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# FIRMS' INNOVATION ACTIVITIES AS AN ADAPTIVE ATTRIBUTE OF FIRMS' RESILIENCE TO ECONOMIC SHOCKS: EVIDENCE FROM POLISH NUTS-2 REGIONS

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**Purpose:** The aim of this article is to examine how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as an adaptive attribute of firms' resilience to economic shocks.
**Design/methodology/approach**: The research applied a comparative analysis, zero unitarization method and a multivariate analysis. These methods made it possible to divide Polish NUTS-2 regions into four groups according to the level of variables related to firms' innovation activities. For the research, data from Local Bank Data, Statistics Poland, were used with special attention to data on firms' internal potential for innovation processes. The study covers the period from 2018 to 2022 when Polish firms were operating under severe conditions.
**Findings:** The results show that despite the economic shocks that occurred during the period analysed, the highest diversity among Polish NUTS-2 regions in the variables considered can be found almost between the very same regions. The results also highlight that the majority of Polish NUTS-2 regions, despite the severe conditions, have a very high, high or average level of variables related to innovation activities of firms.
**Research limitations/implications:** This study has paid particular attention to the variables related to firms' innovation activities in the context of firms' internal potential for innovation processes, such as: firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland. In order to better understand the relationship between firms' innovativeness and firms' resilience, future research could consider other drivers of firms' innovation activities. There is also a need to look more closely at how firms' and regional competitiveness interact to make firms more resilient.
**Practical implications:** The findings point to the need to further improve the innovation potential of firms in order to make them more resilient to economic shocks. The research also suggests that public institutions should continue to create conditions that encourage firms to innovate.
**Originality/value:** This article contributes to the existing discussion on firms' innovation activities and firms' resilience. In this respect, the research provides evidence on the differences between Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks.
**Keywords:** firms' innovation activities, firms' resilience, NUTS-2 regions in Poland.
**Category of the paper:** research paper.

## 1. Introduction

There is a consensus in the literature that resilience to economic shocks is a complex phenomenon (Samborski, 2022). This results from viewing of resilience as a multifaceted phenomenon that can be considered from different perspectives, such as, among others, firms' or regional (Pacheco et al., 2023). For this reason, issues addressed by theoretical and empirical studies on resilience are very diverse. The growing interest in resilience issues is especially seen in recent years (Iammarino et al., 2021; Wziątek-Kubiak, Pęczkowski, 2021; Do et al., 2022; Samborski, 2022; Pacheco et al., 2023). This stems from the need for firms and regions to adapt to changes in the environment in order to maintain or increase their competitive advantage (Teixeira et al., 2013). This is particularly important in the occurrence of economic shocks, such as the covid pandemic, when changes have a multifaceted and rapid impact on firms and regions (Pinto et al., 2019, Gupta, 2020; Brada et al., 2021; Pyrkosz-Pacyna, 2021). In this respect, the resilience of firms can lead to their survival and development apart from the occurrence of severe conditions (Pacheco et al., 2023). Therefore, while the competitiveness of firms and the competitiveness of regions are interrelated (Fritsch et al., 2020), understanding the resilience of firms is of particular importance. In this respect, the growing body of research can be observed in this area (Kantabutra, Ketprapakorn, 2021; Dovbischuk, 2022, Destefanis, Rehman, 2023). Researchers highlight the diversity of issues in this field and call for the need for further research (Conz, Magnani, 2020). One strand of the research in this area emphasizes the role of firms' innovation performance in supporting the resilience of firms and regions (Muštra et al., 2020; Asheim, Herstad, 2021). According to this strand, innovation processes can be seen as crucial for maintaining the resilience of firms and regions under difficult conditions (Gupta, 2020; Engelen et al., 2021; Iammarino et al., 2021). This is because innovation activities of firms stimulate the competitiveness of firms and, consequently, the competitiveness of regions (D'Este et al., 2012; Zygmunt, A., 2017). In this respect, the studies point to the crucial role of firms' innovation performance in responding quickly to changes in the environment and to maintaining resilience (Pacheco et al., 2023). Here, studies have found, among others, an important role of knowledge diffusion (Bristow, Healy, 2018) and access to finance for firms' innovation processes (Dyduch et al., 2021). This is in line with the theories of knowledge spillovers, endogenous growth and resilience, which form the basis of this research.

It should be highlighted that although previous studies have focused on innovation and firms' resilience, there is a limited understanding of Polish firms' innovation activities in the context of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. This study is motivated by this gap in the literature and the need to further comprehend the attitude of Polish firms towards severe conditions related to changes in the environment. Thus, the aim of this research is to examine how Polish regions at the NUTS-2 level differ in

terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. The study uses data from Local Bank Data, Statistics Poland, for the period from 2018 to 2022 when Polish firms were operating under challenging conditions related to inflationary pressures and the covid pandemic. The research employs a comparative analysis, zero unitarization method and a multivariate analysis as hypothesis testing methods.

The study contributes to the rising body of knowledge on innovation and firms' resilience by showing how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. In this context, the study pays particular attention to the resilience of Polish firms under severe conditions associated with inflationary pressures and the covid pandemic, by showing that the internal potential of firms' innovation activities may be a response to the changes in the environment.

This article is structured as follows: the first section explores firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks and presents the hypothesis. This is followed by the presentation of the methodology applied for the research. Subsequently, the results are presented and discussed in following section: the comparative analysis, zero unitarization method and the multivariate analysis. The paper concludes with implications, limitations and future research suggestions.

## 2. Theoretical framework and hypothesis development

Studies linking firms' innovation performance and resilience highlight that issues related to innovation processes have been relatively well studied, in contrast to resilience issues (Pacheco et al., 2023). This may stem from the view of firms' innovation activities as crucial for the competitive advantage of not only firms, but also regions (Fritsch et al., 2020). For this reason, the drivers and sources of firms' innovation performance have been of particular interest to theoretical and empirical studies over the years (Zygmunt, A., 2017; Zygmunt, J., 2017; Audretsch, Belitski, 2024). As firms' innovation performance is considered crucial for competitive advantage, it is argued that it can ensure survival in the occurrence of severe conditions (Teixeira et al., 2013). Therefore, as issues related to resilience have gained particular importance in recent years, firms' innovation performance has attracted considerable attention from researchers (Bristow, Healy, 2018; Destefanis, Rehman, 2023). In particular, this is seen in the context of firms' and regional resilience, and is related to understanding how firms' innovation processes enable them to adapt to change and maintain or increase their competitive advantage (Gupta, 2020; Do et al., 2022).

Considering that innovation performance affects many aspects of firms, studies on innovation processes as a support for firms' and regional resilience are very extensive and multifaceted (Conz, Magnani, 2020; Kantabutra, Ketprapakorn, 2021). In this regard, Do et al.

(2022), investigating small and medium-sized firms (SMEs) from Vietnam under the conditions of the covid pandemic, highlight innovation strategy and human resources policy as important to provide high quality human resources and conditions for knowledge diffusion as necessary to increase firms' innovation activities and support firms' resilience (Do et al., 2022). Dovbischuk (2022) also emphasises knowledge diffusion processes as important for the adaptability of firms to changes in the environment. In this respect, Dovbischuk (2022), analysing selected variables related to the resilience of firms in the context of the covid pandemic suggests that knowledge, as a result of collaboration within firms and with other firms, is crucial for innovation processes and, consequently, for the resilience of firms. Another study, by Pinto et al. (2019), on the resilience of Spanish firms during the financial crisis of 2008, among the variables used in the study, put the focus on expenditures on innovation activities, as the potential of firms for innovation processes under the occurrence of severe conditions. On the other hand, Gupta (2020) emphasises in particular the investment of firms in research and development (R&D) as crucial for innovation performance and adaptation to changes. Gupta (2020), who analyses the resilience of industrial firms in Spain during the financial crisis of 2008, provides evidence that, among others, firms' R&D expenditures, which indicate the ability to innovate, support firms' resilience to the occurrence of severe conditions. Firms' R&D expenditures are also an interest of the research by Destefanis and Rehman (2023) on the resilience of the European Union NUTS-2 regions in the period 2010−2016. In this vein, Bristow and Healy (2018) also support the view that firms' R&D expenditures are important for maintaining resilience. In addition, Bristow and Healy (2018) highlight the importance of patent applications as an effect of firms' innovation activities that can support regional resilience. The emphasis on firms' R&D expenditures and patent applications is also seen in the research by Engelen et al. (2021) on the resilience of firms from the United States during the financial crisis of 2008 and the covid pandemic. In this regard, Engelen et al. (2021) suggest that firms' R&D expenditures and patent applications can support firms' resilience especially when profitability of firms is low prior to the occurrence of severe conditions.

With regard to studies on innovation performance and firms' and regional resilience in the example of Poland, the multidimensionality of the issues addressed in this area should also be highlighted. For instance, the study by Pyrkosz-Pacyna et al. (2021) on the resilience of Polish SMEs during the covid pandemic, suggests that innovation processes are important for the resilience of firms but not the introduction of innovation in the occurrence of severe conditions as firms are focused on survival. On the other hand, Dyduch et al. (2021), who analyse the resilience of Polish SMEs during the covid pandemic point to, among others, the ability of firms to innovate and the availability of funds for innovation as crucial for the firms' resilience. Another study, by Wziątek-Kubiak and Pęczkowski (2021), provides evidence on the resilience of Polish firms during the financial crisis of 2008 by analysing forty-two drivers of firms' innovation activities. Among them, Wziątek-Kubiak and Pęczkowski (2021) particularly highlight firms' expenditures on innovation and R&D as the strongest for firms' adaptability to

economic shocks. However, apart from previous studies, there is still little evidence on firms' innovation processes and their adaptation to the occurrence of high constraints at the NUTS-2 level in Poland. Therefore, in order to address the importance of firms' innovation performance in firms' and regional resilience, it seems essential to examine how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as an adaptive attribute of firms' resilience to economic shocks. Hence, the hypothesis of this research is stated as follows:

H: Firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks differ at the NUTS-2 level in Poland.

## 3. Methodology

The research is based on data retrieved from Local Bank Data, Statistics Poland. This dataset provides information allowing the analysis of how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. In this respect, particular attention has been paid to data on the average share of innovative firms in the total number of firms and such firms' internal innovation potential as: firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland. The study refers to the period from 2018 to 2022, which allows to analyse the resilience of Polish firms under severe conditions associated with inflationary pressures and the covid pandemic. Table 1 presents the description and descriptive statistics of the variables applied for the study.

**Table 1.**
*Descriptive statistics of the variables*

| Variable | Description | Mean | St. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| the average share of innovative firms in the total number of firms ($X_1$) | the average share of innovative firms in the total number of firms (%) | 22.75 | 3.99 | 10.20 | 39.00 |
| firms' own funds for innovation activities ($X_2$) | own funds for innovation activities of firms (PLN) per inhabitant | 337.73 | 307.05 | 63.61 | 1648.73 |
| internal R&D expenditures in the business sector ($X_3$) | internal R&D expenditures in the business sector (PLN) per inhabitant | 644.01 | 548.59 | 100.57 | 3554.08 |
| internal R&D personnel in the business sector ($X_4$) | internal R&D personnel in the business sector per 1000 inhabitants | 2.50 | 1.90 | 0.63 | 10.01 |
| patent applications of firms filed at the Patent Office of the Republic of Poland ($X_5$) | patent applications of firms filed at the Patent Office of the Republic of Poland per 100000 inhabitants | 3.78 | 1.05 | 1.33 | 7.19 |

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

To investigate of how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks the comparative analysis, zero unitarization method and the multivariate analysis were applied. The comparative analysis enables to observe how the variables used in the study evolved during a difficult economic period, while the multivariate analysis and zero unitarization method were used to understand how Polish NUTS-2 regions differ in firms' innovation activities as the adaptive attribute of firms' resilience to the covid pandemic. These methods are regularly used to compare the variables and to analyse the differences between regions and countries (Zygmunt, A., 2017; Kiselakova et al., 2020). For this purpose, four classes were distinguished to illustrate: (i) regions with a very high level of variables related to firms' innovation activities, (ii) regions with a high level of variables related to firms' innovation activities, (iii) regions with an average level of variables related to firms' innovation activities, (iv) regions with a low level of variables related to firms' innovation activities. The first step was to use a constant reference point to normalise the variables (Kukuła, Bogocz, 2014).

$$R(X_{jt}) = \max_{it} x_{ijt} - \min_{it} x_{ijt} \tag{1}$$

The variables used in the study are stimulants. They were standardised using the following formula (Kukuła, Bogocz, 2014, p. 7):

$$z_{ijt} = \frac{x_{ijt} - \min_{it} x_{ijt}}{\max_{it} x_{ijt} - \min_{it} x_{ijt}} \tag{2}$$

where $z_{ijt} \in [0,1]$; $(i = 1,2,\dots,n)$; $(j = 1,2,\dots,m)$; $(t = 1,2,\dots,l)$.

Next, the synthetic index was used (Kiselakova et al., 2020):

$$SM_{it} = \frac{1}{m}\sum_{j=1}^{m} z_{ijt} \tag{3}$$

where $z_{ijt} \in [0,1]$; $SM_{it} \in [0,1]$; $(i = 1,2,\dots,n)$; $(j = 1,2,\dots,m)$; $(t = 1,2,\dots,l)$.

In the following step, the division of Polish NUTS-2 regions was made according to the formula:

(i) regions with a very high level of variables related to firms' innovation activities:

$$SM_{it} \geq \overline{SM_{it}} + S(SM_{it}) \tag{4}$$

where $(i = 1,2,\dots,n)$; $(t = 1,2,\dots,l)$.

(ii) regions with a high level of variables related to firms' innovation activities:

$$\overline{SM_{it}} \leq SM_{it} < \overline{SM_{it}} + S(SM_{it}) \tag{5}$$

where $(i = 1,2,\dots,n)$; $(t = 1,2,\dots,l)$

(iii) regions with an average level of variables related to firms' innovation activities:

$$\overline{SM_{it}} - S(SM_{it}) \leq SM_{it} < \overline{SM_{it}} \tag{6}$$

where $(i = 1,2,\dots,n)$; $(t = 1,2,\dots,l)$.

(iv) regions with an average level of variables related to firms' innovation activities:

$$SM_{it} < \overline{SM_{it}} - S(SM_{it}) \tag{7}$$

where $(i = 1,2,\dots,n)$; $(t = 1,2,\dots,l)$

Where (Zygmunt, A., 2017):

$$\overline{SM_{it}} = \frac{1}{n}\sum_{j=1}^{n} SM_{it} \tag{8}$$

where $(i = 1,2, \dots, n)$; $(t = 1,2, \dots, l)$.

$$S(SM_{it}) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(SM_{it} - \overline{SM_{it}})^2} \tag{9}$$

where $(i = 1,2, \dots, n)$; $(t = 1,2, \dots, l)$.

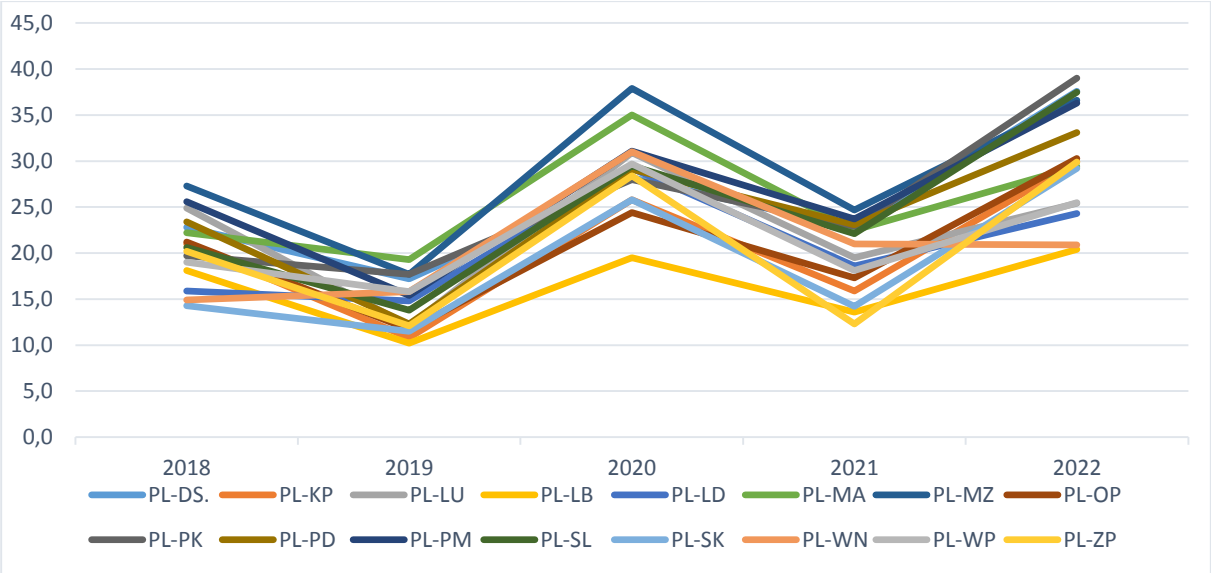
This procedure makes it possible to analyse how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks.

## 4. Results and discussion

### 4.1. The results of the comparative analysis

Figures 1-5 show the results of the comparative analysis of the variables used in the study. A comparison of the average share of innovative firms in the total number of firms, firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland at the NUTS-2 level reveals some key characteristics. In terms of the average share of innovative firms in the total number of firms the results show that changes in the environment have a similar impact on innovative attitude of firms in all Polish NUTS-2 regions (Figure 1).

The findings indicate that the average share of innovative firms in the total number of firms decreased in 2019 and 2021, while an increase in the average share of share of innovative firms in the total number of firms is observed for the years 2020 and 2022. The observed increase in the innovative attitude of the Polish firms, as an adaptation to economic shocks, is in line with the research by Iammarino et al. (2021) and Dovbischuk (2022), suggesting that the innovativeness of firms increases their resilience to changes in the environment. This feature requires further, detailed investigation, especially for 2019 and 2021, when the innovative attitude of Polish firms was contrary to expectations.

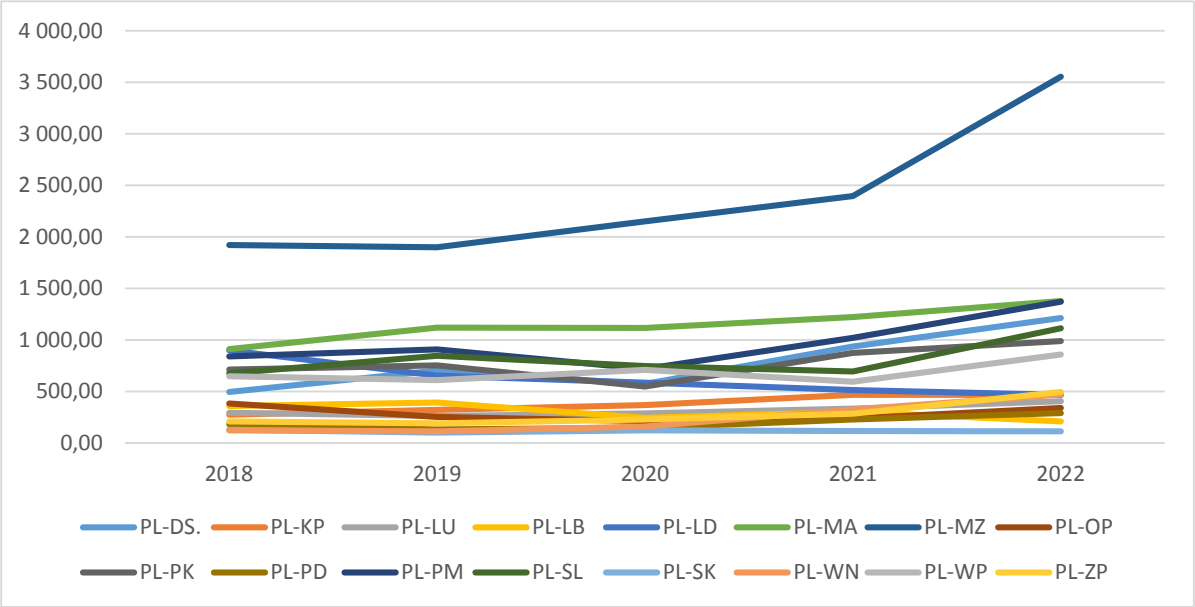



Legend: PL-DS – Lower Silesian Voivodship; PL-KP – Kuyavian-Pomeranian Voivodship; PL-LU – Lublin Voivodship; PL-LB – Lubusz Voivodship; PL-LD – Łódź Voivodship; PL-MA – Lesser Poland Voivodship; PL-MZ – Masovian Voivodship; PL-OP – Opole Voivodship; PL-PK – Subcarpathian Voivodship; PL-PD – Podlaskie Voivodship; PL-PM – Pomeranian Voivodship; PL-SL – Silesian Voivodship; PL-SK – Świętokrzyskie Voivodship; PL-WN – Warmian-Masurian Voivodship; PL-WP – Greater Poland Voivodship; PL-ZP– West Pomeranian Voivodship.

**Figure 1.** The average share of innovative firms in the total number of firms in Poland in 2018-2022 (%).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

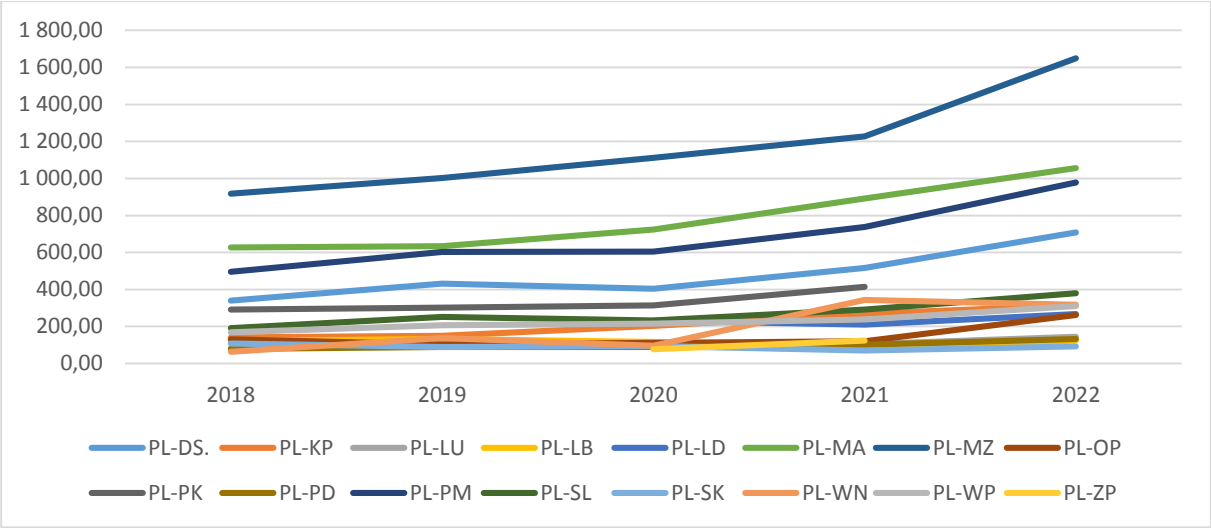
Taking into account the internal expenditures on innovation activities, the results show that firms in the majority of Polish NUTS-2 regions spend most of their own funds on R&D expenditures (Figures 2-3).




Legend: like in Figure 1.

**Figure 2.** Own funds for innovation activities of Polish firms (PLN) per inhabitant (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

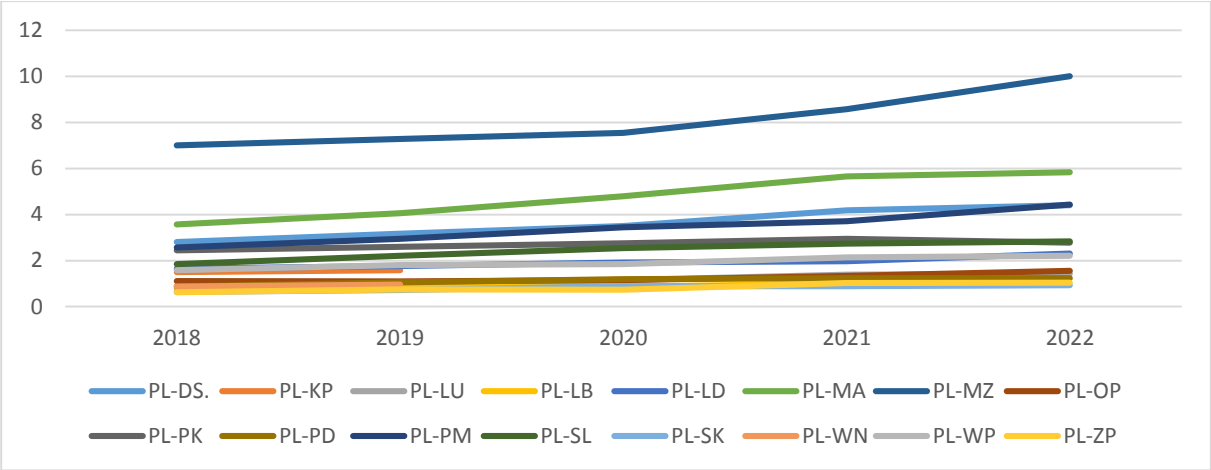



Legend: like in Figure 1. Lack of data: 2019 − PL-LD, PL-ZP; 2022 − PL-PK, PL-ZP.

**Figure 3.** Internal R&D expenditures in the business sector (PLN) per inhabitant in Poland (2018-2022). Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

This feature can be observed throughout the period 2018−2022, which indicates the attitude of Polish firms towards the development of products, services and processes as a necessity to adapt to changes and to maintain or increase competitive advantages. This is particularly evident in 2019, when firms from the majority of Polish NUTS-2 regions increase their attention to innovation processes, increasing both their own funds and internal expenditures on innovation activities in response to rising inflationary pressures. This is in line with the study by Pacheco et al. (2013), which highlights that firms' innovativeness strengthens their resilience to economic disturbances. The results suggest that the emphasis on firms' innovation processes was further strengthened in the majority of NUTS-2 regions in Poland when the covid pandemic forced them to face new requirements of environment. This is consistent with the empirical evidence provided by Do et al. (2022), Gajewski (2022) and Destefansis and Rehman (2023) that innovation processes allow firms to adapt to economic shocks. An interesting feature has also been identified for 2021-2022, when firms from the majority of Polish NUTS-2 regions continue to increase the use of own funds for innovation activities as well as internal expenditures on R&D. This may indicate that there is still need for Polish firms to adapt to changes and to strengthen their ability to withstand future economic shocks. This may lead to an increase in the competitiveness of firms and, consequently, to an increase in the competitiveness of regions. Such results are in line with the research of Pinto et al. (2019) that innovation processes can make firms more resilient in times of economic slowdown.

The results show that Polish firms from all NUTS-2 regions increased the number of internal R&D personnel between 2018 and 2022 (Figure 4). This may indicate that firms were aiming to raise their human resources potential as crucial for innovation activities and increasing competitiveness.



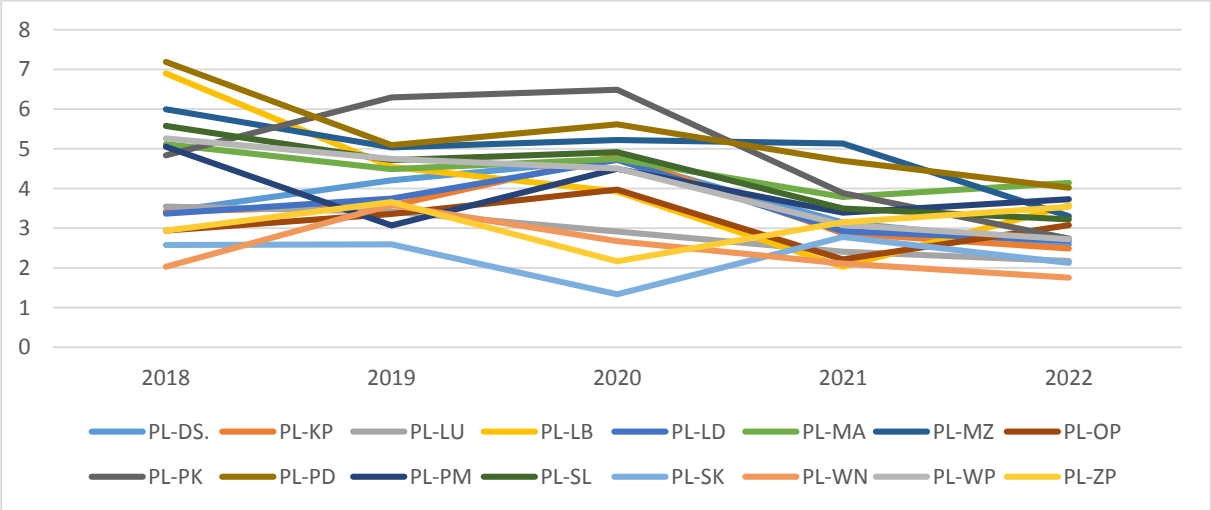

Legend: like in Figure 1. Lack of data: 2020-2021 − PL-KP, PL-WN; 2022 − PL-LB, PL-WN.

**Figure 4.** Internal R&D personnel in the business sector per 1000 inhabitants in Poland (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

This is also evident during the economic shock of the covid pandemic, suggesting that Polish firms were aware that their maintenance or development was linked to innovation processes. Importantly, the results show that Polish firms in all NUTS-2 regions continued to increase the number of internal R&D personnel after the covid pandemic, which may indicate the need for further potential building to increase the resilience of firms. This is in line with the evidence provided by Teixeira et al. (2013), Muštra (2020), and Wziątek-Kubiak and Pęczkowski (2021) that R&D personnel is crucial in facing economic disturbances and strengthening the resilience of firms.

Regarding patents as the ability of firms to absorb of knowledge and innovation potential, the results allow to point out a decrease in the number of patent applications of firms filed at the Patent Office of the Republic of Poland in the majority of NUTS-2 regions (Figure 5).




Legend: like in Figure 1.

**Figure 5.** Patent applications of firms filed at the Patent Office of the Republic of Poland per 100000 inhabitants (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

According to the results, the decline in patenting is observed throughout 2018-2022 period and may indicate that Polish firms have focused on forms of innovation other than product innovation to increase firms' resilience. This is not consistent with the evidence provided by Bristow and Healy (2018) and requires further, detailed investigation. One reason for this may be that the need to adapt to changes in the environment requires a greater emphasis on service or process innovation.

### 4.2. The results of zero unitarization method and the multivariate analysis

Table 2 shows the results of zero unitarization method and the multivariate analysis of the variables under consideration for the period 2018-2022.

**Table 2.**
*Firms' innovation activities as the adaptive attribute of firms' resilience in Poland at the NUTS-2 level in 2018–2022 (the multivariate analysis)*

| 2018 | | | 2019 | | | 2020 | | | 2021 | | | 2022 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Co.** | **SM** | **No.** | **Co.** | **SM** | **No.** | **Co.** | **SM** | **No.** | **Co.** | **SM** | **No.** | **Co.** | **SM** |
| Very High | | | Very High | | | Very High | | | Very High | | | Very High | | |
| 1. | PL-MZ | 0.954 | 1. | PL-MZ | 0.896 | 1. | PL-MZ | 0.951 | 1. | PL-MZ | 1.000 | 1. | PL-MZ | 0.902 |
| 2. | PL-MA | 0.553 | 2. | PL-MA | 0.636 | 2. | PL-MA | 0.643 | 2. | PL-MA | 0.641 | 2. | PL-PM | 0.604 |
| High | | | High | | | High | | | High | | | High | | |
| 1. | PL-PM | 0.533 | 1. | PL-PK | 0.541 | 1. | PL-PM | 0.490 | 1. | PL-PM | 0.539 | 1. | PL-MA | 0.582 |
| 2. | PL-PK | 0.368 | 2. | PL-DS. | 0.457 | 2. | PL-PK | 0.439 | 2. | PL-DS. | 0.474 | 2. | PL-DS. | 0.467 |
| 3. | PL-SL | 0.364 | 3. | PL-PM | 0.410 | 3. | PL-DS. | 0.416 | 3. | PL-PK | 0.469 | 3. | PL-SL | 0.444 |
| 4. | PL-DS. | 0.359 | 4. | PL-SL | 0.358 | 4. | PL-SL | 0.393 | 4. | PL-SL | 0.389 | Average | | |
| 5. | PL-PD | 0.358 | 5. | PL-WP | 0.355 | Average | | | 5. | PL-PD | 0.370 | 1. | PL-PD | 0.343 |
| Average | | | Average | | | 1. | PL-WP | 0.351 | Average | | | 2. | PL-KP | 0.246 |
| 1. | PL-WP | 0.311 | 1. | PL-WN | 0.196 | 2. | PL-PD | 0.289 | 1. | PL-WP | 0.265 | 3. | PL-OP | 0.234 |
| 2. | PL-LB | 0.292 | 2. | PL-PD | 0.195 | 3. | PL-LU | 0.220 | 2. | PL-LD | 0.246 | 4. | PL-WP | 0.177 |
| 3. | PL-LU | 0.253 | 3. | PL-LB | 0.154 | 4. | PL-LD | 0.347 | 3. | PL-LU | 0.178 | | | |
| 4. | PL-LD | 0.220 | 4. | PL-KP | 0.130 | 5. | PL-ZP | 0.140 | 4. | PL-OP | 0.123 | 5. | PL-LD | 0.130 |
| 5. | PL-KP | 0.219 | 5. | PL-LU | 0.113 | Low | | | 5. | PL-ZP | 0.100 | | | |
| 6. | PL-OP | 0.201 | 6. | PL-OP | 0.106 | 1. | PL-OP | 0.183 | Low | | | Low | | |
| Low | | | Low | | | 2. | PL-LB | 0.124 | 1. | PL-SK | 0.079 | 1. | PL-SK | 0.074 |
| 1. | PL-ZP | 0.142 | 1. | PL-SK | 0.029 | 3. | PL-SK | 0.076 | 2. | PL-LB | 0.042 | 2. | PL-LU | 0.056 |
| 2. | PL-SK | 0.033 | | | | | | | | | | | | |
| 3. | PL-WN | 0.017 | | | | | | | | | | | | |

Legend: like in Figure 1. Lack of data: like in Figure 3, Figure 4.

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

The results confirm the stated hypothesis and reveal a relatively high diversity between Polish regions at the NUTS-2 level in regard to firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. Some interesting features can be observed in this respect. First, the research shows that among the changes in the environment in the 2018-2022, including the economic shock related to the covid pandemic, the highest diversity between Polish NUTS-2 regions in the variables under consideration can be observed almost between the very same regions. The highest diversity can be seen between Masovian Voivodship, Lesser Poland Voivodship, Pomeranian Voivodship and Świętokrzyskie Voivodship, Lublin Voivodship. This indicates that despite the changes in the environment,

there have been no substantial differences in the distance between Polish regions with the highest and the lowest level of variables related to firms' innovation activities. Such an occurrence may result from the resilience of regions to economic shocks, which, together with innovation activities of firms, may have an impact on maintaining the resilience of firms under severe conditions - as provided by Bristow and Healy (2018). This may be also related to the conditions created by regions to stimulate the innovation potential of firms as an effect of interactions between the competitiveness of firms and the competitiveness of regions. For this reason, the observed feature for Polish NUTS-2 regions requires further detailed research. Another interesting feature is related to the relatively high level of variables related to innovation activities of firms in Polish regions at the NUTS-2 level in the period 2018-2022. This should be considered positive, as it may have broader impact on increasing the resilience of firms and regions to the changes in the environment. In this respect, the results show that in about half of the Polish NUTS-2 regions, despite the economic shocks that occurred during the period considered, the level of variables related to firms' innovation activities in Polish regions is very high or high. In addition, a large number of NUTS-2 regions show the average level of variables related to firms' innovation activities, which should also be seen as positive, as this potential did not decrease despite the occurrence of severe conditions. It is also positive that only a small number of regions were characterised by the low level of variables related to firms' innovation activities despite having to cope with substantial changes in their environment. This may be related to firms' awareness that innovation potential can support to maintain and increase firms' resilience.

## 5. Conclusions

This research contributes to the growing body of knowledge on innovation and firms' resilience. The study provides evidence on how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience under conditions of high constraints. Particular attention was paid to the period 2018-2022, when Polish firms operated under inflationary pressures and the covid pandemic. The results indicate that, despite the economic shocks, the highest diversity among Polish NUTS-2 regions in the considered variables can be found almost between the very same regions. This can be explained by the resilience of regions to economic shocks, which, together with the innovative activities of firms, can help to maintain the resilience of firms under difficult conditions. The results also show that the majority of Polish NUTS-2 regions, despite the occurrence of high constraints, have a very high, high or average level of variables related to innovation activities of firms. This may be due to the fact that firms are aware that innovativeness can contribute to maintaining and improving firms' resilience.

The research offers implications for practitioners and policy makers. As firms' innovation activities is considered to have an impact on maintaining the resilience of firms under severe conditions, further strengthening of the innovation potential is crucial. Therefore, firms should take further actions to strengthen the drivers of innovation. It is also necessary for public institutions to continue to provide conditions that encourage firms to innovate.

This study is not without limitations, which are associated with the variables related to firms' innovation activities. As the research focuses on variables related to the firms' internal potential for innovation processes, it would be valuable to consider other drivers of firms' innovation activities in order to better understand the relationship between firms' innovativeness and firms' resilience. In this respect, it seems important for future studies to examine the diffusion of knowledge between firms and other firms, research organisations and government institutions as crucial for strengthening firms' innovation activities, which may increase firms' resilience to changes in the environment. Furthermore, as the decline in patenting by Polish firms is observed over the period, it would be valuable to conduct studies on the service or process innovation as important for firms' adaptation to changes in the environment. As the studies found that, despite the occurrence of severe conditions, there were no substantial differences in the distance between Polish regions with the highest and the lowest level of variables related to firms' innovation activities, future research should also further examine issues related to the mutual interactions between the competitiveness of firms and the competitiveness of regions as crucial for firms' resilience.

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