activities and use of internal innovative resources within the group of resistant firms vary considerably. The biggest differences were between permanently and impermanently innovating firms to the advantage of the first ones. For example, much more permanently than impermanently innovating firms introduced marketing innovation, designed new product, used internal financial resources for financing innovation, developed and adapted products by themselves, used internal sources of information and conducted continuous R&D. A smaller part of them also suffered from a shortage of internal financial resources and qualified personnel. Although in the examined period the directions of changes in the use and development of these resources in permanently and impermanently innovating firms were similar, the decrease in resources used was smaller in the former. Innovation capabilities of the former firms improved much more than of the latter. The gap in endowment in internal innovative resource between two groups of firms increased in favour of permanently innovating firms.

However, the group of impermanently innovating firms was diversified and diversifying. Basing on the criteria of experience in selling innovative products on the market before 2008, within this group, we selected two subgroups of firms: those that have gained experience in selling innovative products before 2008 (newcomers) and those that did not have this

experience but began to sell innovative products and continued to do it in the period of world financial crisis.

Table 3.
Internal innovation activities and resources used by the different groups of firms (% of the panel firms)

Share of	2010						2012					
	Resistant				Fight (II)	Total	Resistant				Fight (II)	Total
	Total (I)	Impermanent		Perm (1)			Total (I)	Impermanent		Perm		
		Inex (2a)	EX (2a)					INEX	EXP			
% of employees with higher education	20	18	17	21	17.5	19	21	20	19	22	18.6	21
Development and adaptation of products by the company	71	48	61	76	31	62	73	59	63	77	19	61
Development and adaptation of processes by the company	53	52	48	55	25.9	47	52	52	51	52.5	19	45
Internal R&D – continuous	28	20	15	32	5.2	23	30	27.8	15	34.7	7.5	25
Internal R&D – occasional	25	22	23	25	12	22	19	17	13	21	10	17
Staff training	61	52	53	64	29	54	54	37	47	58	20	47
Marketing of new products	50	32	32	56	16.7	42	46	32	29	52	11	38
Change and design of new products	54	32	38	60	16	45	51	24	35	58	13.5	43
Internal expenditure on innovation	88	70	82	91	36	76	83	63	70	89	35	73
Internal sources of information	84	67	79	87	43	75	83	76	77	85	35	72
Lack of qualified staff	68	76	67	68	68	68	73	83	69	73	72	73
No financial resources in the company	42	57	41	41	38.9	41	52	61	54	51	51	52

Abbreviations: see Table 1

Source: see Table 1.

In 2008-2010 the differences in the use of innovative resources between inexperienced and experienced innovating firms were relatively small. These differences concerned more types than frequency of using resources. As inexperienced innovating firms more often introduced

process innovations and conducted R&D than experienced firms, their perception of scarcity of internal financial resources was bigger and in the analysed period increased more. In spite of the fact that the experienced firms focused on product innovation, while inexperienced – on process innovation, the frequency of introducing marketing innovation by both groups of firms was similar. This suggests a more aggressive marketing policy of inexperienced firms. In the next analysed period, much more inexperienced than experienced firms increased the use of internal financial resources, introduced product innovations to the market and conducted both continuous and occasional R&D. A shift in their innovation strategy from creating innovation capacity towards product innovations strategy (without changing the scope of developing process innovations) serves the accumulation of new types of knowledge and stimulates further innovation also in future unfavourable conditions (Amore, 2015).

To sum up, in the period of turbulence, the drop in the use of most of innovation resources of analysed panel firms accompanied a change in innovation capacity and in the structure of innovative resources across these firms. This stimulates the process of a new differentiation of innovating firms. The gap in innovation capacity between the fighting and other panel firms widened. The innovation capacity of experienced, resistant to turbulences firms as compared to inexperienced and permanently resistant innovating firms deteriorated a bit. So, the gap in internal innovation capacity between newcomers and experienced innovating firms diminished.

The process of managing innovative resources includes also the changes in the acquisition, use or development of external innovation resources also as an effect of cooperation in innovation with other entities. This collaboration is an important source of learning, a component of knowledge accumulation and the premise of persistence in innovation in the longer run.

In the analysed period the use of external resources, except for public aid, external expenditure on innovation and purchase of automation means decreased. However, in terms of scale od this drop, there were quite big differences across analysed groups of firms. The biggest differences were between fighting and resistant to turbulence innovative firms. The use and development of external resources of the former ones was from two to four times lower than the latter ones. Fighters, although like other companies less often used external resources than internal ones, they did it less often. As in the next period the use of external innovative resources (except for external funding for innovation and public support) by fighters declined more than in the case of resistant ones, the gap in the use of these resources between these groups of firms has increased. In 2012-2014 a significant part of the former firms ceases to innovate.

The frequency of using external innovative resources by permanent innovating firms was the highest and slightly higher than in the case of impermanent innovating firms. Although the directions of changes in the use of these resources were similar in both groups of firms, the drop in the use of various innovative resources by the former group was smaller. The increase in the use of financial resources was greater in permanently innovating firms than in the impermanently innovating firms. Thus, the innovation activity of permanent innovators was

less sensitive to turbulence than of impermanently innovating firms. Although in the turbulent period their innovation capacity deteriorated a bit, this drop was the smallest.

Table 4.
Cooperation in innovation activities and the use of external knowledge resources by the different groups of firms (% of the panel firms)

	2010						2012					
	Resistant				Fight (II)	Total	Resistant				Fight (II)	Total
	Total (I)	Impermanent		PER (1)			Total (I)	Impermanent		PER (1)		
		IN-EX (2a)	EXP (2b)					IN-EX (2a)	EXP (2b)			
Development of products with domestic firms and scientific units	22	15	14	24	7	18	21	11	14	24	6	18
Development of processes with domestic firms and scientific units	19	19	18	20	8	17	18	15	14	19	7	15
Development of products with foreign firms and scientific units	13	6	11	14	3	11	10	4	7	12	3	9
Development of processes with foreign firms and scientific units	10	7	11	10	6	9	9	7	5	10	4	8
External expenditure on R&D	32	24	21	36	10	27	32	26	17	36	10	27
Acquisition of machines and software	84	78	82	86	46	76	79	67	75	81	35	69
Acquisition of knowledge	27	17	22	29	9	23	21	9	15	24	7	18
External expenditure on innov.	23	35	24	22	8	20	22	17	20	23	14	20
Public support for innovative activities	23	24	22	24	11	20	25	32	19	26	14	22
Information from other group firms	26	15	21	28	16	24	26	17	22	28	10	22
Information from suppliers	61	59	55	62	36	55	60	52	48	65	29	53
Information from clients	60	33	54	64	33	54	45	33	36	49	16	39
Information from competitors	44	20	36	48	25	40	37	32	34	39	14	32
Research information	38	35	32	40	20	34	37	37	28	40	17	33
Information from public sources	68	52	62	71	38	61	65	50	56	69	27	56

Cont. table 4.

Purchase of a license	13	13	12	13	8	12	8	7	7	9	6	8
Purchase of automation means	16	11	11	17	8	14	18	13	12	20	8	16
Purchase of consulting services	15	7	12	17	11	14	12	9	7	14	5	10
Difficulties in finding co-operators	70	82	70	69	66	69	44	50	50	42	47	45
No financial means outside the firm	52	63	51	51	45	50	62	65	65	61	58	61
Uncertain/lack of demand	81	89	81	80	75	79	39	44	38	39	35	38
Unfavourable market condition	55	76	54	54	54	55	13	20	16	11	17	13

Abbreviations: see Table 1

Source: see Table 1.

In terms of use of external resources experienced firms differ from inexperienced ones. In 2008-2010 external financial sources and public support were more often used by inexperience firms. More inexperienced firms cooperated with domestic firms in product and process innovation, while more experienced firms cooperated with foreign firms and scientific units. The use of information was more frequent in experienced firms. As the drop in the use of information by experienced firms was more frequent than in case of inexperienced ones, in this respect the gap between the two groups of firms diminished. As external (and internal) R&D was explored by more inexperienced than experienced firms, the gap between the two groups of firms increased. In total, in turbulent period the gap in the innovation capacity between two groups of firms decreased. Changes in the innovation strategy of inexperienced innovative firms have led to a reduction of the gap in innovation capacity as compared to experienced innovating firms.

Summing up, in the turbulent period, internal innovative resources were used more often than external ones. Smaller decrease in the use of internal than external resources suggests the focus of the firms on the use of the first ones. On the other hand, turbulence in environment led to new differentiation of innovating firms. The innovation capacity of some of them (like fighting firms) deteriorate while in the case others (permanently innovating and inexperienced firms) it improved.

c. Difference in the innovation performance across groups of innovative firms in turbulent time

Differences in the use of innovative resources and their changes result in difference in innovation performance. Surprisingly, the improvement in perception of market and demand conditions of Polish firms (see Table 4) accompanied a continuous deterioration in the innovation performance of the panel firms. It concerned the frequency of launching various

forms of innovation and sale of innovation products shares (Table 5). However, the size of this drop varied considerably across firms.

In 2008-2010 in all groups of firms, except for inexperienced ones, the frequency of introducing all forms of innovation decreased. Fighters recorded the strongest decline. The drop in the use of innovation resources by the fighters accompanied the biggest among the analysed groups of firms' deteriorations in innovation performance. The frequency of introducing product innovations has decreased by almost half, and sales of innovative products share and export share has decreased even more.. And yet a very small part of these firms sold innovative products at home (12%) and abroad (11%). In 2012 innovation performance of fighters was two times worse than of the resistant group. Almost five times smaller part of fighters than resistant innovating firms sold innovative products.

Innovation performance, especially share of sales of innovative products of experienced innovating firms, also deteriorated significantly. On the other hand, the percentage of newcomers introducing product, process and organizational innovations and export of innovative products increased the most. The increase in export of innovation products shares among the surveyed groups of firms (except for the fighting ones) indicates that their competitiveness of innovative products increased.

The biggest differences in innovation performance and its changes took place between fighters and resistant innovating firms and within the latter group – between permanent and inexperienced firms. Considerable worsening of endowment in innovative resources of many fighters confirms that they will shift to the group of noninnovative firms.

In 2008-2010 the difference in innovation capacity and strategy between inexperienced and permanent innovating firms resulted in difference in the share of sales and export of innovative products. Both indicators of innovation performance of inexperienced firms were about twice lower than of permanently innovating firms and also much lower than of experienced firms. The inexperienced firms focused on building and developing innovation capacity, in which process innovations played a key role. This in turn translated into a lower shares of sales and export of innovative products. However, regardless of turbulence in the environment, in the next period inexperienced firms continued to expand their innovation capacity. It was accompanied by the strongest among the examined groups of firms increase in the share of export of innovative products and introduction of all forms of innovation (Table 5).

Table 5.
Innovation performance of selected groups of innovative manufacturing firms in 2008-2012 (% of the panel firms)

	2010						2012					
	Resistant				Fight (II)	Total	Resistant				Fight (II)	Total
	Total (I)	Impermanent		PER (1)			Total (I)	Impermanent		PER (1)		
		IN-EX (2a)	EXP (2b)					IN-EX (2a)	EXP (2b)			
Product innovations	86	63	76	91	40	76	86	69	73	91	25	72
Process innovations	76	80	76	76	43	69	75	82	73	75	30	65
Organizational innovations	50	35	41	54	29	45	48	43	36	53	27	43
Marketing innovations	47	30	31	54	23	42	46	30	31	52	22	41
Share of sales of innovative product	62	33	52	67	28	54	56	30	42	62	12	46
Share of export of innovative products	54	35	37	60	19	46	57	43	39	63	11	46

Abbreviations used: see Table 1

Source: see Table 1.

To sum up, turbulence on the global market has contributed to a change in the picture of diversity in innovative activity, capacity and innovation performance across selected manufacturing innovative firms. On the one hand, there was a strong drop in innovation performance of the fighters. On the other hand, a new group of dynamic inexperienced innovating firms, mostly medium-sized, private and not belonging to capital groups, has emerged. Their innovation performance has improved the most. The innovation capacity they have developed in the past and accumulated knowledge resources have served the improvement in their innovation performance. The gap in innovation performance and endowment with innovation resources between the newcomers on the one hand and on the other – experienced and permanent innovating firms dropped, while between these three groups of firms and fighting firms – it increased. Turbulences in environment stimulates selection process across firms and their resources.

Discussion and conclusion

Being one of the riskiest business activities, innovative activities strongly affect the development and expansion of firms. Its continuity depends on the management of knowledge resources on the one hand and on the other - on changes in the environment, especially of a discontinuous nature. In addition to the crisis, there are various types of turbulence that

negatively affect economic activity, especially its risky types. The highly uncertain and risky nature of innovative activities increases the importance of knowledge resources management for innovation performance and economic growth. It impacts the selection of firms on the market: strengthening the innovative position of some and weakening or even pushing other innovative products from the market. This process takes place on regional and macroeconomic level.

In the study, on the example of Poland, we showed how strongly the global financial crisis of 2008-2012. which caused turbulence rather than crisis in the Polish economy, influenced innovation activities of firms. Although in the years 2008-2012 the Polish economy did not undergo an economic crisis, the riskiest areas of its economy, such as innovative activity, were influenced. This suggests that even if the global crisis does not cause visible macroeconomic changes in a given country's economy ("Singapore paradox"), some areas of the economy may strongly feel its negative effects. In innovative activity, this impact translates into changes in the use and structure of knowledge resources, and indirectly – in innovation performance and persistence in innovation of firms. This in turn contributes to the intensification of the processes of selecting firms on the market. The weakness of the innovation potential of firms from Poland has caused turbulence which reversed the previous trend of reducing the innovation gap between Polish and EU firms.

In the paper, we showed how turbulence in environment affects the diversity of knowledge resource management and innovation performance across firms. Therefore, these processes contribute to the cessation of innovative activity by some firms (fighters), and stimulate innovative activity of other firms, including those who did not introduce innovation (inexperienced firms) before the turbulence but have been developing innovation capacity.

Some firms (like fighters) that in the turbulence period most strongly diminished the use of innovative resources and innovation performance, ceased to be innovative in the following period. In turn, newcomers to innovation, who built innovative potential but did not commercialize innovations before the surveyed period, increased the use of innovative resources in the examined period, improved innovation performance and continued to introduce innovations in subsequent periods. Among the identified groups of firms, the best ability to manage innovative resources and good innovation performance were shown by permanently innovating firms, which systematically introduced innovations to the market for over 10 years. However, during the analysed unstable period innovation performance improved the most for newcomers.

The study of knowledge resource management under the influence of dramatic changes in the environment shows not only various changes in the structure of resources used, but also the acceleration of selection processes among innovative firms at the level of industries, regions and macroeconomy. Therefore, it is important not only for firms but also for regional and macroeconomic development.

Acknowledgements

The study was a part of the National Science Centre Poland project "Diversification of innovation strategies of Polish manufacturing firms as an effect of changes in macroeconomic environment", contract No. UMO-2015/17/B/HS4/02742. The study uses data from Statistical Office in Szczecin. The Statistical Office in Szczecin is not responsible for conclusions in the publication.

References

1. Amore, M.D. (2015). Firms learning to innovate in recessions. *Research Policy, 44(8),* 1574-1583.
2. Antoneli, C., Crespi, F., and Scellato, G. (2013). Internal and external factors in innovation persistence. *Economics of Innovation and New Technology, 22(3),* 256-280. Retrieved from: http://hdl.handle.net/2318/134344 since 2016-01-25T08:49:11.
3. Antonelli, C. (2011). The economic complexity of technological change: knowledge interaction and path dependence. In: Antonelli (Ed.), *Handbook on the Economic Complexity of Technological Change*. Cheltenham: Edward Elgar.
4. Antonioli, D., Bianchi A., Mazzanti M., Montresor S., and Pini, P. (2011). Economic Crisis, Innovation Strategies and Firm Performance. Evidence from Italian Firm-level Data, Universita Degli Studi di Ferrara. *Quaderno, 2.* Retrieved from: citeseerx.its.psu.edu.
5. Antonioli, D., Montresor, S. (2018). Persistence of innovation in times of crisis: An analysis of Italian firms. Retrieved from: https://siecon3-607788.c.cdn77.org.
6. Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17,* 99-120.
7. Bartolacci, F., Paolini, A., and Zigiotti, E. (2016). Innovation and profitability in a population of italian listed firms during a time of crisis. *Rivista Piccola Impresa/Small Business, 2,* ISSN 0394-7947. Retrieved from: http://doi: 10.14596/pisb.238.
8. Bontis, N., and Fitzenz, J. (2002). Intellectual capital ROI: A causal map of human capital antecedents and consequents. *Journal of Intellectual Capital, 3, (3),* 223-247, https://doi.org/10.1108/14691930210435589.
9. Chatterjee, S., and Wernefeld, B. (1991). The link between resources and type of diversification: Theory and evidence. *Strategic Management Journal, 12(1),* 33-34.
10. Coccia, M. (2019). A theory of classification and evolution of technologies within a Generalised Darwinism. *Technology Analysis & Strategic Management, 31(5),* 517-531, https://doi.org/10.1080/09537325.2018.1523385.

11. Cohen, W.M., and Levinthal, D.A. (1989). Innovation and Learning: The Two Faces of R&D. *The Economic Journal, 99(397),* 569-596.
12. Cohen, W.M., and Levinthal. D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly, 35*, 128-152.
13. Cohen, W.M. (2010). Fifty years of empirical studies of innovative activities and performance. In: B.H. Hall, and N. Rosenberg (Eds.), *Handbook of the Economics of Innovation* (pp. 219-213). Amsterdam: Elsevier.
14. Galbreath, J. (2005). Which resources matter the most to firm success? An exploratory study of resource-based theory. *Technovation, 25(9),* 979-987.
15. Gault, F. (2018). Defining and measuring innovation in all sectors of the economy. *Research Policy, 43(3),* 617-622, http://doi: 10.1016/j.respol.2018.01.007.
16. Giedeman, D.C., Isely, P.N., Simons, G.P.W. (2006). Innovation and the Business Cycle: A Comparison of the U.S. Semiconductor and Automobile Industries. *International Advances in Economic Research, 12,* 277-286.
17. Hall, R. (1992). The strategic analysis of intangible resources. *Strategic Management Journal, 13*, 135-144.
18. Hall, R. (1993). A framework linking strategic resources and capabilities to sustainable competitive advantage. *Strategic Management Journal, 14*, 607-618.
19. Le Bas, C., and Scellato, G. (2014). Firm innovation persistence: A fresh look at the frameworks of analysis. *Economics of Innovation and New Technology, 23*, 423-446.
20. Máñez-Castillejo, J.A., Rochina-Barrachina, M.E., Sanchis-Llopis, A., and Sanchis-Llopis, J.A. (2009). The Role of sunk costs in the decision to invest in R&D. *Journal of Industrial Economics, 57(4)*, 712-735.
21. Nelson, R. (1991). The role of firm differences in an evolutionary theory of technical advance. *Science and Public Policy, 18(6*), 347-352.
22. Nelson, R., and Winter, S. (1982). *An Evolutionary Theory of Economic Change.* Cambridge: The Belknap Press of Harvard University Press.
23. OECD/Eurostat (2005). *Oslo Manual, Guidelines for Collecting and interpreting Innovation Data.* Paris: OECD Publishing.
24. Penrose, E.T. (1959). *The Theory of the Growth of the Firm*. New York: John Wiley.
25. Reinganum, J. (1989). The Timing of Innovation: Research and Diffusion. In: R.R. Schmalensee, and R.D. Wiling (Eds.), *Handbook of Industrial Organization* (pp. 489-908). Amsterdam: Elsevier.
26. Simmie, J., and Martin, R. (2009). The economic resilience of regions: towards an evolutionary approach. *Cambridge Journal of Regions, Economy and Society, 3(1),* 27-43, https://doi:10.1093/cjres/rsp029.
27. Suarez, D. (2014). Persistence in innovation in unstable environment: Continuity and change in the firm's innovative behavior. *Research Policy, 43*, 726-736.

28. Teece, D. (2010). Technological innovation and the theory of the firm: the role of enterprise-level knowledge, complementarities and (dynamic) capabilities. In: B.H. Hall, and N. Rosenberg (Eds.), *Handbook of Economics Innovation* (pp. 679-730). Amsterdam: Elsevier.
29. Teece, D.J., Pisano, G., and Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18(7),* 509-533.
30. Vogus, T.J., and Sutcliffe, K.M. (2007). *Organizational Resilience: Towards a Theory and Research Agenda.* Conference: Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Montréal, Canada, 7-10 October, 3418-422. https://www.researchgate.net/publication/220756654.