OECONOMIA
COPERNICANA

VOLUME 10 ISSUE 4 DECEMBER 2019

p-ISSN 2083-1277, e-ISSN 2353-1827
www.oeconomia.pl

ORIGINAL ARTICLE

Citation: Jakimowicz, A., & Rzeczkowski, D. (2019). Firm ownership and size versus innovation activities over the business cycle: near-zero inertia as a sign of the transition from the fifth to the sixth Kondratieff wave. *Oeconomia Copernicana*, *10*(4), 689–741. doi: 10.24136/oc.2019.033

Contact to corresponding author: ajakimowicz@inepan.waw.pl; Department of World Economy, Institute of Economics, Polish Academy of Sciences, Palace of Culture and Science, 1 Defilad Sq., 00-901 Warsaw, Poland

Received: 23.06.2019; Revised: 3.10.2019; Accepted: 29.10.2019; Published online: 25.12.2019

Aleksander Jakimowicz
Polish Academy of Sciences, Poland
orcid.org/0000-0003-2522-082X

Daniel Rzeczkowski
University of Warmia and Mazury in Olsztyn, Poland
orcid.org/0000-0002-8458-5987

Firm ownership and size versus innovation activities over the business cycle: near-zero inertia as a sign of the transition from the fifth to the sixth Kondratieff wave

JEL Classification: *E32; L16, O33, Q55*

Keywords: *industrial processing enterprises; goals of innovative activity; business cycle; technological revolution; Kondratieff waves*

Abstract

Research background: The innovation activity of Polish industrial processing enterprises is examined in a broader time context than typical business cycle frames, which makes it possible to look at the investigated problems from the perspective of Kondratieff waves.
Purpose of the article: The aim of the research is to describe the combined effect of mutual interactions between the ownership and size of Polish industrial processing enterprises on the goals of innovative activity and their degree of importance for the further development of the innovativeness of those firms. These relations are examined in various phases of the business cycle. Additionally, taking secular changes into account made it possible to lend credence to the claim that the global financial crisis is a typical phenomenon for the breakthrough period between two Kondratieff waves.
Methods: A characteristic feature of the applied method is the focus on the combined effect of the enterprise type and ownership structure on firms' innovation over three periods: prosperity 2004–2006, crisis 2008–2010 and recovery 2012–2014. As regards statistical techniques, the

Pearson's χ^2 independence test and correspondence analysis were applied. The results of the research are presented in a graphic form in three- and two-dimensional correspondence maps, which indicate the co-occurrence of (1) ownership sectors and enterprise types taken together, and (2) effects (goals) of the innovative activity of enterprises, together with the degree of their influence (importance) for further innovative activity. Mutual interactions between ownership sectors and enterprise types were visually analysed, indicating significant features of the triangles representing them.

Findings & Value added: A significant combined effect of the ownership sectors and enterprise types on firms' innovative activity was found. There was a certain type of dynamic equilibrium between those variables, which changes depending on the business cycle phase. In the global financial crisis of 2008–2010, a surprising phenomenon was found, consisting of the growth of innovative activity in most enterprises as compared to the period of prosperity in 2004–2006. The enterprises achieved the goals assumed, and the degree of their importance proved the significant influence on further innovative activity of those firms. Additionally, it was demonstrated that in the period of recovery (2012–2014) mutual interactions between ownership and size eliminated the relationship between those variables and the goals of innovative activity, and eco-innovations proved to be directly subordinated to traditional types of innovations, mainly product and process innovations. Changes occurring in the last of the examined periods are related to the near-zero inertia of the entire industrial processing section, which allows to interpret the global financial crisis as a typical phenomenon for a breakthrough marking the end of one Kondratieff wave and the beginning of the next. Moreover, 2015 is identified as the year of breakthrough, ending the Fifth and beginning the Sixth Kondratieff Wave, which was related to the transition from the information and telecommunications revolution to the biomedical-hydrogen revolution. The calculations presented in this paper are consistent with those forecasts.

Introduction

Ownership structure and the size of the enterprise belong to the most important factors determining the level of its innovation activity. On the one hand, innovations are the driving force behind economic growth, while on the other they disturb the macroeconomic equilibrium and induce the cyclical fluctuations. The inverse relationship between the business cycle and innovations is also true. In the opinion of Schumpeter (1939, pp. 86–87, 138–143) innovations are outstanding facts in the history of capitalism and are found in the centre of almost all economic and social phenomena. Economic development is a cyclic process composed of two basic phases, prosperity and recession, the duration of which largely depends on individual features of a given innovation.

Extended literature studies, which are not discussed here fully due to the lack of space, led to the identification of three research gaps and this article is an attempt to fill them in. The identified gaps concern the following issues: (1) the effect of mutual interaction of the ownership and type (size) of enterprises on their effects or objectives of innovative activity, (2) extending the time frames of the analysis outside the periods related to business cycles, to include both phenomena characteristic for individual phases of the business cycle, and secular changes occurring in periods lasting several

decades, as well as (3) looking at the examined phenomenon from the cybernetic point of view and including positive feedback loops concerning the effects (objectives) of innovative activity and the degree of their influence (importance) on innovations in the future.

The first gap is of a methodological nature and results from the assumed method of examining the effect of independent variables on the innovativeness of enterprises. The ownership and size of the firm are usually treated as independent variables, and their effect on the innovation of enterprises is described separately. This paper applies another approach, consisting of grasping their simultaneous, combined effect on innovative activity.

The second gap is related to the assumed periods of analysis of the innovation of firms. Typically, in such cases, investigated time frames are not longer than the periods of economic cycles; however, this approach leads to omission of secular changes occurring in periods lasting several decades. Innovations are related to technological revolutions and the Kondratieff waves distinguished on their basis, which last between 48 and 60 years (Kondratieff, 1935, p. 112). Their long-term nature is conditioned by the need for relevant technological progress to be completed. Each wave must consist of two phases: an innovation phase and an application phase (Šmihula, 2009). The innovation phase covers the period in which inventions are gaining increased practical applications, which initiates a new technological revolution. Next, the application phase emerges, including the period of improvement of a new technology, which lasts until the rate of profit from the innovative industry branch drops to the level typical of traditional industries. In the second phase, innovations become common and generally accessible. A given technology has reached the limits of its development, and the emergence of a new technology is needed to overcome the impasse. A typical phenomenon between the end of one and the beginning of the next Kondratieff wave is an economic crisis, related to stagnation and increased demand for new inventions and technologies. The decreasing (in time) inertia of Polish enterprises in the industrial processing section, and independence of the objectives of innovative activity from the total effect of ownership and firm size in the period of 2012–2014, indicates that the global financial crisis of 2008–2010 is related to the end of the Fifth and the beginning of the Sixth Kondratieff Wave, i.e. a transition from the information and telecommunications revolution to the biomedical-hydrogen revolution. It is also very probable that the industrial processing enterprises in Poland are subject to the Red Queen effect, which means their participation in the zero-sum game.

The third gap consists of the absence of research concerning (1) the effects of innovative activity in 2004–2006 and four degrees of influence

exerted by innovations introduced by enterprises in these years on the activity of enterprises at the end of 2006 as well as (2) the goals of innovation activity in the period of 2008–2010 and four degrees of their importance for innovative activity as regards product or process innovation in those years. Information on positive feedback loops appear in statistical questionnaires PNT-02, used to collect empirical data in the two above-mentioned periods, while in 2012–2014 this problem does not occur. In the last period, only four degrees of importance of the nine factors driving companies to implement eco-innovations appear, but this issue was not examined due to the near-zero inertia of the entire industrial processing section (almost all firms, regardless the ownership sector or type, implemented eco-innovations).

The further part of the paper consists of the following sections: literature review, research methodology, results, discussion, conclusions and references. The section devoted to the literature review, which obviously had to be reduced to the most important items, includes an evaluation of the research concerning the impact of the size and ownership on the assumed objectives of innovative activity. The methodology section explains the basic terms and the issue of mutual interactions between ownership sectors and types of enterprises, as well as discusses the statistical methods applied. The next part presents the results of the research divided into three periods. The section devoted to the discussion contains a summary of the findings and their comparison to the current state of knowledge. The part containing conclusions explains the significance of new findings for the present economic theory and practice. The paper ends with a list of literature references.

Literature review

The ownership sector and the type of enterprise have a significant effect on the innovative activity of companies. Their importance was observed by Schumpeter, who treated innovations as a driving force for the economy. In his opinion, the innovative activity of enterprises threw the economy out of balance and was the main cause of the business cycle. He believed that the basic task of an entrepreneur was to search for new combinations of productive means, significantly differing from those existing so far. Schumpeter (1949, pp. 65–66) understood new combinations of materials and forces to be the ones that emerged discontinuously and were not the result of improving previously existing combinations. They included five following cases: introducing a new product in the market, creating new production methods, opening new markets, acquiring a new source of raw materials or

semi-manufactured goods, and introducing new organisation of any industry. The entrepreneur was, therefore, identified with an innovator. Schumpeter (1942, pp. 81–82; 1949, pp. 66–67) believed that in a competitive economy, new enterprises — which do not have to be large — are carriers of innovation. In such conditions, new enterprises are not formed from the old ones but operate beside them. He illustrated this with a vivid example, claiming that it was not owners of stagecoaches who built railways. However, the emergence of large corporations reduces the competitiveness of the economy and makes them more innovative, since the introduction of new combinations is already an internal matter of the economic organisation itself. As regards the issue of ownership, he claimed that its high importance for innovation results from the privilege to use it either for direct realization of a new combination, or exchange for necessary goods and services. He also claimed that the capitalist process de-materialises ownership, which deprives it of its basic functions it should perform in business. Thus, the production process lacks its most significant feature, which is moral allegiance. Replacing factory walls and machines with a mere parcel of shares means deprivation of the material substance of property, thus causing the holder of the title to lose the legal right of the possibility to deal with his property at his own discretion. Consequently, he loses the will to fight economically, physically and politically for "his" factory and control over it, thus also the ability to die, if necessary, on its stairs. This affects not only the attitude of holders but also the attitude of the workmen and the general public. Finally, there will be nobody left to care about ownership, both within large corporations and outside them (Schumpeter, 1942, pp. 141–142; 1949, pp. 68–69). To sum up, Schumpeter demonstrates that ownership and size of the business are the most important, crucial factors determining the innovative activity of entrepreneurs, without which the economic growth would not be possible. Therefore, they must be considered jointly.

In studies of the changes of the innovative activity of enterprises depending on their ownership sector and size, the approach consisting in the separation of the impact of these variables prevails (Abazi-Alili, 2014; Aggarwal, 2018; Decker & Günther, 2017; Dzikowski, 2013, 2014; Ortega-Argilés *et al*., 2005). This results in omitting their mutual interactions which also affect the examined phenomenon (Bitler *et al*., 2005). Nevertheless, the literature relatively often implicitly demonstrates the existence of mutual relations between the system of ownership and the size of the firm, and the effect of those interactions on innovation (Balsarı *et al*., 2015; Brossard *et al*., 2013; Falk, 2008; Minetti *et al*., 2015).

The explicit recognition of the effect of the ownership sector and enterprise type jointly on innovation is less frequently found in literature. Such an approach was applied for examining Chinese enterprises (Huang *et al*., 2017). The research indicates that state-owned enterprises are as innovative as private firms. This is most probably one of the effects of most Chinese government-owned corporations adopting a 'modern enterprise system', which consists of carrying out corporate or shareholding reforms and assuming a sound corporate structure. In state enterprises, such institutions as boards of shareholders, directors, supervisors and managers were established. The innovative activity of Chinese public and private firms is more or less at the same level, and discrepancies mostly concern the innovation diversification. State enterprises in comparison with private enterprises have greater achievements in the field of process innovation and lower achievements as regards other types of innovations (product, organisational and marketing innovations). The advantage of state enterprises over private enterprises as regards process innovations decreases along with an increase in enterprise size. This is caused, on the one hand, by growing management cost, and on the other, by problems with reducing production costs when the number of workers is growing. State enterprises can simply care more for the welfare of employers than private enterprises. Taking into account the joint effect of the ownership sector and the enterprise size indicates that state-owned enterprises and foreign firms can have a relative advantage as regards various types of innovation, but it significantly depends on the type (size) of an enterprise. It was also found that the effect of interaction between the ownership and the size of business on innovative activity of public and private firms depends on the geographical region in which they conduct their activity, as well as on the industry branch.

Succurro and Costanzo (2019) investigate the firm-level heterogeneity in patent propensity by studying the relationship between ownership structure and patenting activity in Italian manufacturing firms from 2006 to 2013. Their empirical results show that ownership concentration increases the probability of successful patent applications, but at decreasing returns to scale. Moreover, Rehman (2017) analyses the self-selection (SS) and learning-by-exporting (LBE) hypothesis by using firm-level data on 29 countries from Eurasia and Central and Eastern European (CEE) firms. According to the results of this paper, foreign-owned firms are more productive and innovative, and have a greater tendency to export than domestic firms, because they are superior in terms of technology and management capabilities.

The literature review proves the existence of three important research gaps. The first one consists in the fact that the combined effect of the own-

ership structure and business size on the innovation activity of enterprises was not taken into account in previous studies. This may lead to the omission of important economic relations. This paper takes up this challenge and focuses on grasping the effect of mutual interaction of the business ownership and size on innovative activity of Polish industrial processing firms in various phases of the business cycle. The second gap is related to the several decades-long period of development and course of phenomena related to innovation, indicated in the introduction and often omitted in studies on innovation. Those problems will be discussed in the further parts of the paper. The third gap is related to positive feedback loops concerning present innovations and four degrees of their influence on innovations in the future.

Research methodology

This paper applies a method which takes into account not only the simultaneous effect of ownership sectors and types of firms but also their mutual interactions on the innovative activity of enterprises. Such an approach results from the fact that the number of enterprises belonging to individual ownership sectors, i.e. public S1, private S2 and mixed S3, equals the sum of enterprises belonging to individual types of enterprises, i.e. small FR_1, medium FR_2 and large FR_3. The basic balance equation of the industrial processing section then takes the following form:

$$\sum_{i=1}^{N} Ownership\ sectors = \sum_{i=1}^{N} Types\ \ of\ enterprises, \qquad (1)$$

where N is the number of enterprises in the industrial processing section. They can be also presented in a more detailed form, which will be used in this paper:

$$\begin{gathered} \sum_{i=1}^{N1} S1 + \sum_{i=1}^{N2} S2 + \sum_{i=1}^{N3} S3 \ = \ \sum_{i=1}^{N4} FR\_1 + \sum_{i=1}^{N5} FR\_2 + \sum_{i=1}^{N6} FR\_3\,, \\ N1 + N2 + N3 \ = \ N \ = \ N4 + N5 + N6\,, \end{gathered} \qquad (2)$$

where symbols $N1$, $N2$, and $N3$ denote, respectively, the numbers of enterprises in the public S1, the private S2 and the mixed S3 sectors, while $N4$, $N5$, and $N6$ are, respectively, the numbers of small FR_1, medium FR_2 and large FR_3 enterprises. This equation shows the occurrence of mutual interaction between ownership sectors and types of enterprises. Changes on one side of the equation, representing ownership sectors, must be compen-

sated by changes on the other side of the equation responsible for the types of enterprises. Because each side of this equation describes a different type of structure in the industrial processing section, this relationship must not only be quantitative, but also qualitative. This paper examines the effect of mutual interactions between those two types of industrial structures on the innovative activity of enterprises, which — using mathematical formalism — can be presented as follows:

$$\left.\begin{array}{c}\boxed{Ownership\ sectors} \\ \downarrow \quad \uparrow \\ \boxed{Types\ of\ enterprises}\end{array}\right\} \Rightarrow \boxed{Innovation\ activities\ of\ firms}.$$

The paper applies the enterprise typology compliant with the European Union standards. Three types of enterprises, small, medium and large, were identified based on such criteria as the number of employees and annual turnover or annual balance sheet total (Commission Regulation (EU) No. 651/2014). Available databases do not include micro-enterprises, perhaps due to the fact that they have at their disposal scarce means of production (resources). Additionally, as it has been already mentioned, three ownership sectors are investigated: public, private and mixed.

The calculations are based on three databases containing information on innovative industrial processing enterprises in Poland. The first one covers the years of prosperity 2004–2006 and contains 10,149 enterprises, the second one concerns the period of the global financial crisis 2008–2010 and describes data of 20,655 enterprises, while the third one refers to the recovery years of 2012–2014 and includes 10,244 enterprises. Data was collected by the Statistical Office in Szczecin using statistical forms PNT-02 relevant for each period. As regards the effects (goals) of the innovation activity of enterprises and related feedback loops, they did not change substantially, which ensured the comparability of data from all periods. Consequently, the results of a comparative analysis could be referred to the current state of knowledge in the field of innovation and placed both in time frames suitable for business cycles and in decades-long periods taking into account secular changes.

Tables 1–3 present the characteristics of enterprise types and ownership sectors in percentage terms, in three periods under examination, i.e. 2004–2006, 2008–2010 and 2012–2014. Each table includes both the share of individual enterprises types in ownership sectors and the share of individual ownership sectors in enterprise types. According to the assumed method for coding variables, small, medium and large enterprises were marked with

symbols FR_1, FR_2, and FR_3, respectively, while ownership sectors, public, private and mixed, are represented by symbols S1, S2 and S3, respectively.

The tables should be read as follows. The Type column contains the percentage share of a given type of enterprises in individual ownership sectors. Looking at Table 1, it can be seen that in the first period, large enterprises (FR_3) accounted for 8.28% of the public sector (S1), 76.61% of the private sector (S2) and 15.11% of the mixed sector (S3). The Subtotal (FR) row contains the percentage shares of individual types of enterprises in the total number of enterprises. Therefore, in 2004–2006, small enterprises accounted for 30.06%, medium — 55.66%, and large 14.28% of the total number of enterprises. On the other hand, the Sector column presents the share of a given ownership sector in individual types of enterprises, while it should be read horizontally, taking into account every second cell of a given row. Examining the Private (S2) row, it can be seen that the private sector consisted of 27.58% small enterprises, 58.64% medium enterprises and 13.78% large enterprises. As for the Subtotal (S) column, it contains shares of enterprises from a given ownership sector in the total number of enterprises. Looking again at Table 1, it can be noted that in the first period, the public sector (S1) accounted for 4.37%, the private sector (S2) — 79.39%, and the mixed sector (S3) — 16.24% of the total number of the examined enterprises. Tables 2 and 3 should be read in the same way. Generally, information included in individual tables concerns the role and the importance of individual types and ownership sectors of enterprises in the entire section of industrial processing. Thus, they are indispensable for interpretation of the biplots showing the co-occurrence of points representing types and ownership sectors of enterprises and points denoting the effects (goals) of innovative activity.

In the research presented here, ownership sectors and enterprise types are grouping variables. This is due to the fact, repeatedly emphasized by Schumpeter, that these variables and the interrelations between them are important factors determining the effects and objectives of the innovative activity of firms. This ensures sorting the data into categories or groups with a clear economic sense.

Two statistical methods were used for calculations: Pearson's χ^2 test for independence and correspondence analysis. The test for independence was used to examine the relationship between two nominal variables, and the test value was examined with the use of χ^2 statistics. It consists in comparison of empirical values resulting from the studies with expected values assuming the lack of a relationship between variables. A statistically significant difference between those values indicates the existence of a depend-

ency between variables (McHugh, 2013). Correspondence analysis is a multi-dimensional statistical method used to examine the co-occurrence of phenomena (Beh & Lombardo, 2014; Glynn, 2014; Greenacre, 2007; Nenadić & Greenacre, 2007). It consists in the reduction of the dimension of the examined issue, which means reproduction of the distance between points representing rows and columns of the contingency table in a space with a lower number of dimensions. Contingency tables contain certain measures which describe relations between rows and columns. The calculation method provides as much information about the differentiation of rows and columns as possible. As a result of applying this method, we receive two- or three-dimensional correspondence maps referred to as biplots, graphically presenting the relations between categorical variables. The research carried out applied row and column profile standardization, which means a simultaneous analysis of points representing row profiles and column profiles. The analysis of points representing individual variables is carried out based on the χ^2 metric, i.e. the weighted Euclidean distance. Inertia emerging during the calculations is a measure of dispersion of row profiles and column profiles around their average profiles.

The research tests the following types of null hypotheses:

1) the type and ownership sector of enterprises have no influence on the effects of their innovative activity and degrees of influence of innovations introduced by enterprises in 2004–2006 on the activity of enterprises at the end of 2006;
2) the type and ownership sector of enterprises have no effect on the goals of innovation activity and degrees of importance for innovation activities of enterprises as regards product or process innovation in 2008–2010;
3) the type and ownership sector of enterprises have no effect on the goals of innovation activity;
4) the type and ownership sector of enterprises have no effect on the activity of firms as regards eco-innovation;
5) the type and ownership sector of enterprises have no effect on the goals of innovation activity, taking into account eco-innovations as supplementary points.

The first hypothesis concerns the prosperity period (2004–2006), the second one refers to the global financial crisis (2008–2010), while all three other hypotheses were used to examine the recovery period (2012–2014). Each of the above null hypotheses on independence of variables forms a pair with a corresponding alternative hypothesis. Comparison of the *p*-value with the significance level determines which of them is to be accepted.

Results

Analysis in the period of 2004–2006

This was a period of prosperity for the Polish economy. The existence of relationships between (1) enterprise types and ownership sectors and (2) effects of innovative activity and degrees of influence of innovations introduced by enterprises in 2004–2006 on the activity of enterprises at the end of 2006 was confirmed with Pearson's χ^2 test of independence (Jakimowicz & Rzeczkowski, 2019b). The next stage of the research consisted of applying the correspondence analysis in order to specify the relationships between the examined variables. As a result, the biplots showing the co-occurrence of phenomena were obtained. Table 1 features two grouping variables in the form of enterprise types and ownership sectors, which jointly can take nine states. On the other hand, Table 4 shows nine variables describing the effects of innovative activity of enterprises, and each of them can take four states. The effects of innovative activity can affect the operation of enterprises to a high, medium or low degree, or they can be irrelevant. Consequently, the study includes eleven variables in total, which can take forty-five states.

The 3D biplot in Figure 1 presents a visualisation of the co-occurrence of points representing types and ownership sectors of enterprises marked with blue circles and points indicating the effects of innovative activity and the degree of their influence on the operation of enterprises, marked with red squares. In three dimensions, it was possible to reproduce 77.77% inertia, thus the general value of χ^2 statistics. This is a satisfactory result, as it allows for relatively precise reflection of relations included in the initial data. The system of variable coding is consistent with Tables 1 and 4. For grouping variables (enterprise types and ownership sectors), the first part of the code denotes the ownership sector, while the other part is the symbol for the enterprise type. Consequently, a small enterprise in the private sector is represented by the variable S2FR_1.

The 3D biplot in Figure 1 is a general representation of relationships between variables, and precise determination of co-occurrence of individual variables requires a simultaneous analysis of its tree two-dimensional cross-sections, as presented in Figure 2–4. However, despite its general nature, the 3D biplot allows us to see the first interesting phenomenon, which consists of a relatively significant distance between points representing all enterprises belonging to the public sector S1, therefore small S1FR_1, medium S1FR_2 and large enterprises S1FR_3, and points representing the effects of the innovative activity of enterprises and the degrees of their

influence on enterprises' activity. Even at this stage of analysis, it can be concluded that all public sector enterprises, regardless of their size, lead innovative activity on a small scale compared to all other enterprises in the 2004–2006 database.

Figures 2–4 present three two-dimensional biplots as cross-sections of the 3D biplot in Figure 1 performed for each dimension. Aspects taken into account included the co-occurrence of enterprise types related to ownership sectors and types of effects resulting from innovative activities, together with the degrees of their influence on enterprises. Since the analysis is conducted both from the perspective of the enterprise types and ownership sectors, it is necessary to isolate those two variables and their states. Ownership sectors are indicated by hatched black triangles so that the names of their vertices contain the same first part of the code for the sector-enterprise, i.e. symbols S1 (public), S2 (private), or S3 (mixed). Consequently, the private sector S2 forms a hatched black triangle with vertices S2FR_1, S2FR_2 and S2FR_3, as it is composed of all three types of enterprises: small FR_1, medium FR_2 and large FR_3. The same principle applies to other ownership sectors. On the other hand, types of enterprises were marked with full-colour triangles in a similar way, the difference being that names of their vertices contain the same second part of the code for the sector-enterprise, i.e. the symbols FR_1, FR_2 and FR_3. The type of small enterprises FR_1 is represented by a yellow triangle, the type of medium enterprises FR_2 is marked with a pink triangle, and large enterprises FR_3 are represented by a light blue triangle. Consequently, the type of small enterprises is described by a yellow triangle with vertices S1FR_1, S2FR_1 and S3FR_1, since it contains enterprises belonging to all three sectors: S1, S2 or S3. The same yellow triangle can be seen on all three 2D biplots in Figures 2–4 although, in each of them, it is observed from another point of view. This principle applies to the other types of enterprises, i.e. a pink triangle representing medium firms (FR_2) and a light blue triangle assigned to large firms (FR_3).

As previously mentioned, a precise description of relationships concerning the co-occurrence of variables requires a simultaneous analysis of all three two-dimensional biplots in Figures 2–4. The public sector (S1) presents the most stretched hatched black triangle, since points representing small, medium and large enterprises from this sector, marked, respectively, with S1FR_1, S1FR_2 and S1FR_3 points, are relatively isolated and situated near the edges of the plots. As can easily be seen, those points are located outside the cluster of red squares. It means that the innovative activity of enterprises from this sector was low, and even if they reached any innovation-related effects, the degree of their influence on the operation of

those enterprises was low or irrelevant. Black hatched triangles representing the private sector (S2) and the mixed sector (S3) have significantly smaller areas than the triangle corresponding to the public sector (S1) and their vertices are usually situated near the points related to the effects of innovative activity and significant degrees of their influence. This proves the high innovative activity of enterprises belonging to the private and the mixed sector, as well as the significant impact of the innovation-related effects on the operation of these firms. However, another phenomenon also occurs here, which proves the relatively low innovative potential of small enterprises. The triangle representing the private sector (S2) has the S2FR_1 vertex shifted towards the area where the degrees of influence of innovations carried out by enterprises on the operation of those enterprises are low or irrelevant. The same applies to the mixed sector (S3), where point S3FR_1 demonstrates similar properties. This means that type of small enterprises provide relatively low innovative activity, which results from its low level of factors of production, i.e. capital and labour.

As results from the detailed analysis of three 2D biplots (Figures 2–4) in the private sector (S2), large enterprises FR_3 were highly influenced by the effects of increasing the product assortment (E1_1), entering into new markets or increasing the existing market share (E2_1) and reducing consumption of materials and energy per unit of product (E7_1). In turn, large enterprises (FR_3) from the mixed sector S3 experienced, to a high degree, the effects of reducing consumption of materials and energy per unit of product (E7_1) and reducing harmfulness to the environment and improvement of work safety (E8_1).

Let us now examine the location of full-colour triangles representing enterprise types. The yellow triangle, representing the type of small enterprises, making up a part of all ownership sectors, has its S1FR_1 vertex shifted towards the external edges of the plots, which is clearly observed in all 2D biplots (Figures 2–4). Vertices of pink and light blue triangles are similarly shifted, thus points S1FR_2 and S1FR_3, which represent the type of medium and large enterprises, respectively. Therefore, enterprises in the public sector, regardless of their size, distort full-colour triangles representing enterprise types: yellow (FR_1), pink (FR_2) and light blue (FR_3), so that they move away one of their vertices from the area of strong influence (i.e. high and medium degree) of the effects resulting from innovative activity. As follows from Table 1, the public sector represents only 4.37% of all enterprises, which would indicate its low importance in the section of industrial processing; nevertheless, it changes the geometry of triangles responsible for the types of enterprises, i.e. yellow (FR_1), pink (FR_2) and

light blue (FR_3), which means that its impact on this section is quite important.

To summarise, it can be observed that the relative isolation of points representing small, medium and large enterprises from the public sectors, marked, respectively, with the symbols S1FR_1, S1FR_2 and S1FR_3, extends the yellow, the pink and the light blue triangles which correspond to those types. As regards other types of enterprises, in medium enterprises the best situation is observed for enterprises in the private sector, due to a relatively small distance between point S2FR_2 and points E1_2, E2_2, E8_2 and E9_2. A good situation is observed for large enterprises from the private and the mixed sector, which is expressed by a relatively small distance between point S2FR_3 and points E1_1 and E9_1 and a small distance between point S3FR_3 and points E7_1 and E8_1.

As results from the relationships presented in Figures 2–4, an interaction exists between ownership sectors in the form of hatched black triangles and enterprise types, represented by full-colour triangles. A triangle representing a given ownership sector has no common points with triangles representing two other ownership sectors, just like a triangle corresponding to a given type of enterprises has no common points with triangles corresponding to two other types of enterprises. The effect of a given ownership sector on another ownership sector is exerted through triangles representing enterprise types, and the effect of a selected type of enterprises on another type of enterprises requires the agency of triangles related to ownership sectors.

For proper interpretation of results, it is very important to simultaneously analyse the biplots presented in Figures 2–4. In Figure 2, it can be observed that the left side of the biplot mostly shows points related to the effects of innovative activity affecting enterprises to a high and medium degree, whereas on the right side there are mainly points representing effects influencing enterprises to a low or irrelevant degree. Taking into account small enterprises from the public sector S1FR_1, it is possible to come to the erroneous conclusion that the effects of improving production flexibility (4_1), increasing production capacity (E5_1) and reducing labour costs per unit of product (E6_1) demonstrated a high degree of influence on those enterprises. This would be indicated by the low distance between points E4_1, E5_1 and E6_1 and point S1FR_1. However, this is an illusion, as it is not confirmed in the biplots in Figures 3 and 4.

Analysis in the period of 2008–2010

In this period, the global financial crisis emerged, whose effect on the innovative activity of Polish industrial processing enterprises is the subject of the research. The existence of the relation between (1) enterprise types and ownership sectors and (2) goals of innovative activity and their degrees of importance for innovative activity of enterprises as regards product or process innovation in 2008–2010 was confirmed with the χ^2 test of independence (Jakimowicz & Rzeczkowski, 2019b). Specifying the relationships between examined variables required the application of correspondence analysis. Table 2 presents the percentage list of types and ownership sectors of enterprises, while Table 5 presents variables describing the goals of innovative activity, each of them able to take four states. Since two grouping variables occur in nine states, and ten variables describing the goals of innovative activity can take forty states, the study involves in total 12 variables assuming 49 states.

Figure 5 presents a 3D biplot describing the co-occurrence between the examined variables and their states, while Figures 6–8 demonstrate three of its two-dimensional cross-sections; therefore, one cross-section was performed for each of the selected dimensions. Determinations of ownership sectors and enterprise types did not change, ownership sectors still form three hatched black triangles, while enterprise types are marked with three full-colour triangles: yellow (FR_1), pink (FR_2) and light blue (FR_3). Vertices of triangles representing types and ownership sectors of enterprises are marked with blue circles, and the goals of innovative activity and the degrees of their importance for the innovative activity of enterprises are marked with red squares. It should be emphasized that the formal system of variable marking was changed in comparison to the previous period of analysis, as in 2008–2010, the PNT-02 statistical questionnaire used for collecting empirical data concerning innovative activity of enterprises was changed. As a result, the symbols of variables presented in Table 5 differ from those applied in Table 4.

Taking into account Figure 5, it should be noted that in three dimensions it was possible to reproduce 85.833% inertia, therefore the total value of χ^2 statistics, which indicates a very good representation of initial data. Despite its general nature, Figure 5 leads to the first significant observation made in the period of the global financial crisis, i.e. a significant distance between points S1FR_1 and S1FR_2, representing small and medium enterprises from the public sector, and red squares symbolising the goals of innovative activity and the degree of their importance. Precise examination of this

phenomenon requires a simultaneous analysis of three two-dimensional biplots (Figures 6–8).

At the beginning, let us examine the public sector S1, represented by the largest hatched black triangle shown in biplots in Figures 6–8. It is clearly stretched towards the edge of the plot by points S1FR_1 and S1FR_2, therefore outside the area including red squares representing the goals of innovative activity and degrees of their importance. Taking into account the scale of the plots, in biplots in Figure 6–8 the distances between points S1FR_1 and S1FR_2 and red squares are much larger than in the biplots in Figures 2–4. This means that during the global financial crisis, the situation of small and medium enterprises in the public sector deteriorated as regards reaching the goals of innovative activity. Additionally, the degrees of importance of those goals for further activity of the discussed firms significantly decreased.

A reduction in innovative activity of enterprises S1FR_1 and S1FR_2 not only extended the sizes of the hatched black triangle representing the public sector S1 but also stretched towards external edges of plots triangles yellow and pink, corresponding to the types of small and medium enterprises, respectively (Figures 6–8). According to Table 2, small enterprises from the public sector accounted for 0.38% of all small enterprises, and relevant shares for small enterprises in the private and mixed sectors in the entire set of enterprises of this type accounted for 73.82% and 25.80%, respectively. At the same time, the public sector had 21.31% small enterprises, 48.77% medium enterprises and 29.92% large enterprises. Additionally, small enterprises accounted for 66.81% of all surveyed enterprises, and the public sector alone formed 1.18% of the whole set of those enterprises. This demonstrates that the role of the public sector in the industrial processing section should be insignificant, which especially applies to small enterprises belonging to this sector. Similar conclusions could be formulated with regard to medium enterprises from the public sector. According to Table 2, medium enterprises from the public sector accounted for 2.17% of all examined medium enterprises, and relevant shares for medium enterprises in the private and mixed sectors in the entire set of enterprises of this type accounted for 78.89% and 18.94%, respectively. However, the mutual links between ownership sectors and types of enterprises should also be taken into account.

As previously mentioned, relationships between ownership sectors and types of enterprises exist. Hatched black triangles representing individual ownership sectors have no common vertices, just like full-colour triangles symbolising the types of enterprises. However, each ownership sector is composed of three points, which are at the same time points belonging to

three different triangles indicating types of enterprises. In addition, each type of enterprises is composed of three points, which are at the same time vertices of three different ownership sectors. These relationships describe the propagation paths of interactions between ownership sectors and types of enterprises. From this perspective, the phenomenon of extending the yellow and pink triangles by points S1FR_1 and S1FR_2, corresponding to, respectively, the type of small and medium enterprises in the public sector, seems to be important. In this way, these triangles leave the region of impact of red squares denoting goals of the innovation activity and the degrees of their importance for further operation of enterprises. It seems that small and medium enterprises from the public sector can have an unfavourable effect on small and medium enterprises from other ownership sectors. Following the same principle, the public sector, through full-colour triangles representing types of enterprises, can send to other ownership sectors stimuli that are unfavourable for conducting innovative activity. Unsatisfactory innovative activity of small and medium enterprises from the public sector can provide a bad example for all other enterprises in the industrial processing section, and thus be contrary the principle of sustainable economic growth and development of all ownership sectors and types of enterprises.

To summarise, it follows from Figures 6–8 that reduction of innovative activity in small and medium enterprises from the public sector affects the location of the yellow and the pink triangle, related to these types of enterprises. The highest reduction in innovative activity was recorded by S1FR_1 enterprises. Therefore, the yellow triangle is partially located in this area where the degree of importance of goals of innovative activity for further innovative operation of the enterprise as regards product or process innovations is low or irrelevant. Because of its location, two hatched black triangles representing ownership sectors, private S2 and mixed S3, are stretched. Nevertheless, enterprises from these sectors, regardless of their types, carried out innovative activity at a quite high level, and it was the source of further product and process innovations.

When evaluating the effect of the global financial crisis on the innovative activity of Polish enterprises in the industrial processing section, it should be noted that it was relatively low. Although it slightly deteriorated the situation of small and medium enterprises from the public sector, it should be remembered that this situation already was not good in 2004–2006, i.e. in the prosperity period. As it was mentioned above, this deterioration had a certain effect on other ownership sectors, private and mixed. However, it seems that the situation of most industrial processing enterprises in the time of crisis was better than before the crisis. Large enterprises

from the public sector S1FR_3 even recorded improvement. Almost all firms, apart from enterprises S1FR_1 and S1FR_2, implemented the assumed goals of innovative activity G1–G10, and the degrees of their importance were usually high or medium. Hatched black triangles representing ownership sectors private S2 and mixed S3, and pink and light blue triangles corresponding, respectively, to the types of medium and large enterprises have at least two vertices situated very close to the cluster of red squares. A very good position is taken by a light blue triangle representing large enterprises, as it is situated in the area where degrees of importance of innovative activity goals are high. Additionally, this triangle is much lower than in the previous period, which proves the effective implementation of similar innovation strategies by large enterprises.

Attention should also be paid to another phenomenon, which did not occur in the previous period. Blue circles, corresponding to enterprise types and ownership sectors, and red squares, representing goals of innovative activity and high or medium degrees of their importance, create one compact cluster in a relatively small area of space. The highest concentration of both types of points occurs near the origin of the coordinate system. This leads to the paradoxical conclusion that the global financial crisis contributed to the intensification of the innovative activity of Polish enterprises in the industrial processing section. Most enterprises implemented assumed goals of innovative activity, which to a high or medium degree affected their further innovation activity as regards product and process innovations in the examined period.

It is quite difficult to accept the view that we owe an improvement of the situation to the global financial crisis. The possibility that seems to be more probable is that the crisis was only a catalyst of changes, which contributed to an increase in innovation activity of Polish enterprises. Dramatic information from global financial markets probably made Polish enterprises prepare for unfavourable changes beforehand, i.e. search for the solution by intensifying their innovative activity before the crisis. As it can be judged today, such activity has been proved correct.

Analysis in the period of 2012–2014

In this period in the Polish economy, the effects of the global financial crisis were slowly disappearing and recovery emerged. To maintain comparable results, it is required to confirm the existence of relationships between enterprise types and ownership sectors and the goals of their innovative activity in this period. With this aim in view, similar to studies concerning two previous periods, Pearson's χ^2 test of independence was applied. Inno-

vation types, goals of innovative activity of enterprises and their coding method are presented in Table 6.

In order to determine the relationships between enterprise types and ownership sectors and the goals of innovative activity, the statistical verification of the following hypotheses was carried out:

H_0: *The type and ownership sector of enterprises have no effect on the goals of innovative activity;*

H_1: *The type and ownership sector of enterprises have an effect on the goals of innovative activity.*

Table 7 presents the results of the null hypothesis verification. Because inequality $p = 0.99759 > \alpha = 0.05$ occurs in this case, there are no grounds to reject the null hypothesis. Thus the goals of innovative activity of an enterprise do not depend on its type and ownership sector. It should be emphasized that all twenty-two goals of innovative activity presented in Table 6 were taken into account. This is a quite unexpected and noteworthy difference in comparison to two previous periods. It can be interpreted as a further increase in investment activity by a large majority of enterprises, regardless of their type and ownership sector, which see the highest chances for development in these activities. Every firm wants to develop and be innovative, regardless of the ownership sector or its size.

In relation to the above results, it was decided to examine the role of eco-innovations alone in the innovative activity of enterprises, as this is a relatively new item in the examined period, which did not occur in 2004–2006 and 2008–2010. The PNT-02 questionnaires from those periods were simply not used for gathering information on eco-innovations. Determining relationships between types and ownership sectors of enterprises and their activity as regards eco-innovations requires statistical verification of the following hypotheses:

H_0: *The type and ownership sector of enterprises have no effect on the activity of a firm concerning eco-innovation;*

H_1: *The type and ownership sector of enterprises have an effect on the activity of a firm concerning eco-innovation.*

The results of null hypothesis verification are presented in Table 8. An inequality occurs here: $p < \alpha$, therefore the null hypothesis should be rejected for the benefit of an alternative hypothesis. This indicates the de-

pendence of the activity of enterprises in the area of eco-innovation on the type and ownership sector. In this case, the ten last goals of innovative activity listed in Table 6 were taken into account, namely ECO1–ECO10 variables. The result seems understandable, as each innovation enterprise was probably forced to develop one's own method to undertake a relatively new type of innovative activity, which was the case with eco-innovation. The type and ownership sector of the enterprise must have been here of high importance. The occurrence of this dependence is partially confirmed by our previous result, which consisted in demonstrating relationships between types of enterprises alone and the type of eco-innovations undertaken by them (Jakimowicz & Rzeczkowski, 2019a).

Since the second stage of research uses correspondence analysis, it was decided to test one more research hypothesis regarding the relationship between types and ownership sectors of enterprises and the goals of innovative activity as regards product, process, organisational and marketing innovations only, with eco-innovations as supplementary points in the correspondence analysis. With this aim in view, the following hypotheses were statistically verified:

H_0: *The type and ownership sector of enterprises have no effect on the goals of innovative activity, taking into account eco-innovations as supplementary points;*

H_1: *The type and ownership sector of enterprises have an effect on the goals of innovative activity, taking into account eco-innovations as supplementary points.*

The list of assumptions and calculations necessary to verify the null hypothesis is presented in Table 9. Here we deal with inequality $p = 0.96687 > \alpha = 0.05$, therefore there are no grounds to reject the null hypothesis. Thus, the goals of innovative activity as regards product, process, organization and marketing innovations, taking into account eco-innovations as supplementary points do not depend on enterprise types and ownership sectors. The test took into account the first twelve goals of innovative activity mentioned in Table 6. This result becomes understandable if we consider the relationship between eco-innovation and traditional types of innovation, mainly of the product and process types. Eco-innovations may simply be a factor accompanying product and process innovations. This is consistent with the results presented in Table 7, which contain calculations proving the lack of relations between types and ownership sectors

of enterprises and the goals of innovative activities, taking into account eco-innovation as a separate type of innovation.

The application of correspondence analysis makes it possible to gain a more detailed view of the obtained results. Comparison of the results from all three tests, proving subordination of eco-innovations to traditional types of innovations, particularly product and process innovations, indicates rich possibilities for applying correspondence analysis for detailed exploration of the third case, concerning independence of product, process, organisational and marketing innovations (taking into account eco-innovations as supplementary points) from types and ownership sectors of enterprises.

Table 10 presents the quantitative characteristics of the correspondence matrix. It contains the following items: singular values, eigenvalues, percent of inertia, accumulated percent of inertia, and χ^2-distances. This Table shows that the research problem is eight-dimensional, as only with eight dimensions is it possible to explain 100% of inertia, therefore the total value of the χ^2 statistic. Hence, dimension reduction is necessary, which is the idea behind the correspondence analysis. As it is not possible to include more than three dimensions for graphic representation of the phenomena of co-occurrence, this was chosen as the solution. Three dimensions explain 74.48% of the total inertia, which allows for a quite precise representation of initial data. The choice of a three-dimensional space to reproduce dependencies existing in empirical data was marked by applying bold font in the first three rows in Table 10. Additionally, attention should be paid to the *p*-value being equal to 0.96687. In this case a χ^2 test is used to verify the hypothesis claiming that the total inertia value is/is not significantly different than zero. It is not used here for determining model fit statistics or comparing models with different variables, but only for testing the inertia value against zero. Since it results from Table 10 that *p*-value is higher than the commonly accepted significance level, i.e. $p = 0.96687 > \alpha = 0.05$, the total inertia value is not significantly different than zero. Indeed, according to Table 10, the total inertia value equals 0.00593.

In correspondence analysis, the notion of inertia is the equivalent of the concept of variance commonly applied in statistics. Total inertia is the sum of the squares of eigenvalues and it is used as the measure for profiles dispersion around respective average profiles. Total inertia of rows describes the difference between respective row profiles and the average row profile. By analogy, the total inertia of columns determines the differences between respective column profiles and the average column profile. Inertia for rows is equal to inertia for columns. If total inertia did not significantly differ from zero, as in the examined case, the difference between profiles and the

average profile is low. This means low dispersion of profiles around the average profile. The lower the total inertia of the given system, the lower is the chance of emergence of a significant relationship between rows and columns of the contingency table. An average row profile is the result of dividing column sums in the contingency table by the grand total. In turn, dividing row sums in the contingency table by the grand total gives the average column profile. The average row profile is the average of the row profiles weighted by the marginal row frequencies, and the average column profile is the marginal frequency distribution over the sum of the columns (Sourial *et al*., 2010). Since the point representing the average row or column profile is situated in the centre of the system of coordinates, it is often referred to as a centroid. The average profile is, therefore, the centre of gravity of the analysed profiles. Consequently, as regards variables being the subject of the study, they should be concentrated in biplots near the origin of the coordinate system.

A three-dimensional map of correspondence from Figure 9 presents a visualisation of the co-occurrence of points representing enterprise types and sectors (blue circles), points corresponding to the goals of innovative activity of enterprises (red squares), and points related to eco-innovations (green rhombuses). Since it enables only a general view of the examined phenomena, Figures 10–12 present three two-dimensional biplots as cross-sections of the three-dimensional map (Figure 9) obtained for each of the dimensions.

Three two-dimensional biplots presented in Figures 10–12 confirm the information provided in Table 10. Points representing all examined variables are usually situated near the origin of the coordinate system. Blue points representing types and ownership sectors of enterprises, red squares concerning the goals of innovative activity and green rhombuses corresponding to eco-innovations create one great cluster, which indicates most enterprises achieving all the goals of innovative activity mentioned in Table 6. Nevertheless, stretching hatched black triangles, corresponding to ownership sectors, and full-colour triangles, representing types of enterprises, indicate the existence of certain exceptions. As regards ownership sectors, there are elongated triangles corresponding to the public sector S1 and the mixed sector S3. Responsible for this situation are points S1FR_1, S1FR_3 and S3FR_3, thus, respectively, small and large enterprises from the public sector and large enterprises from the mixed sector. The same points also result in stretching the yellow and the light blue triangles, which represent, respectively, the type of small and large enterprises. In addition, slight stretching can be observed with regard to the hatched black triangle corresponding to the private sector S2, by point S2FR_3 (Figures 11–12), i.e.

large enterprises of the private sector, which has a certain impact on the light blue triangle of large enterprises. Additionally, point S1FR_2, representing medium enterprises from the public sector, slightly extends the hatched black triangle representing the public sector S1, and the pink triangle corresponding to the type of medium enterprises.

After a detailed analysis, it can be assumed that point S1FR_2 satisfies the condition of the hypothesis confirmed above (Table 10) that total inertia value is not significantly different than zero. This point is situated relatively close to the origin of the three-dimensional coordinate system (Figures 9–12), where most points representing the goals of innovative activity and eco-innovations are situated. Since point MAR2 is situated the closest to point S1FR_2, it can, therefore, be assumed that medium enterprises from the public sector focused on marketing innovations related to the use of new media or product promotion techniques. A similar situation occurs for point S2FR_3, which is located near the average profile and quite close to points PRS2 and MAR1. This means that large enterprises from the private sector implemented new logistic processes (PRS2) and introduced significant changes in the design/construction or packaging of goods or services (MAR1).

Finally, it can be found that since points S1FR_1, S1FR_3 and S3FR_3 are the most remote from the centroid, they do not satisfy conditions provided in Table 10. These are small and large enterprises from the public sector S1 and large enterprises from the mixed sector S3. Table 3 provides information about the importance of those firms in the total number of industrial processing enterprises. Taking into account the public sector S1, its share in the entire industrial processing section was 1.10%. Small enterprises from the public sector accounted only for 0.56% of all small enterprises, and large enterprises from this sector accounted for 2.68% of all large enterprises. The share of small enterprises from the public sector in all enterprises of this sector amounted to 17.7%, and the respective share of large enterprises was 34.51%. On the other hand, large enterprises from the mixed sector S3 accounted for 34.92% of all large enterprises, and a share of large enterprises in the mixed sector accounted for 9.23%. Taking into account the numbers of the enterprises under analysis, i.e. S1FR_1 = 20, S1FR_3 = 39 and S3FR_3 = 507, and comparing them with the total number of firms in entire database equal to 10,244, it should be noted that these three exceptions have no significant effect on the total image of the industrial processing section in 2012–2014 (Jakimowicz & Rzeczkowski, 2019b). Thus, the conclusion concerning the total inertia of the system not being significantly different than zero should be considered correct.

Discussion

The paper examines the joint effect of enterprise types and ownership sectors on the goals (effects) of the innovation activities of Polish industrial processing enterprises. The analysis is based on data originating from three periods (2004–2006, 2008–2010 and 2012–2014). The data were gathered by the Statistical Office in Szczecin based on the statistical questionnaire PNT-02. The research applied Pearson's χ^2 test of independence which provided reliable information on relationships or their absence between variables, as well as a correspondence analysis, which made it possible to determine in detail the co-occurrence of phenomena. The results obtained with those two methods complement each other and are reliable since they satisfy relevant statistical significance criteria. The graphic presentation of results uses three-dimensional correspondence maps and their two-dimensional cross-sections. In all examined cases, a good representation of the initial data was obtained. In the period 2004–2006, 77.77% of total inertia could be reproduced and for the periods 2008–2010 and 2012–2014 those rates amount to 85.833% and 74.48%, respectively. Two-dimensional biplots, which are cross-sections of the three-dimensional maps made for each dimension, provide a detailed insight into the relationships between variables.

The evaluation of the impact of enterprise types and ownership sectors on the goals (effects) of innovative activity used an original method for a comprehensive approach to the co-occurrence of phenomena, which has never been presented before. Points representing types and ownership sectors of enterprises (blue circles) were combined in such a manner as to take account mutual interactions between types and sectors. In this way, a hatched black triangle was created, which represented ownership sectors: public S1, private S2 and mixed S3, and full-colour triangles: yellow, pink and light blue, which represented types of small FR_1, medium FR_2 and large FR_3 enterprises, respectively.

In each studied period, the influence of types and ownership sector of enterprises on the goals (effects) of innovation activity was examined, and it was observed how these relationships change in various phases of the business cycle. Empirical data originated from three databases, which included such phases of the business cycle as prosperity (2004–2006), global financial crisis (2008–2010) and recovery (2012–2014). As concerns the goals (effects) of innovative activity, they were precisely formulated for each of the examined period, as shown in Tables 4, 5 and 6. This facilitates a comparative analysis of all examined periods. Basic conclusions resulting from the research can be formulated as follows:

1. In each of the examined periods, points representing enterprise types and ownership sectors (blue circles) were situated near the points corresponding to the goals (effects) of innovative activity (red squares), which proves that most industrial processing enterprises implemented the assumed goals of their innovative activity. Additionally, implementation of those goals caused a positive feedback reaction, i.e. contributed to further intensification of innovative activity of most enterprises. This fact provides a justification for treating the Polish economy as a 'green island' of economic growth and development in Europe, and perhaps even in the world (Jakimowicz & Rzeczkowski, 2019b).
2. Innovative activity of public sector enterprises, practically regardless of their type, is clearly weaker than of all other enterprises. This is demonstrated by the relatively high distances between the points representing those enterprises, i.e. small S1FR_1, medium S1FR_2 and large S1FR_3, and the points representing the goals (effects) of innovative activity. This phenomenon occurs with various intensity in all examined periods, which is symbolised by the largest hatched black triangle representing public sector S1 (Figures 2–4, 6–8, 10–12). This may be due to political criteria for the selection of management staff in these enterprises (Jakimowicz & Rzeczkowski, 2019b) or to a substantial pay gap between the public and the private sector, to the disadvantage of the former (Démurger *et al*., 2012). Treating the period of 2004–2006 as a point of reference, the situation of small and medium enterprises in the public sector deteriorated in the global financial crisis period, while the situation of large enterprises from this sector improved. On the other hand, in the recovery period, 2012–2014, only small changes occurred in the public sector, consisting in a slight improvement of innovative activity of medium enterprises S1FR_2 and a decline in large enterprises S1FR_3.
3. Interrelations exist between ownership sectors of enterprises, represented by hatched black triangles: S1 (public), S2 (private) and S3 (mixed), and types of enterprises, symbolised by full-colour triangles: yellow FR_1 (small), pink FR_2 (medium) and light blue FR_3 (large), although the degree of their intensity has not been described. This requires carrying out separate research. Most probably, the public sector S1 exerts an unfavourable effect on other ownership sectors, private S2 and mixed S3, which is suggested in Figures 2–4, 6–8, 10–12 by deformations of hatched black triangles representing these sectors, i.e. S2 and S3. This effect can be partially independent from a small or even insignificant share of the public sector in the entire industrial processing section. According to Tables 1–3, this share in the periods of prosperity,

crisis and recovery gradually decreased and amounted to 4.37%, 1.18% and 1.10%, respectively. Additionally, the public sector can inhibit the innovative activity of all types of enterprises: small FR_1, medium FR_2 and large FR_3, represented, respectively by yellow, pink and light blue triangles. On the other hand, the positive effect of the private and the mixed sector on the public sector should also be taken into consideration. The bioplots, therefore, demonstrate a certain type of dynamic equilibrium between ownership sectors and types of enterprises, which changes depending on the business cycle phase. However, this issue requires further studies.

4. The relationships between enterprise types and ownership sectors and the goals (effects) of innovative activity differ insignificantly depending on the business cycle phase. The prosperity period can be taken as the basis for a comparative analysis. In 2004–2006, points representing enterprise types and ownership sectors (blue circles) and effects of innovative activity (red squares) formed a common cluster, which means that most enterprises reached the assumed effects, but the average distances between those two types of variables were relatively large. Those effects affected, to a high or medium degree, the innovation activity of enterprises at the end of 2006. On the other hand, in the period of the global financial crisis of 2008–2010, two types of changes were observed. The first change consisted in reducing average distances between points representing enterprise types and ownership sectors and points responsible for the goals of innovative activity and large and medium degrees of their importance for further innovation activity as regards product and process innovations in 2008–2010. In this way, a cluster of points was identified which contained a vast majority of enterprises that effectively implemented the goals of innovative activity. The other consisted in forming a much smaller cluster of points, situated at a quite large distance from the cluster of the best firms, in which enterprises demonstrated low innovative activity, and if they reached any goals of innovative activity, the degree of their importance was low or irrelevant. This cluster consisted mainly of small enterprises, represented by a yellow triangle. Medium enterprises of the public sector S1FR_2 were located outside those two clusters. To conclude, the crisis must have been a catalyst for some favourable changes, which encouraged most enterprises to increase innovative activity and to effectively implement its goals. As regards the third period, in the prosperity years of 2012–2014, enterprise types and ownership sectors did not exert any more effect on the goals of innovative activity, if we treat eco-innovations as supplementary points. This should be interpreted as a further increase in the innovation

activity by almost all enterprises, regardless of their type or ownership sector. Therefore, they assessed the innovative activity as a prerequisite for their future development. This was reflected in further decreasing the distance between types and ownership sectors of enterprises and the goals of their innovative activity, including eco-innovations. The biplots depicted in Figures 10–12 present an even more compact cluster of points representing both types of variables in comparison to the two previous periods.

5. The phenomena identified in point 4 confirm the changes in the inertia of the Polish industrial processing section. In the period of prosperity, the examined system demonstrated a total inertia of 0.0126, and in the period of crisis and recovery, its value amounted to 0.01801 and 0.00593, respectively. Leaving aside the already-signalled slight increase in the dispersion of variables during the global financial crisis, it should be expected that in the long term, the total inertia of the industrial processing section will demonstrate a decreasing trend. Each enterprise, regardless of the type or ownership sector, seeks to be innovative and reach its assumed goals while introducing eco-innovations. It seems that this trend is less related to the business cycle and more to secular factors of economic growth and development. They are the reason for supercycles or Kondratieff waves (K-waves), whose lengths range from 48 to 60 years. Such secular changes, unlike business cycles, have a casual nature and result from extra-economic circumstances and events. Kondratieff (1935, p. 112) distinguishes four basic groups of secular factors: (1) changes in technique, (2) wars and revolutions, (3) the assimilation of new countries into the world economy, and (4) fluctuations in gold production. As regards the Polish industrial processing section, at least two factors out of the above-mentioned could be of significant importance, i.e. definitely the first one and the third one (and perhaps even all four).
6. Taking into account changes in the inertia of the industrial processing section in various phases of the business cycle, two regularities can be observed. The first of them concerns the decreasing effect of two classical economic variables, i.e. types and ownership sectors of enterprises, on the goals of the innovative activity. Nowadays, innovative activity has become a basic developmental condition, regardless of the type and ownership sector. The second type indicates the diminishing importance of the public sector, which have clear difficulties with reaching the goals of innovative activity as compared to other sectors.
7. Small enterprises have a serious innovation barrier to overcome in the form of insufficient supply of production factors. Therefore, changes in

economic policy are necessary to increase the availability of external sources of financing for such firms.

Neglecting the mutual influence of ownership and type of enterprise on the goals of their innovative activity has a significant effect on the result of the research in the last period under the analysis. According to previous findings, in 2012–2014, all four innovation types, i.e. product, process, organisational and marketing innovations, as well as eco-innovations were dependent on the type (size) of enterprises (Jakimowicz & Rzeczkowski, 2019a). The research presented in this paper proves that taking into account the mutual interactions of ownership sectors and types of enterprises lifts the above-mentioned dependence in the recovery period, which occurred after the global financial crisis. It should be observed that in periods of 2004–2006 and 2008–2010, the effects and goals of innovative activity and corresponding positive feedback loops depended on the combined effect of ownership sectors and types of enterprises (Jakimowicz & Rzeczkowski, 2019b). The results obtained from 2012–2014 are also dependent on simultaneous consideration of the influence of mutual interactions of ownership sectors and types of enterprises on innovation barriers in the research (Jakimowicz & Rzeczkowski, 2019b). This means that significant qualitative, structural changes occurred after the global financial crisis. Entrepreneurs realized what Schumpeter had claimed in the past (1939, p. 87), that innovations are in the heart of economic life and are its most important part.

This is in line with the Red Queen hypothesis: "Now, *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" (Carroll, 1872, p. 42). The economic interpretation of this hypothesis, which would certainly require further elaboration, emphasizes that innovations resulting from technological revolution contribute to a self-driving perpetual motion of the economic environment, which requires adaptation measures of the enterprises operating within it. If the firm wants to develop and be successful, it must increase innovation indicators (Hall & Jaffe, 2018; Pererva *et al*., 2010) above the threshold determined by the environmental average. If the firm is below this threshold, then it will not be able to meet the challenge of the competition and sooner or later it will end its operation. Therefore, the processes of group and individual selection appear which cause the development of the total population of companies in a directional manner. This shows that each technological progress has a relative nature. The truth of the Red Queen dynamics would indicate that each innovative enterprise is part of a zero-sum game against other enterprises operating in the same industrial branch (Van Valen, 1973). This is consistent with the views

of Schumpeter (1939, pp. 94–96, 105–108), who perceives economic development through a prism of the rise and decay of firms and entire industries. Firms, just like a living organism, cannot last forever, and the reason for their decline is always an inability to keep up with innovations. Profit is a bonus for an innovative success, but it is temporary out of its nature, as it disappears in subsequent processes of competition and adaptation. Therefore, each enterprise is in danger of collapse and already from the moment of its establishment must activate appropriate defensive mechanisms.

Decreasing in the long term total inertia of the industrial processing section in Poland requires further research; nevertheless, even now it is possible to draw certain conclusions in the context of secular variations. Anticipation of future trends is closely related to multiple practical aspects important for enterprises, as it provides significant support for firms, involving the possibility to prepare for future innovative activity.

An interesting development of the theory of Kondratieff cycle was provided by Šmihula (2009, 2010, 2011), who in modern times (calculated from 1600) distinguished six K-waves, which were related to technological innovations evoked by technological revolution: 1) financial-agricultural revolution (1600–1780; 180), 2) industrial revolution (1780–1880; 100), 3) technical revolution (1880–1940; 60), 4) scientific-technical revolution (1940–1985; 45), 5) information and telecommunications revolution (1985–2015; 30), and 6) post-information technological revolution, i.e. biomedical-hydrogen revolution (2015–2035; 20). Two characteristics of each of those waves are provided in brackets, i.e. the period of K-wave based on technological revolution and length of the whole wave of technological innovations. As it can be easily seen, an important feature of this concept is the decreasing length of each subsequent wave, which results from the acceleration of scientific and technological progress. As forecast by Šmihula (2009, p. 47; 2011, p. 67), a hypothetical seventh wave, which should take place in 2035–2048, would last only 13 years. The next ones will be even shorter, and consequently, in 2080–2090 it could turn out that technological development will be so fast that K-waves will indistinguishable from classic business cycles.

According to Šmihula's concept, technological innovation waves in the modern era are part of a much larger whole, including a longer chain of technological revolutions, which occurred in the pre-modern era, i.e. in the Middle Ages and the Ancient era. Šmihula (2011, p. 66) identified five K-waves based on technological revolution, which occurred before 1600: A) Indo-European technological revolution (1900–700 BC; 1200), B) Celtic and Greek technological revolution (700 BC–300 AD; 1000), C) German and Slavic technological revolution (300–930 AD; 630), D) Medieval tech-

nological revolution (930–1340 AD; 410), and E) Renaissance technological revolution (1340–1600 AD; 260). As above, their periods of occurrence and duration are provided in brackets. The repetition of the pattern known from the modern era, i.e. shortening lengths of successive waves, is also visible.

All K-waves have specific common features, which consist of maintaining certain regularities of development (Šmihula, 2009, pp. 36–38; 2010, pp. 60–61). The beginning of each wave features an innovation phase, where inventions take a form allowing practical application, which means a technological revolution. It is followed by an application phase when the number of revolutionary innovations decreases and full attention is focused on exploiting and extending already existing innovations. The availability of a given innovation makes it more beneficial for enterprises to invest in its implementation, improvement and exploitation than to develop new innovations. This lasts until the innovation becomes so popular that it becomes a part of everyday life. If the rate of return from a new innovation decreases to the level attained in other, traditional industry branches, it means the end of a given wave of innovations. In this period, a given technology has already reached its limit of development and it is not possible to cross this limit without the application of another novel technology. An economic crisis and stagnation, as well as an increased demand for new inventions and innovations, are the typical end of each K-wave and its application phase. In this way, innovation waves — generated by technological revolutions — follow each other in a logical order, so that each of them creates appropriate conditions for the next one.

From a practical point of view, the Fifth and the Sixth technological waves of the modern era are most important for the industrial processing enterprises. Each wave of technological innovation is based on the leading branches of industry, i.e. those that have experienced the most revolutionary changes. The Fifth K-wave was related to the emergence of the Internet and very important innovations in such fields as telecommunications, cybernetics and information technology. This was based on technological revolutions in these fields, and its effect was the mass use of the computers, cell phones and other data processing devices, which led to the emergence of the global financial market, international economic integration and globalisation. It also resulted in the development of the digital economy and the emergence of the information society. However, as Šmihula observes (2009, pp. 42–43, 46; 2010, pp. 63–65), the emergence of the global financial crisis in 2008 ended both the innovation phase and the application phase of the K-wave of the information technology and telecommunications. Information technology has already become an integral part of every-

day life and it should be expected that the highest profits and the most revolutionary inventions will be seen in other industry branches. A global financial crisis, related to reduction of economic growth rates, high oil and agricultural produce prices, should be therefore perceived as a typical crisis ending each technological wave and heralding the arrival of a new one. Consequently, governmental efforts aimed at overcoming a crisis through a monetary policy will not be very effective. Instead, they should focus on the development of new technologies and support science and education to accelerate the arrival of a new technological revolution.

A look at the innovativeness of Polish industrial processing enterprises from the perspective of long-term technological changes in the economy can explain the close to zero inertia obtained for the period 2012–2014. This is a period after the global financial crisis, which Šmihula marks as the beginning of the Sixth K-wave, related to the biomedical-hydrogen revolution. Nowadays, being an innovative entrepreneur is becoming more common, which is indicated by the low dispersion of profiles around the average profile (Figures 9–12). In future, achieving success will require even more innovativeness. The Sixth K-wave may be the next stage of economic development of humanity and provide a new chance for the development of most innovative enterprises. Therefore, the inertia of the industrial processing section which is only slightly different from zero may confirm that the period after the global financial crisis heralds the end of one K-wave and the beginning of the next one.

Šmihula (2009, pp. 44–45; 2010, p. 64) claims that in post-information society, the biomedical-hydrogen revolution will emerge, which, taking into account an ageing society, will be based on progress in pharmaceutics, biotechnology, biomedicine and nanotechnology. Fields of great importance will include genetic engineering, cloning and transhumanism — seeking to develop direct links between machines and living organisms for the purpose of modifying and improving certain features of living organisms, including humans. Traditional fossil fuels, hazardous to the environment, will be replaced with hydrogen or fuels obtained from agricultural products. Exploitation of alternative energy sources in the form of water, wind and solar power is also anticipated, but it is to be expected that increased energy demand may require the use of nuclear energy. Additionally, the development of the robotics industry is highly probably. Technological development is anticipated by other researchers in a similar manner. A view exists that the Sixth K-wave will be based not only on new medical technologies and biotechnologies but also on attempts to improve the psychosocial health of people (Nefiodow & Nefiodow, 2014). Others claim (Grinin & Grinin, 2014) that the Sixth K-wave will start only in the 2020s

and will mean a merger of the final phase of the Cybernetic Revolution, i.e. the phase of self-regulating systems, with breakthrough medical technologies and many other technologies, which will result in emergence of a single complex of MBNRIC (medico-bio-nano-robo-info-cognitive) technologies.

Conclusions

The aim of the study was to determine the impact of ownership sectors and types of enterprises on the innovative activity of Polish industrial processing companies in various phases of the business cycle. We intended to fully utilize the information contained in empirical data, and thus to minimize any information losses during calculations. This forced us to use a custom methodology in the form of a cybernetic approach, which is based on feedback loops. The analysis included feedback loops between:

1. ownership sectors and types of enterprises,
2. ownership sectors and types of enterprises treated as a whole and the goals of innovative activity of enterprises,
3. innovations undertaken at different times; these interactions were mediated by ownership and the size of the business.

The cybernetic approach has enabled the demonstration of positive feedbacks between innovations undertaken at different times. This method also prompted the discovery of other new phenomena, which would not have been possible if the impact of independent variables had been considered separately and unidirectionally. The most important finding was that in the three studied periods the inertia of the industrial processing sector showed a downward trend and eventually approached zero. This means that the examined system is not sensitive to cyclical fluctuations. Structural changes that take place in the industrial processing sector indicate a breakthrough associated with the end of the Fifth and the beginning of the Sixth Kondratieff wave. This is synonymous with the transition from information and telecommunications revolution (1985–2015) to the biomedical-hydrogen revolution (2015–2035). This is of great practical importance for enterprises, as they must reckon with the possibility of changing innovation strategies in the future. These results should be confirmed by further research, which should include sources of information relevant for innovation activities. Nevertheless, the trends outlined above are very likely, as they result from both theoretical and practical premises.

The correspondence maps presented in Figures 1–12 provide information on various other interdependencies between the examined variables,

which could not be discussed in the paper due to its limitations. In fact, it can be claimed that the issues addressed here are only the tip of the iceberg. The presented biplots contain knowledge about relationships between several dozens of variables and how they evolved over the three periods under consideration. Readers interested in the subject matter but unable to access the databases used in this research can discover other relations of particular interest to them on their own.

References

Abazi-Alili, H. (2014). Innovation activities and firm performance: empirical evidence from transition economies. *Journal of Contemporary Economic and Business Issues*, *1*(2).

Aggarwal, A. (2018). The impact of foreign ownership on research and development intensity and technology acquisition in Indian industries: pre and post global financial crisis. *Asian Development Review*, *35*(1). doi: 10.1162/adev_a_00103.

Balsarı, Ç. K., Varan, S., & Özkan, S. (2015). Impact of foreign ownership on innovation. *Journal of Economics and Management*, *20*(A).

Beh, E. J., & Lombardo, R. (2014). *Correspondence analysis: theory, practice and new strategies*. Chichester: John Wiley & Sons.

Bitler, M. P., Moskowitz, T. J., & Vissing-Jørgensen, A. (2005). Testing agency theory with entrepreneur effort and wealth. *Journal of Finance*, *60*(2). doi: 10.1111/j.1540-6261.2005.00739.x.

Brossard, O., Lavigne, S., & Sakinç, M. E. (2013). Ownership structures and R&D in Europe: the good institutional investors, the bad and ugly impatient shareholders. *Industrial and Corporate Change*, *22*(4). doi: 10.1093/icc/dtt018.

Carroll, L. (1872). *Through the looking-glass, and what Alice found there*. London: Macmillan and Co.

Commission Regulation (EU) No. 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty. Official Journal of the European Union, L 187/1, 26.6.2014.

Decker, C., & Günther, C. (2017). The impact of family ownership on innovation: evidence from the German machine tool industry. *Small Business Economics*, *48*(1). doi: 10.1007/s11187-016-9775-0.

Démurger, S., Li, S., & Yang, J. (2012). Earnings differentials between the public and private sectors in China: exploring changes for urban local residents in the 2000s. *China Economic Review*, *23*(1). doi: 10.1016/j.chieco.2011.08.007.

Dzikowski, P. (2013). Size and ownership of enterprise and innovation activities of food and beverages manufacturers in western Poland in 2009–2012. *Management*, *17*(1). doi: 10.2478/manment-2013-0008.

Dzikowski, P. (2014). The impact of a firm's size and its ownership on innovation activity in medium-high and high technology sectors. *Global Management Journal*, *6*(1–2).

Falk, M. (2008). Effects of foreign ownership on innovation activities: empirical evidence for twelve European countries. *National Institute Economic Review*, *204*(1). doi: 10.1177/00279501082040011001.

Glynn, D. (2014). Correspondence analysis: exploring data and identifying patterns. In D. Glynn & J. A. Robinson (Eds.). *Corpus methods for semantics: quantitative studies in polysemy and synonymy*. Amsterdam: John Benjamins Publishing Company.

Greenacre, M. (2007). *Correspondence analysis in practice*. Boca Raton, FL: Chapman & Hall/CRC – Taylor & Francis Group.

Grinin, L. E., & Grinin, A. L. (2014). The sixth Kondratieff wave and the cybernetic revolution. In. L. E. Grinin, T. C. Devezas & A. V. Korotayev (Eds.). *Kondratieff waves. Juglar – Kuznets – Kondratieff. Yearbook*. Volgograd: 'Uchitel' Publishing House.

Hall, B. H., & Jaffe, A. B. (2018). Measuring science, technology, and innovation: a review. *Annals of Science and Technology Policy*, *2*(1). doi: 10.1561/110.00000005.

Huang, Y., Salike, N., Yin, Z., & Zeng, D. Z. (2017). Enterprise innovation in China: does ownership or size matter? *RIEI Working Papers Xi'an Jiaotong-Liverpool University, Research Institute for Economic Integration*, *2017-06*.

Jakimowicz, A., & Rzeczkowski, D. (2019a). Diversification of innovation strategies of Polish industrial processing enterprises depending on their size after the global financial crisis. *Journal of Entrepreneurship, Management and Innovation*, *15*(4). doi: 10.7341/20191542.

Jakimowicz, A., & Rzeczkowski, D. (2019b). Do barriers to innovation impact changes in innovation activities of firms during business cycle? The effect of the Polish Green Island. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *14*(4). doi: 10.24136/eq.2019.030.

Kondratieff, N. D. (1935). The long waves in economic life. *Review of Economics and Statistics*, *17*(6). doi: 10.2307/1928486.

McHugh, M. L. (2013). The Chi-square test of independence. *Biochemia Medica*, *23*(2). doi:10.11613/BM.2013.018.

Minetti, R., Murro, P., & Paiella, M. (2015). Ownership structure, governance, and innovation. *European Economic Review*, *80*. doi: 10.1016/j.euroecorev.2015.09.007.

Nefiodow, L., & Nefiodow, S. (2014). The sixth Kondratieff. The growth engine of the 21st century. In L. E. Grinin, T. C. Devezas & A. V. Korotayev (Eds.). *Kondratieff waves. Juglar – Kuznets – Kondratieff. Yearbook*. Volgograd: 'Uchitel' Publishing House.

Nenadić, O., & Greenacre, M. J. (2007). Correspondence analysis in R, with two- and three-dimensional graphics: the ca package. *Journal of Statistical Software*, *20*(3). doi: 10.18637/jss.v020.i03.

Ortega-Argilés, R., Moreno, R., & Caralt, J. S. (2005). Ownership structure and innovation: is there a real link? *Annals of Regional Science, 39*(4). doi: 10.1007/s00168-005-0026-6.

Pererva, P., Schimpf, K., & Gladenko, I. (2010). Monitoring of efficiency of innovative activity of industrial enterprise. *Club of Economics in Miskolc. Theory, Methodology, Practice*, *6*(2).

Rehman, N.U. (2017). Self-selection and learning-by-exporting hypotheses: micro-level evidence. *Eurasian Economic Review, 7*(1). doi: 10.1007/s40822-016-0063-8.

Schumpeter, J. A. (1939). *Business cycles: a theoretical, historical, and statistical analysis of the capitalist process (Vols. 1–2)*. New York: McGraw-Hill Book Company.

Schumpeter, J. A. (1942). *Capitalism, socialism, and democracy*. New York: Harper and Brothers Publishers.

Schumpeter, J. A. (1949). *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle*. Cambridge, MA: Harvard University Press.

Šmihula, D. (2009). The waves of the technological innovations of the modern age and the present crisis as the end of the wave of the informational technological revolution. *Studia Politica Slovaca, 1*.

Šmihula, D. (2010). Waves of technological innovations and the end of the information revolution. *Journal of Economics and International Finance, 2*(4).

Šmihula, D. (2011). Long waves of technological innovations. *Studia Politica Slovaca, 2*.

Sourial, N., Wolfson, C., Zhu, B., Quail, J., Fletcher, J., Karunananthan, S., Bandeen-Roche, K., Béland, F., & Bergman, H. (2010). Correspondence analysis is a useful tool to uncover the relationships among categorical variables. *Journal of Clinical Epidemiology, 63*(6). doi:10.1016/j.jclinepi.2009.08.008.

Succurro, M., & Costanzo, G.D. (2019). Ownership structure and firm patenting activity in Italy. *Eurasian Economic Review, 9*(2). doi: 10.1007/s40822-018-0109-1.

Van Valen, L. (1973). A new evolutionary law. *Evolutionary Theory, 1973*(1).

Acknowledgments

The study presented here was conducted as part of the Opus 9 project entitled "Różnicowanie się strategii innowacji polskich przedsiębiorstw przetwórstwa przemysłowego pod wpływem zmian uwarunkowań makroekonomicznych" (Differentiation of innovation strategies of Polish manufacturing firms as an effect of changes in macroeconomic environment) funded by the National Science Centre, Poland, under the Contract No. UMO-2015/17/B/HS4/02742. 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.

Annex

Table 1. Percentage share of enterprise types (FR) in ownership sectors (S) and percentage share of ownership sectors in enterprise types in the period 2004–2006

Database 2004–2006 (%)							
Type/Ownership Sector (Codes)	**Small (FR_1)**		**Medium (FR_2)**		**Large (FR_3)**		**Subtotal (S)**
	Type	**Sector**	**Type**	**Sector**	**Type**	**Sector**	
Public (S1)	2.95	20.27	4.14	52.70	8.28	27.03	4.37
Private (S2)	72.83	27.58	83.64	58.64	76.61	13.78	79.39
Mixed (S3)	24.22	44.84	12.22	41.87	15.11	13.29	16.24
Subtotal (FR)	30.06		55.66		14.28		**Total** = 100

Source: Statistics Poland (GUS), Statistical Office in Szczecin.

Table 2. Percentage share of enterprise types (FR) in ownership sectors (S) and percentage share of ownership sectors in enterprise types in the period 2008–2010

Database 2008–2010 (%)							
Type/Ownership Sector (Codes)	**Small (FR_1)**		**Medium (FR_2)**		**Large (FR_3)**		**Subtotal (S)**
	Type	**Sector**	**Type**	**Sector**	**Type**	**Sector**	
Public (S1)	0.38	21.31	2.17	48.77	5.33	29.92	1.18
Private (S2)	73.82	65.61	78.89	27.87	73.81	6.52	75.17
Mixed (S3)	25.80	72.88	18.94	21.27	20.86	5.85	23.65
Subtotal (FR)	66.81		26.55		6.64		**Total** = 100

Source: Statistics Poland (GUS), Statistical Office in Szczecin.

Table 3. Percentage share of enterprise types (FR) in ownership sectors (S) and percentage share of ownership sectors in enterprise types in the period 2012–2014

Database 2012–2014 (%)							
Type/Ownership Sector (Codes)	**Small (FR_1)**		**Medium (FR_2)**		**Large (FR_3)**		**Subtotal (S)**
	Type	**Sector**	**Type**	**Sector**	**Type**	**Sector**	
Public (S1)	0.56	17.70	1.04	47.79	2.68	34.51	1.10
Private (S2)	57.09	44.27	32.26	36.18	62.40	19.55	45.25
Mixed (S3)	42.35	27.69	66.70	63.08	34.92	9.23	53.65
Subtotal (FR)	35.09		50.74		14.17		**Total** = 100

Source: Statistics Poland (GUS), Statistical Office in Szczecin.

Table 4. Variables describing the effects of innovative activity of enterprises in 2004–2006, the degrees of influence of innovations introduced by enterprises in 2004–2006 on the activity of enterprises at the end of 2006, and the method of coding

Effect Type	Effects of innovative activity Scale: 1 – high; 2 – medium; 3 – low; 4 – irrelevant	Degree of influence	Codes
Product effects	Increase of the product assortment	1, 2, 3, 4	E1
	Entering into new markets or increasing the existing market share	1, 2, 3, 4	E2
	Product quality increase	1, 2, 3, 4	E3
Process effects	Improvement in production flexibility	1, 2, 3, 4	E4
	Increase of production capacity	1, 2, 3, 4	E5
	Reduction of labour costs per unit of product	1, 2, 3, 4	E6
	Reduction of consumption of materials and energy per unit of product	1, 2, 3, 4	E7
Other effects	Reduction of harmfulness to the environment and improvement of work safety	1, 2, 3, 4	E8
	Compliance with regulations, norms or standards	1, 2, 3, 4	E9

Source: own elaboration based on questionnaire PNT-02: Report on industrial innovation for 2004–2006, Statistics Poland (GUS).

Table 5. Variables describing the goals of innovative activity in the years 2008–2010, their degrees of importance for innovative activity of enterprises as regards product or process innovation in 2008–2010, and the method of coding

Goals of innovative activity **Scale: 1 – high; 2 – medium; 3 – low; 4 – irrelevant**	**Degree of importance**	**Codes**
Increase of the product or service assortment	1, 2, 3, 4	G1
Replacement of obsolete products or processes	1, 2, 3, 4	G2
Entering into new markets or increasing the existing market share	1, 2, 3, 4	G3
Improvement of the quality of products or services	1, 2, 3, 4	G4
Improvement in production flexibility	1, 2, 3, 4	G5
Increase of production capacity	1, 2, 3, 4	G6
Reduction of labour costs per unit of product	1, 2, 3, 4	G7
Reduction of consumption of materials and energy per unit of product	1, 2, 3, 4	G8
Reduction of harmfulness to the environment	1, 2, 3, 4	G9
Improvement of work safety	1, 2, 3, 4	G10

Source: own elaboration based on questionnaire PNT-02: Report on industrial innovations for the years 2008–2010, Statistics Poland (GUS).

Table 6. Variables describing the types of innovation, the goals of innovative activity in the years 2012–2014, and coding method

	Types of innovation	Goals of innovative activity	Codes
Eco-innovations	**Products**	New or significantly improved manufactured goods	PRC1
		New or significantly improved services	PRC2
	Processes	New or significantly improved methods of producing goods and services	PRS1
		New logistic processes	PRS2
		New management processes	PRS3
	Organisation	New methods under the principles of operation adopted	ORG1
		New methods of distribution of tasks and decision-making powers among employees	ORG2
		New organisational methods in terms of relations with the environment	ORG3
	Marketing	Significant changes in the design/construction and/or packaging of goods and/or services	MAR1
		New media or product promotion methods	MAR2
		New methods in terms of product distribution or sales channels	MAR3
		New methods of pricing goods and services	MAR4
	Environmental benefits obtained during the production of products or services	Reduction of material consumption or water consumption per unit of product	ECO1
		Reduction of energy intensity or carbon dioxide emissions	ECO2
		Reduction of soil, water, air or noise pollutions	ECO3
		Use of materials that are less polluting or less dangerous to the environment	ECO4
		Reduction of the fossil fuels, higher use of energy obtained from renewable sources	ECO5
		Re-use (recycling) of waste, water or materials for personal use or sale	ECO6
	Environmental benefits obtained during the period of use of the purchased product or use of the service by end users	Reducing energy consumption or carbon dioxide emissions	ECO7
		Reduction of air, water, soil or noise pollutions	ECO8
		Facilitating the re-use (recycling) of the product after use	ECO9
		Extending the life of products thanks to increased durability and strength	ECO10

Source: own elaboration based on questionnaire PNT-02: Report on industrial innovation for 2012–2014, Statistics Poland (GUS).

Table 7. List of assumptions and calculations necessary to verify the hypothesis regarding the relationship between the type and ownership sector of an enterprise and the goals of its innovative activity (2012–2014)

Pearson's χ^2 test of independence	
χ^2 statistics value	120.85
Critical region	right-tailed
Level of significance (α)	$\alpha = 0.05$
P-value (p)	$p = 0.99759$
Decision	Since $p > \alpha$, there are no grounds for rejecting H_0

Table 8. List of assumptions and calculations necessary to verify the hypothesis regarding the relationship between the type and ownership sector of an enterprise and the eco-innovations (2012–2014)

Pearson's χ^2 test of independence	
χ^2 statistics value	311.44
Critical region	right-tailed
Level of significance (α)	$\alpha = 0.05$
P-value (p)	$p = 0.0000$
Decision	H_0 hypothesis should be rejected in favour of H_1

Table 9. List of assumptions and calculations necessary to verify the hypothesis regarding the relationship between the type and ownership sector of an enterprise and the goals of its innovative activity with the eco-innovations as supplementary points (2012–2014)

Pearson's χ^2 test of independence	
χ^2 statistics value	65.248
Critical region	right-tailed
Level of significance (α)	$\alpha = 0.05$
P-value (p)	$p = 0.96687$
Decision	Since $p > \alpha$, there are no grounds for rejecting H_0

Table 10. Correspondence matrix characteristics

Number of dimensions	Eigenvalues and inertia for all dimensions. Input table (row × column): 9×12. [Total inertia = 0.00593, chi-square (χ^2) = 65.248, df = 88, p = 0.96687]				
	Singular values	**Eigenvalues**	**Percent of inertia**	**Cumulated percent of inertia**	**Chi-square distances (χ^2)**
1	**0.046302**	**0.002144**	**36.16033**	**36.1603**	**23.59377**
2	**0.038434**	**0.001477**	**24.91513**	**61.0755**	**16.25655**
3	**0.028187**	**0.000795**	**13.40057**	**74.4760**	**8.74356**
4	0.025667	0.000659	11.11151	85.5875	7.25000
5	0.017644	0.000311	5.25090	90.8384	3.42609
6	0.016981	0.000288	4.86337	95.7018	3.17324
7	0.013345	0.000178	3.00357	98.7054	1.95976
8	0.008761	0.000077	1.29462	100.0000	0.84471

Figure 1. 3D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the effects of innovative activity and degrees of their influence on enterprises in period 2004–2006 (dimensions 1–2–3; 77.77% of total inertia)

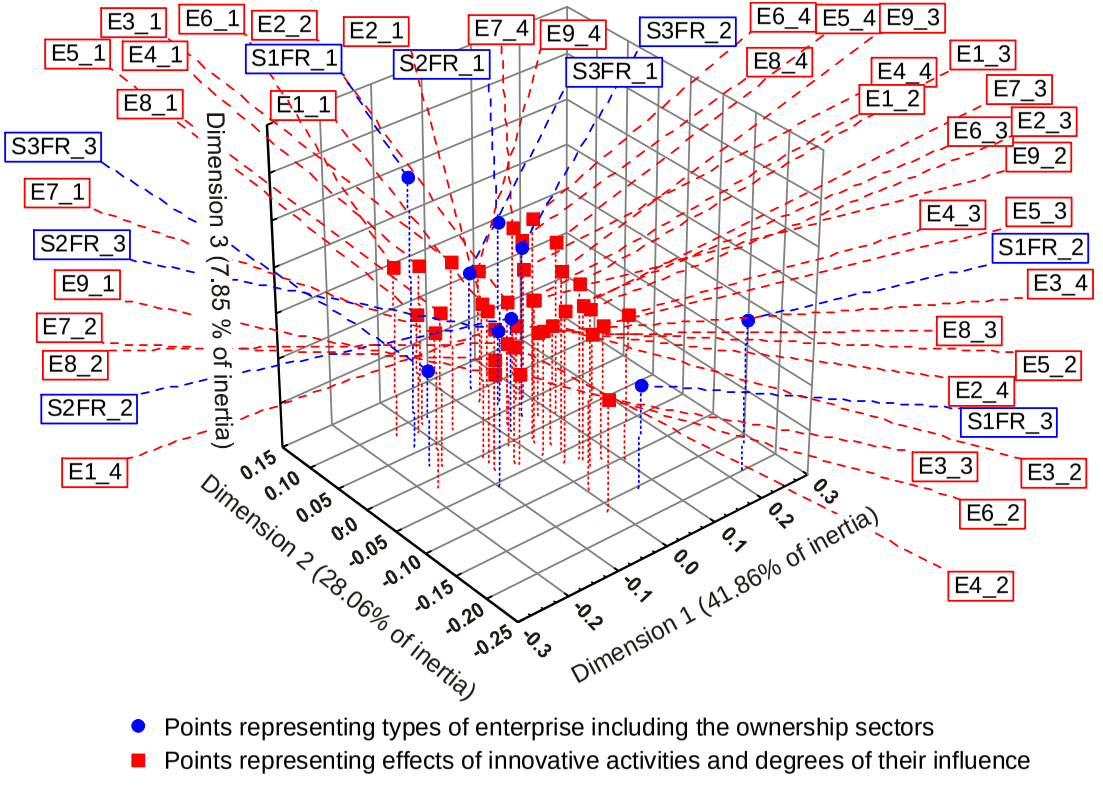

Figure 2. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the effects of innovative activity and degrees of their influence on enterprises in period 2004–2006 (dimensions 1–2; 69.92% of total inertia)

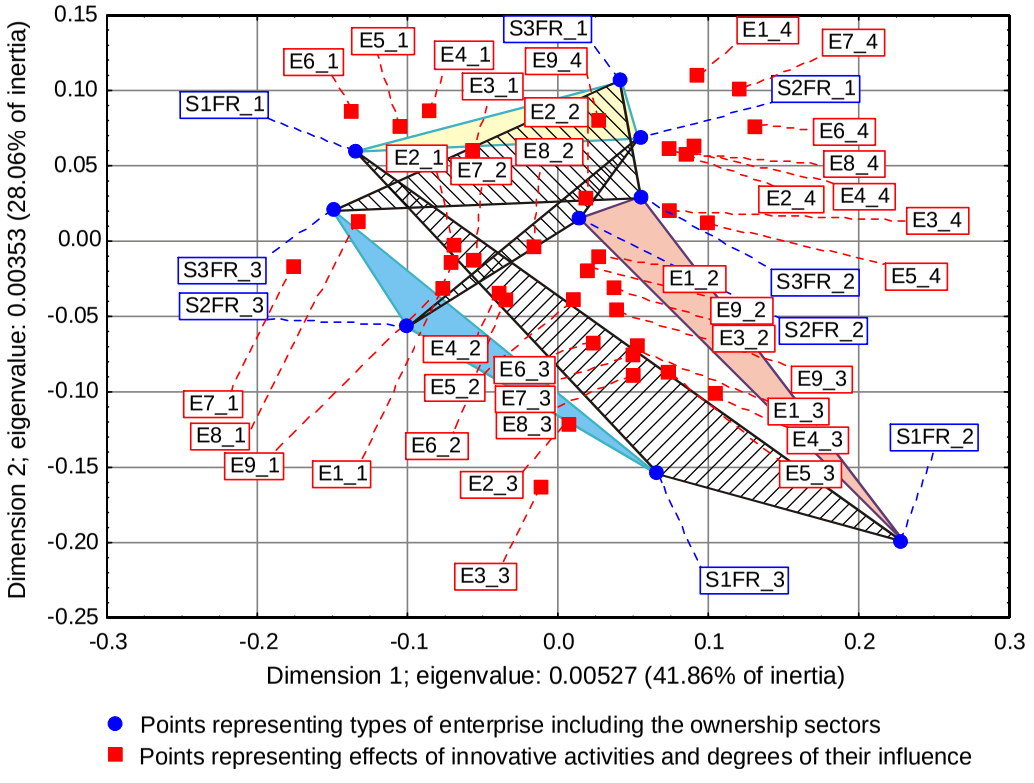

Figure 3. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the effects of innovative activity and degrees of their influence on enterprises in period 2004–2006 (dimensions 1–3; 49.71% of total inertia)

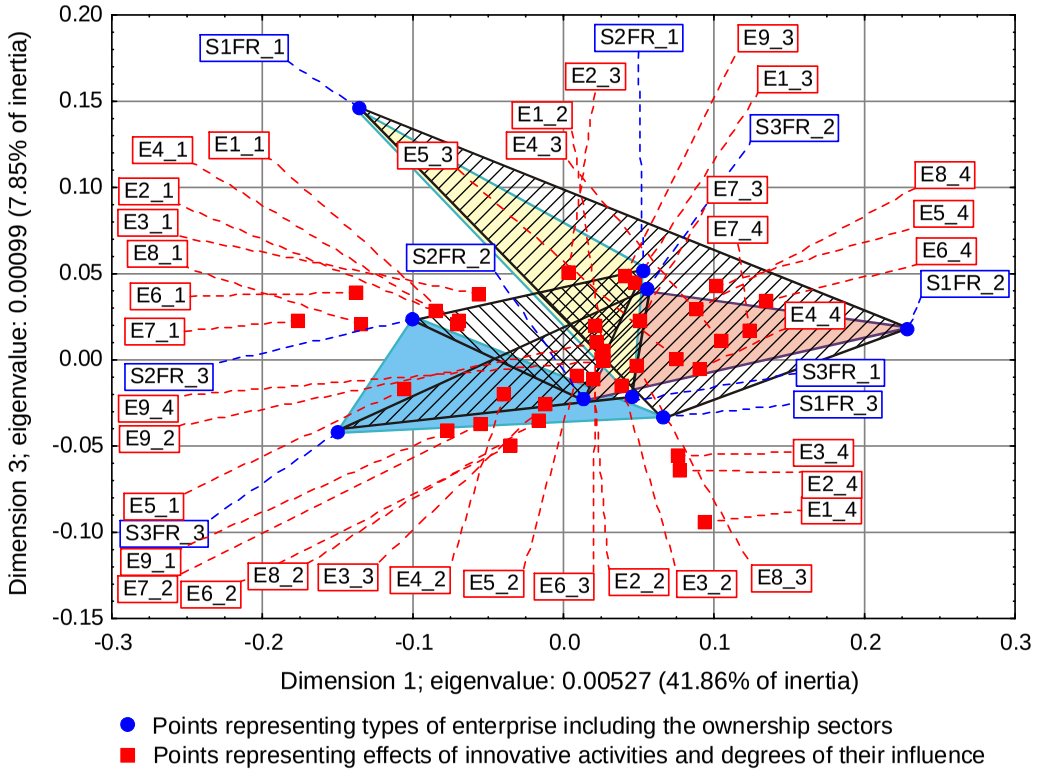

Figure 4. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the effects of innovative activity and degrees of their influence on enterprises in period 2004–2006 (dimensions 2–3; 35.91% of total inertia)

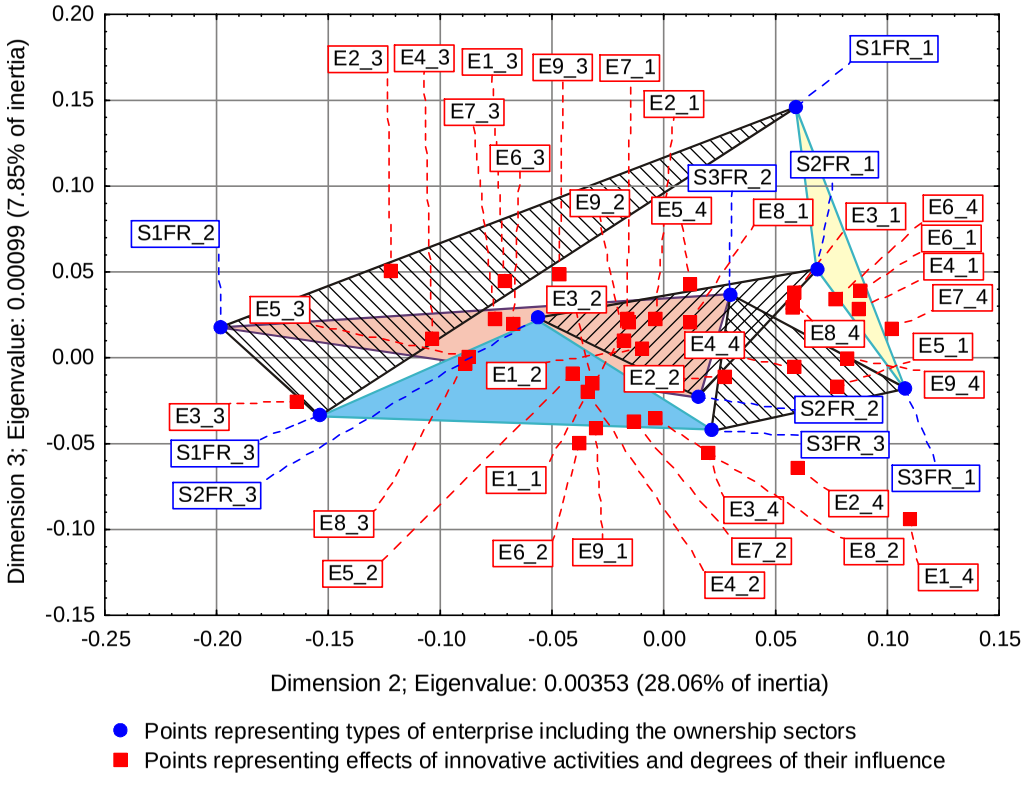

Figure 5. 3D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the goals of innovative activity and their degrees of importance for enterprises in period 2008–2010 (dimensions 1–2–3; 85.833% of total inertia)

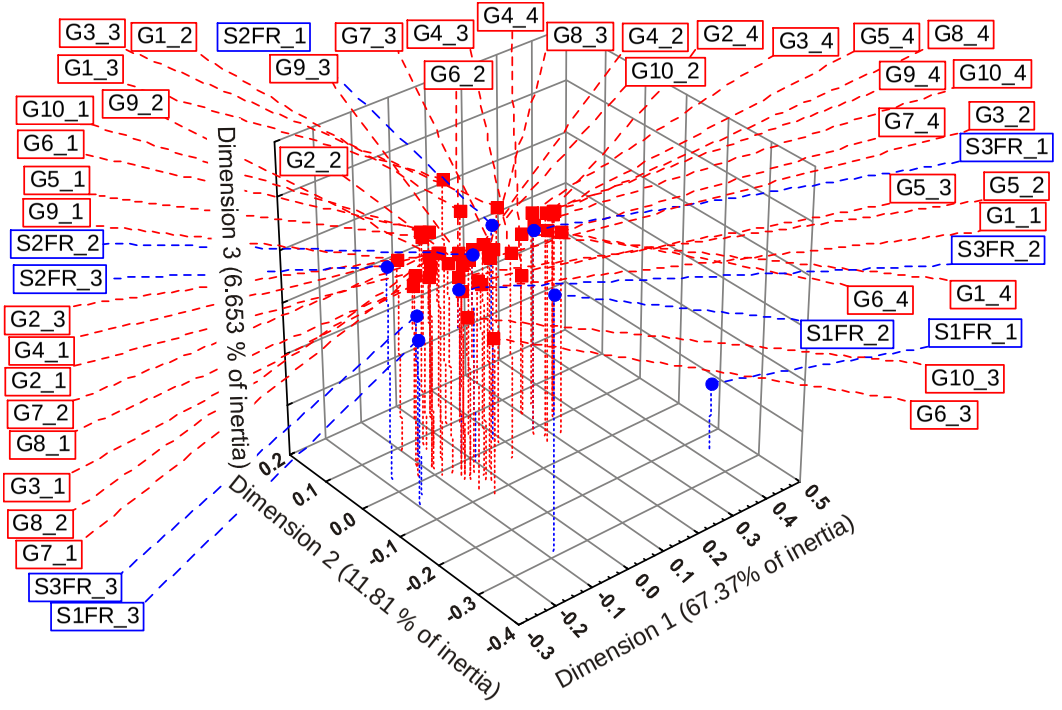

Figure 6. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the goals of innovative activity and their degrees of importance for enterprises in period 2008–2010 (dimensions 1–2; 79.18% of total inertia)

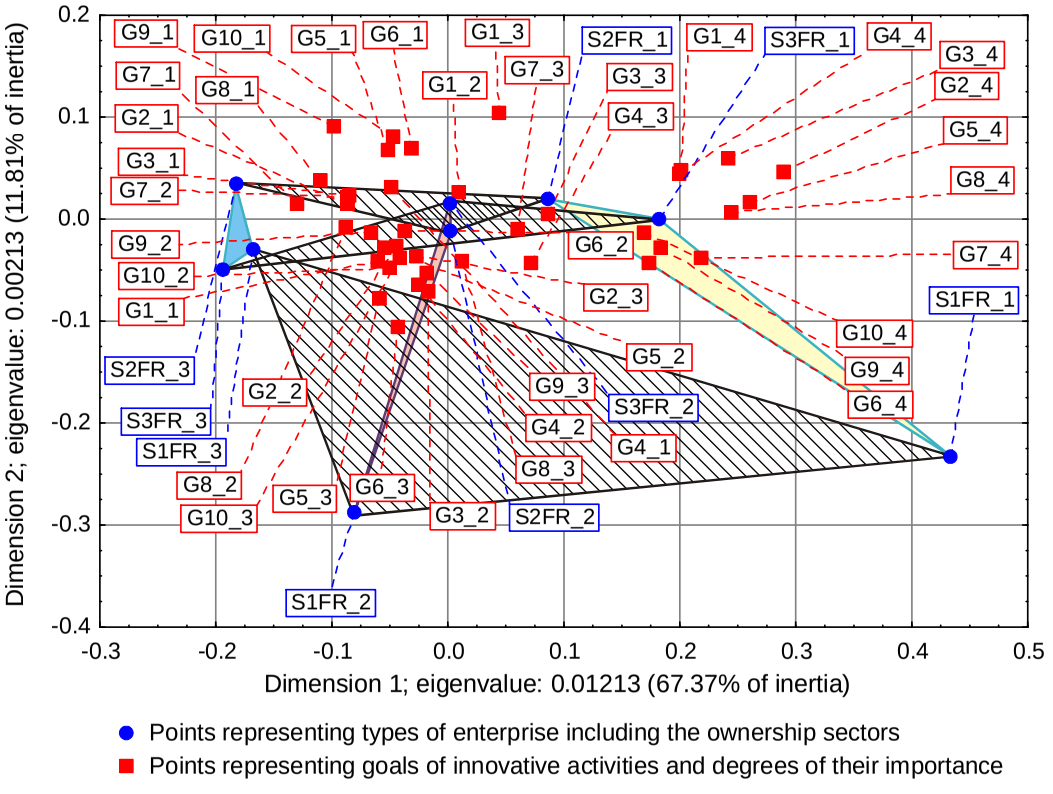

Figure 7. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the goals of innovative activity and their degrees of importance for enterprises in period 2008–2010 (dimensions 1–3; 74.023% of total inertia)

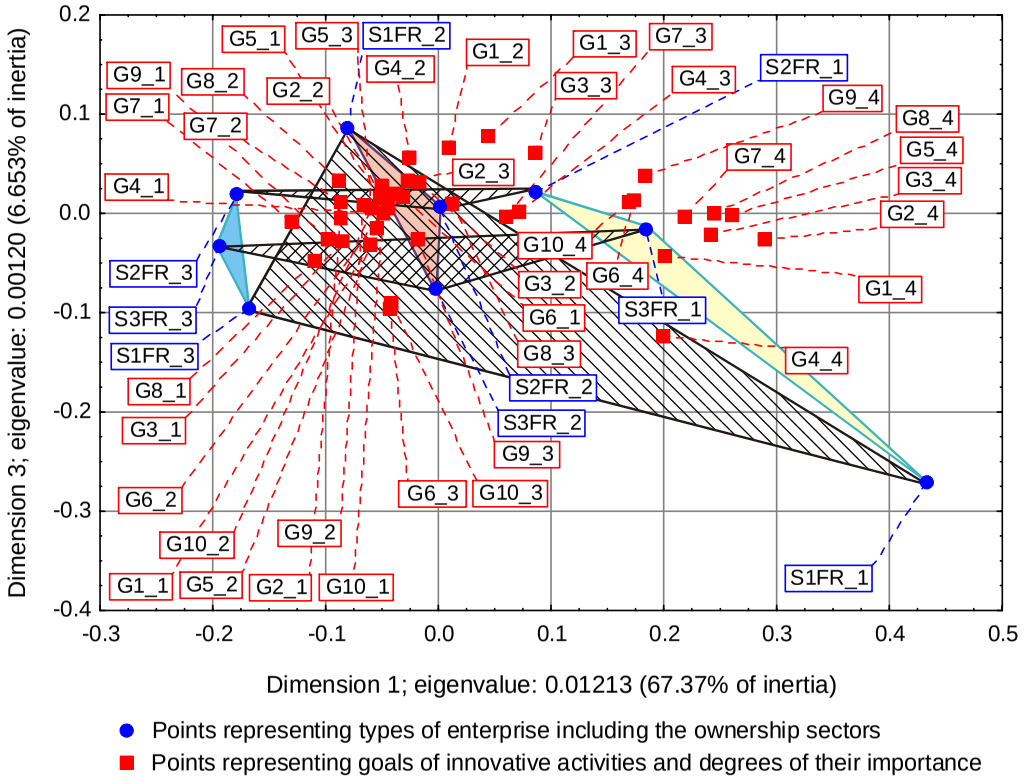

Figure 8. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the goals of innovative activity and their degrees of importance for enterprises in period 2008–2010 (dimensions 2–3; 18.463% of total inertia)

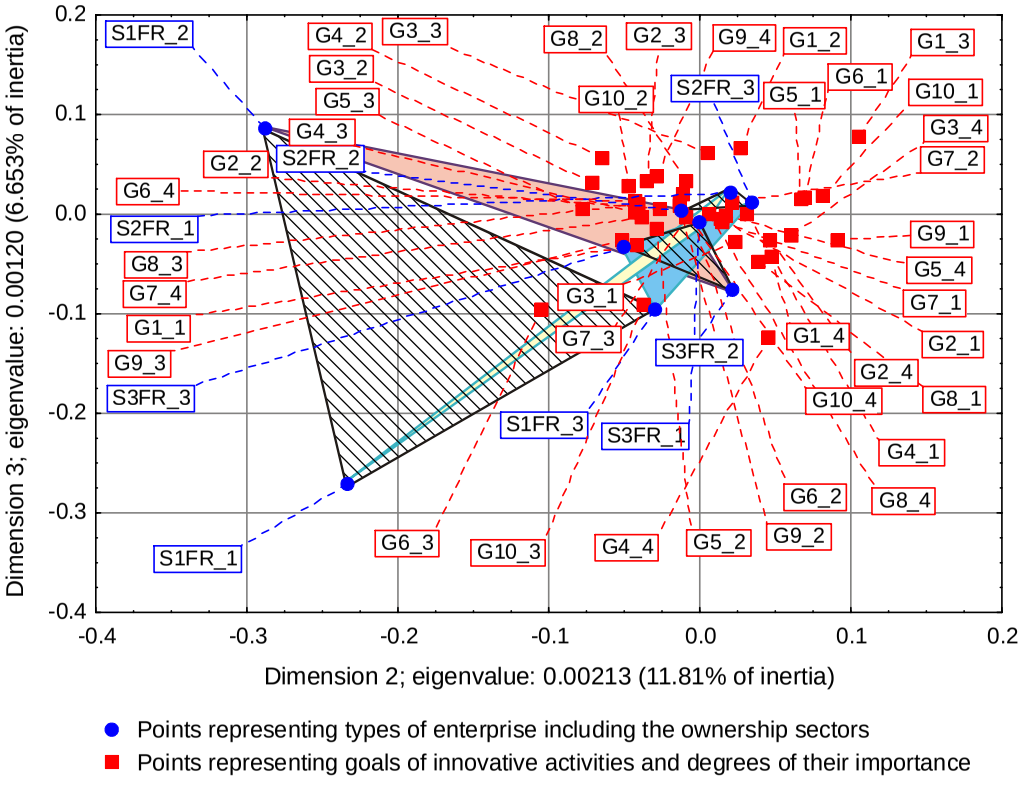

Figure 9. 3D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the types of innovation, and the environmental benefits in period 2012–2014 (dimensions 1–2–3; 74.48% of total inertia)

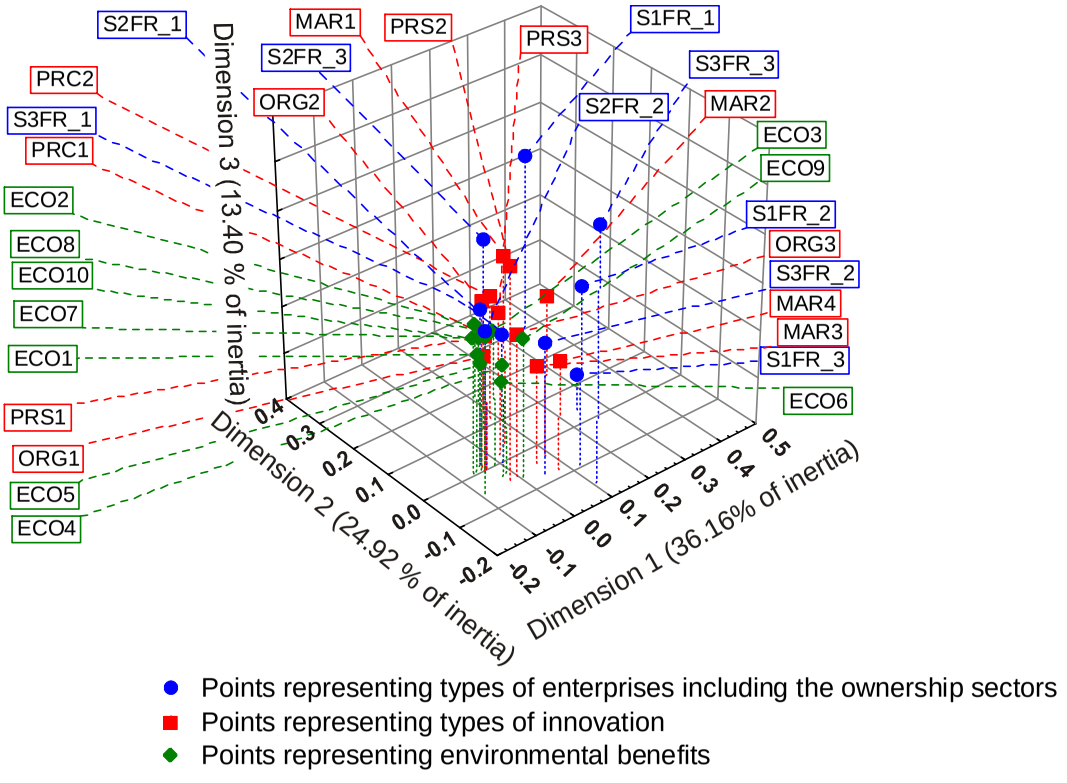

Figure 10. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the types of innovation, and the environmental benefits in period 2012–2014 (dimensions 1–2; 61.08% of total inertia)

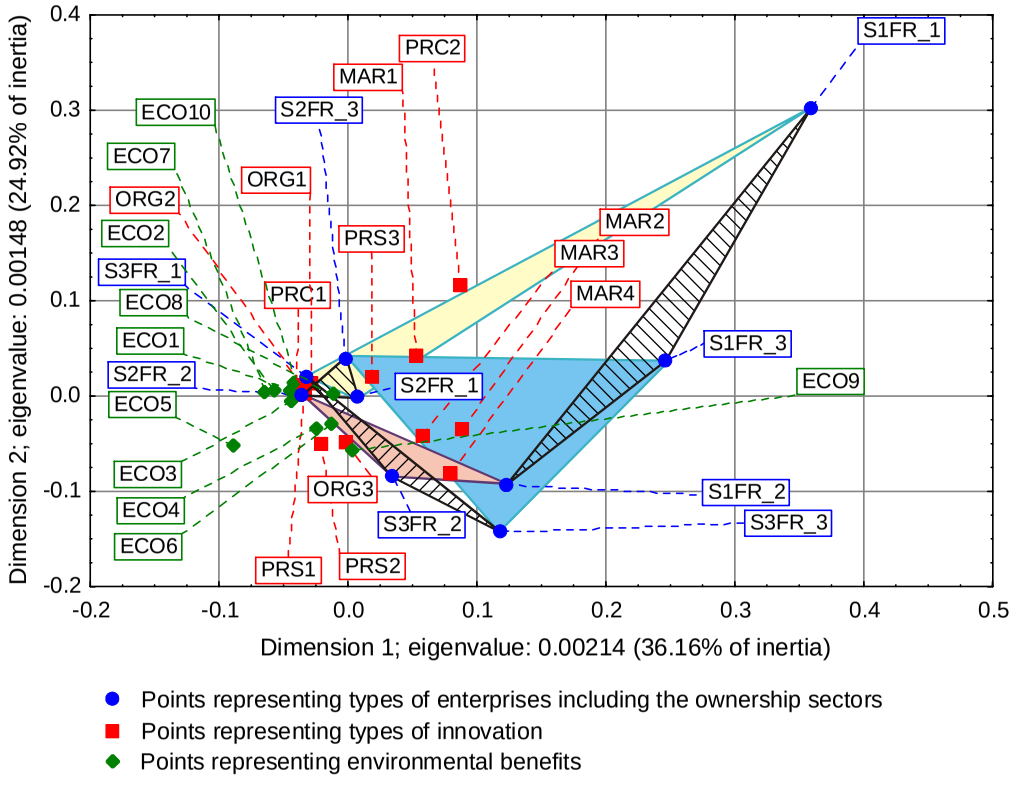

Figure 11. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the types of innovation, and the environmental benefits in period 2012–2014 (dimensions 1–3; 49.56% of total inertia)

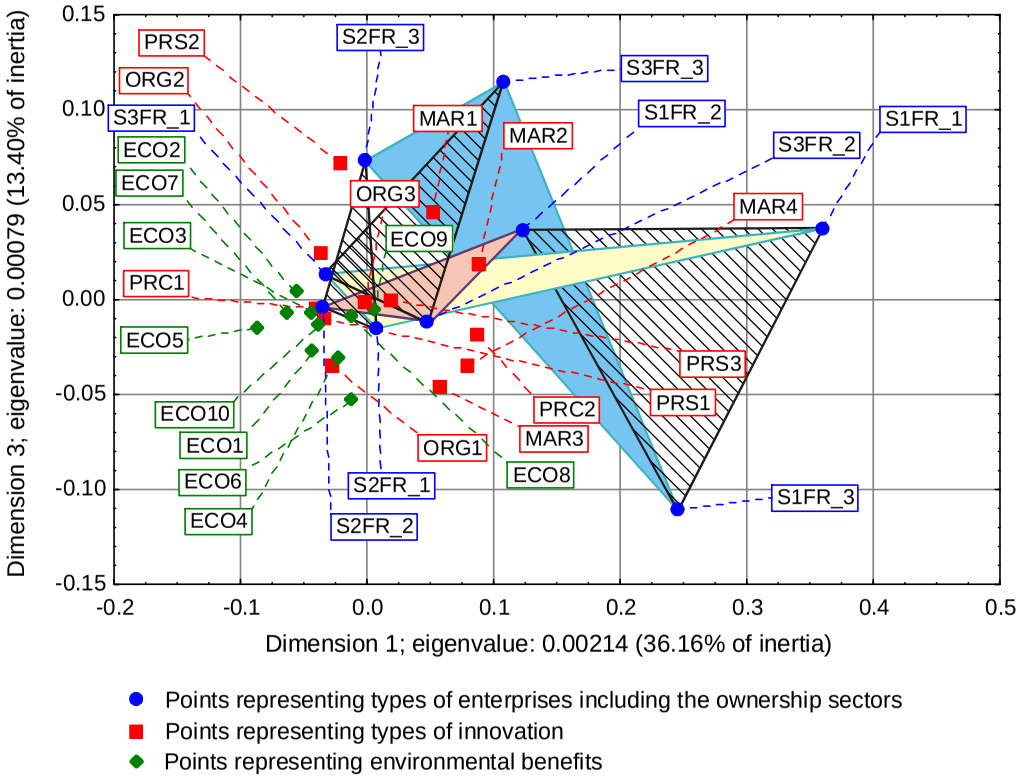

Figure 12. 2D biplot showing the co-occurrence of the types of enterprises including the ownerships sectors, the types of innovation, and the environmental benefits in period 2012–2014 (dimensions 2–3; 38.32% of total inertia)