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EXPENDITURES ON INNOVATION ACTIVITIES OF FIRMS IN POLAND AT THE NUTS-2 LEVEL (COVID AND POST-COVID PERSPECTIVES)

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Purpose: This research aims to identify how expenditures on firms' innovation activities in Poland differ at the NUTS-2 level (with a focus on the covid and post-covid perspectives).
Design/methodology/approach: This study adopts the following methods: comparative analysis, zero unitarization method and multivariate analysis. The research draws on data from Local Bank Data, Statistics Poland, related to expenditures on firms' innovation activities in the period 2018−2022.
Findings: The results reveal that, despite of the occurrence of conditions of high constraints caused by the covid pandemic, the highest diversity in expenditures on innovation is observed between almost the very same Polish NUTS-2 regions in 2018-2022. The results also indicate that the covid pandemic noticeably encourages Polish firms, especially from the service sector, to increase expenditures on innovation processes.
Research limitations/implications: This study has some limitations. As the focus of the research is on total firms' innovation expenditures and firms' own resources for innovation, it would be useful to see whether the results are similar for other variables describing expenditures on firms' innovation activities. It would also be worth investigating the reasons for maintaining the highest diversity between Polish NUTS 2 regions in terms of expenditure on firms' innovation processes, which can be observed almost between the same regions despite the conditions of severe constraints due to the covid pandemic.
Practical implications: The results suggest a further strengthening of the pro-innovation attitude of Polish industrial and service firms. The research also highlights the need for policy makers to further strengthen the conditions for fostering innovation processes of firms.
Originality/value: This research contributes to the ongoing discussion on the drivers and sources of firms' innovation activities through the identification of the differences between the NUTS-2 regions in Poland in terms of expenditures on innovation activities in the covid and post-covid perspectives. The study also reveals more about the innovation processes of Polish firms under severe conditions.
Keywords: expenditures on firms' innovation activities, innovation activities of firms, the covid perspective, the post-covid perspective.
Category of the paper: research paper.

1. Introduction

As firms' innovation activities is valued for its contribution to firms' competitiveness (Fitsch et al., 2020), the increasing body of research addresses the drivers and sources of innovation (Isaksen, Jakobsen, 2017; Lehnert et al., 2020; Zygmunt, 2020; Gritlsch, 2021; Zygmunt, 2022b; Brodny, Tutak, 2022). The growing interest in this area stems from the crucial role of firms' innovation performance not only for firms' competitiveness but also for the competitiveness of regions and countries (Fitsch et al., 2020). This relationship is of concern in endogenous growth and knowledge spillover theories, which emphasise networks between firms and, inter alia, the research system and government institutions (Gritlsch, 2021). Over the decades, scholars have highlighted, among others, the role of knowledge cooperation in firms' innovation activities (Isaksen, Jakobsen, 2017). Other studies focus specifically on the relationship between human resources and the improvement of firms' innovativeness (Zygmunt, 2022b). Research and development (R&D) processes have also attracted interest as a driver of firms' innovation performance (Lehnert et al., 2020). Research attention has also been paid to expenditures on firms' innovation activities. Such expenditures are believed to be a key element in increasing firms' innovativeness (Decyk, 2023). This study focuses on the above driver of firms' innovation activities to provide further considerations in this area. Previous studies provide evidence that the issues related to expenditures on firms' innovation activities have been previously considered for Poland. In this context, the main areas of research have been placed mostly on firms' R&D expenditures as a stimulator of firms' innovativeness (Zygmunt, 2020a; Lubacha, 2021; Wyrwa, 2022; Brodny, Tutak, 2022; Decyk, 2023). The previous research also has considered the innovation processes of Polish firms under severe conditions, such as the covid pandemic (Kozioł-Nadolna, 2022; Dominiak, Rachwał, 2022; Wojnicka-Sycz et al., 2022). However, there is still a relatively small amount of research on expenditures on innovation performance of Polish firms in the context of the covid and post-covid perspectives. This, together with the growing need to understand the attitude of Polish firms towards innovation under conditions of high constraints, motivated this research. Therefore, this study aims to assess how expenditures on firms' innovation activities in Poland differs at the NUTS-2 level (with a focus on the covid and post-covid perspectives). The hypothesis was tested using the following methods: comparative analysis, zero unitarization method and multivariate analysis. The data for this study comes from Local Bank Data, Statistics Poland. The 2018-2022 period is covered in this study.

This study provides contribution to the ongoing discussion on innovation drivers and sources by identifying of how NUTS-2 regions in Poland differ in terms of expenditures on firms' innovation activities in the covid and post-covid perspectives. This research also sheds more light on the innovation processes of Polish firms under severe conditions.

The paper proceeds as follows: the first section builds the theoretical background and hypothesis development. The next section presents the methodology used to explore how expenditures on firms' innovation activities in Poland differ at the NUTS-2 level (with a focus on the covid and post-covid perspectives). The results of the study are then presented. Conclusions, implications, limitations and suggestions for further research are presented in the last section.

2. Literature review

The growing interest in expenditures on firms' innovation activities stems from the need to understand the drivers and sources of firms' innovation processes. This is because firms' innovativeness can shift firms' competitive advantages, which can contribute to the competitiveness of regions and countries (Fitsch et al., 2020). In this context, expenditures on firms' innovation activities is considered to be essential for stimulating firms' innovation attitudes (Zygmunt, 2020a; Decyk, 2023). For this reason, research in this area is of great importance and has been the subject of a number of studies (Brodny, Tutak, 2022; Wyrwa, 2022). In this respect, various aspects of expenditure on innovation activities of firms are the focus of the research considered for Poland. In particular, a lot of attention has been paid to firms' R&D expenditures as a booster of the innovation capacity of firms. In this vein, Zygmunt (2020a) applies R&D expenditures of firms to assess the differentiation between Polish NUTS-2 regions in terms of intramural R&D expenditures incurred by firms, universities and regional policy actors. Wyrwa (2022) uses R&D expenditures of firms as an important indicator of firms' innovation activities and innovation development of the European Union countries. On the other hand, Brodny and Tutak (2022) apply R&D expenditures of firms as a one of the indicators to assess the innovation capacity of Polish NUTS-2 regions. Firms' R&D expenditures are also used as a one of the measures of innovation activities of firms in the study of regional innovativeness in Poland provided by Lubacha (2021). Another study, by Decyk (2023), emphasises not only firms' R&D expenditures but also other expenditures on innovation activities of firms (such as, among others, investment expenditures) in order to evaluate the level of innovation activities between the Member States of the European Union. Special attention is paid here to the innovation capacity of the service sector. Thus, the above studies suggest that the issues related to expenditures on firms' innovation activities in Poland are a relevant area of research, that can be approached from different perspectives.

With regard to expenditures on innovation activities by firms, it seems crucial to also consider the attitude of Polish firms towards innovation under conditions of high constraints. This is related to the argument that firms through the crisis may characterise the innovation capacity to adapt to changes and be more resilient (Heinonen, Strandvik, 2020; Hossain, 2020;

Schilling, 2020; Sheng et al., 2020; Netz et al., 2022). Consistent with this argument are the majority of the results on the attitudes of Polish firms under conditions of severe constraints induced by the covid pandemic. Among them, Wojnicka-Sycz et al. (2022) provide evidence that the majority of Polish firms from Subcarpathian Voivodship and Lower Silesian Voivodship distinguish an increase in innovation processes as an effect of the need to face to new requirements of the environment. Similarly, Kozioł-Nadolna (2022) finds that during the covid pandemic firms from West Pomeranian Voivodship do not indicate a significant reduction in their innovation activities. Another study, by Dominiak and Rachwał (2022), pays special attention to the attitude of the industrial and service sectors in the context of the high constraints of the covid pandemic. In this regard, Dominiak and Rachwał (2022) indicate that the covid pandemic has a short-term impact on the industrial and service sectors in Poland. Dominiak and Rachwał (2022) also provide evidence that the industrial and service sectors during the covid pandemic show better resilience to conditions of high constraints than during the 2009 global crisis. This is consistent with the argument of Heinonen, Strandvik (2020), Hossain (2020), Schilling (2020), Sheng et al. (2020), and Netz et al. (2022) that firms through the crisis may characterise the attitude to adapt to changes and be more resilient. In this vein, Gajewski and Kutan (2023), considering among others the attitude of Polish firms under severe conditions, find that Polish NUTS-4 that were better adapted to the 2009 global crisis were also better adapted to the changes caused by the covid pandemic.

The above studies highlight the growing interest in understanding the attitude of Polish firms towards innovation under conditions of high constraints. While there is a dearth of research on how expenditures on firms' innovation activities in Poland differs at the NUTS-2 level in the covid and post-covid perspectives this study aims to fill this gap. Thus, the hypothesis to be tested is as the following:

H: Innovation activities in Poland differ at the NUTS-2 level (in the covid and post-covid perspectives).

3. Methodology

The data for this research was gathered from Local Bank Data, Statistics Poland, as a dataset which makes it possible to analyse how expenditures on firms' innovation activities in Poland differ at the NUTS-2 level in the covid and post-covid perspectives. A special focus has been placed on data related to total expenditures on innovation activities in order to illustrate in total all the sources through which firms in Poland improve their innovation processes under conditions of high constraints. These include domestic funds from public institutions, own funds, foreign funds and credits, loans and other financial liabilities from banks and financial institutions. To understand how Polish firms were willing to finance innovation

activities from their own resources under conditions of severe constraints, the data on firms' own funds for innovation activities were have been included separately for the study. To illustrate the differences between sectors, the data on expenditures on innovation activities were collected for industrial and service firms. In order to show the changes in expenditures on innovation activities in Poland at the NUTS-2 level in the covid and post-covid perspectives, the study covers the period 2018-2022. Table 1 presents descriptive statistics of the variables.

Table 1.
Descriptive statistics

Variable	Description	Mean	St. Dev.	Min.	Max.
industrial firms with expenditures on innovation activities (X_1)	industrial firms with expenditures on innovation activities (%)	16.70	2.95	8.80	26.20
service firms with expenditures on innovation activities (X_2)	service firms with expenditures on innovation activities (%)	9.58	3.92	1.70	28.80
total expenditures on innovation activities by industrial firms (X_3)	total expenditures on innovation activities by industrial firms (PLN) per inhabitant	504.11	243.57	184.22	1424.21
total expenditures on innovation activities by service firms (X_4)	total expenditures on innovation activities by service firms (PLN) per inhabitant	346.38	486.78	1.79	3104.62
own funds for innovation activities of industrial firms (X_5)	own funds for innovation activities of industrial firms (PLN) per inhabitant	375.43	191.13	88.89	842.17
own funds for innovation activities of service firms (X_6)	own funds for innovation activities of service firms (PLN) per inhabitant	297.75	464.85	1.79	2855.51

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

In order to examine how expenditures on innovation activities differs in Poland at the NUTS-2 level in the covid and post-covid perspective, the following methods were used: comparative analysis, zero unitarization method and multivariate analysis. The first one allows for a comparative analysis of the variables used in the study between Polish NUTS-2 regions. The zero unitarization method and multivariate analysis on the other hand allow for an understanding of how NUTS-2 regions in Poland differ in terms of expenditures on innovation activities in the covid and post-covid perspective. The following methods are commonly used to make variables comparable (Kiselakova et al., 2020). First, a constant reference point was employed to normalize the variables (Kukuła, Bogocz, 2014):

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

As the variables used in the study are stimulants, they were standardised according to the formula (Kukuła, Bogocz, 2014):

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

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

The synthetic index was then calculated as follows (Kiselakova et al., 2020):

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

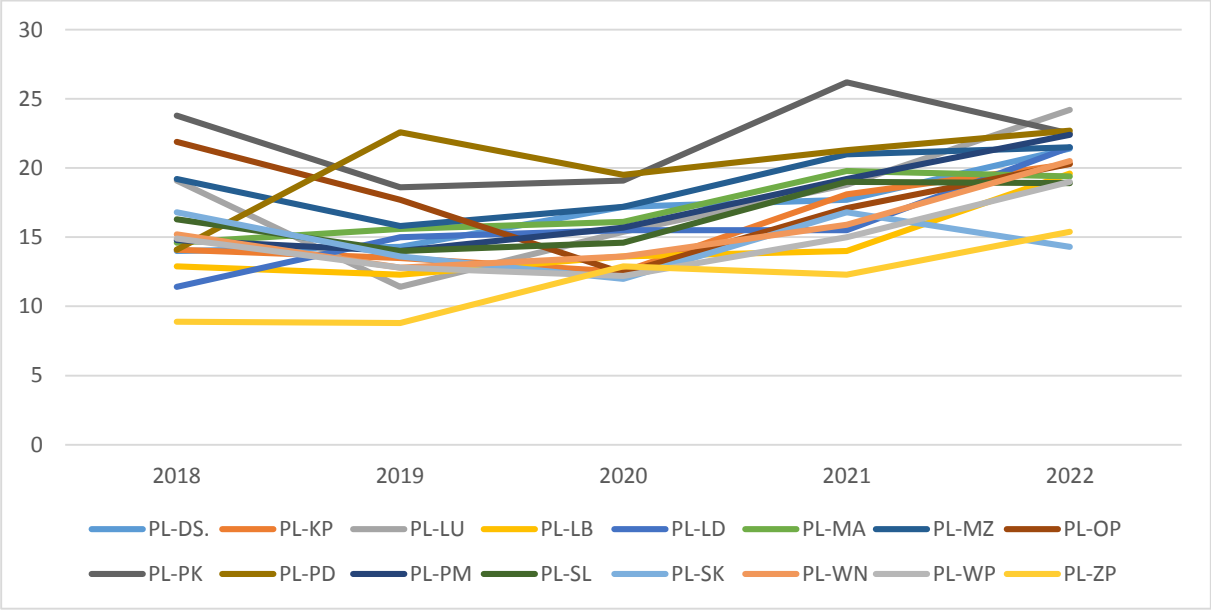
where $z_{ijt} \in [0,1]$; $SM_{it} \in [0,1]$; $(i = 1,2,\dots,n)$; $(j = 1,2,\dots,m)$; $(t = 1,2,\dots,l)$.

This approach allows to analyse differences in innovation expenditure in Poland at the NUTS-2 level in the covid and post-covid perspectives.

4. Results and discussion

4.1. The comparative analysis

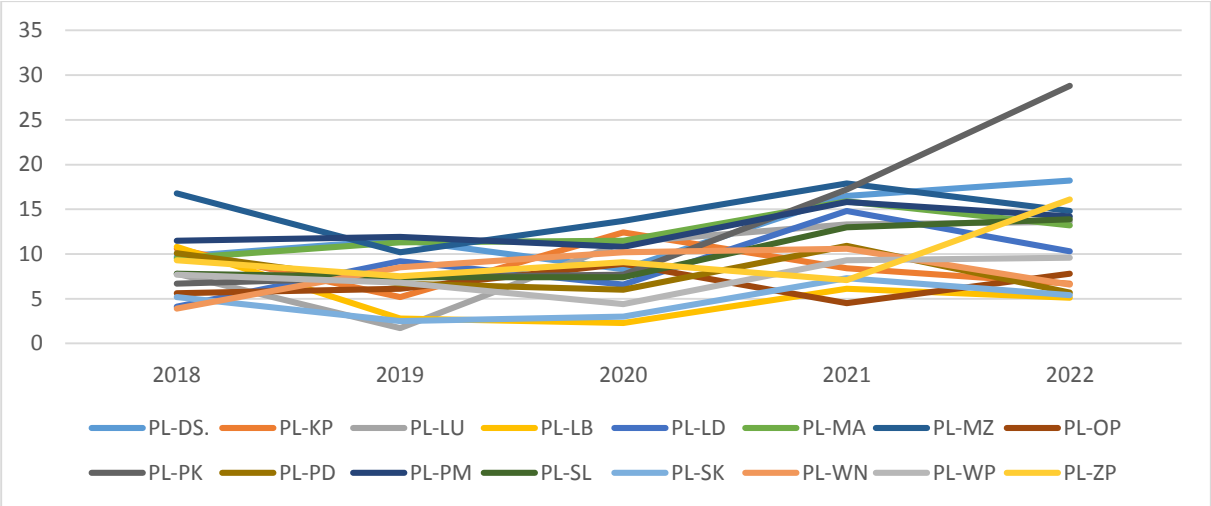
The results of the comparative analysis of the variables considered in the study reveal interesting features for 2018-2022 (Figures 1-6). Regarding the sector of analysis, the results show a higher percentage of industrial firms spending on innovation activities than service firms (Figures 1-2). This can be observed not only in the covid perspective but also in the post-covid perspective in the majority of NUTS-2 regions in Poland. Apart from this, similar trends can be seen in the industrial and service sectors.



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. Percentage of industrial firms with expenditures on innovation activities in Poland (2018-2022).

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

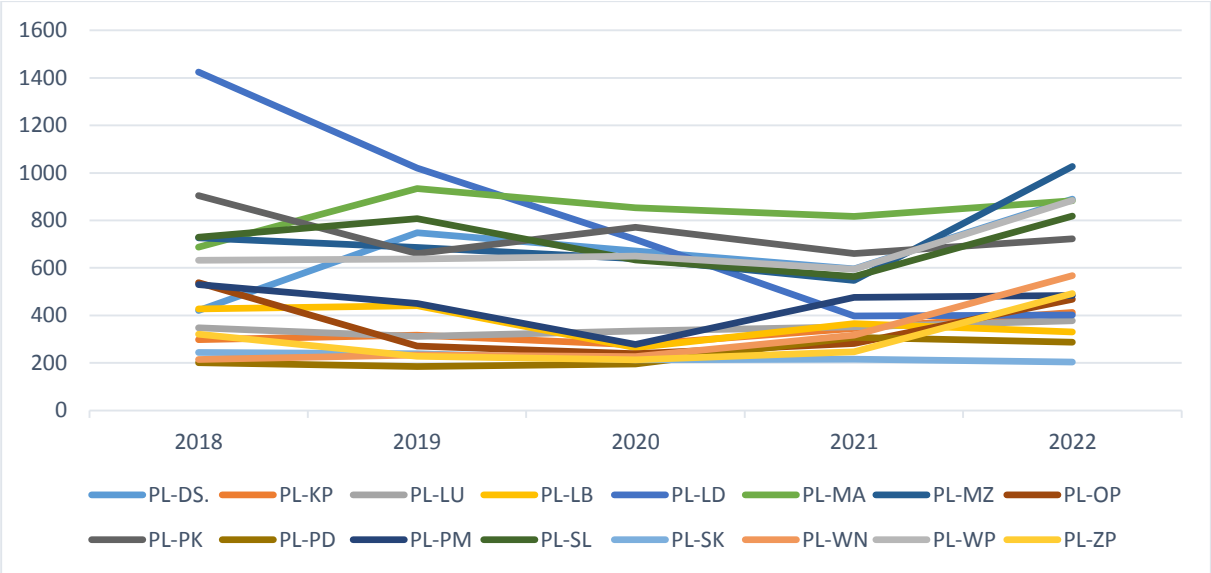


Legend: like in Figure 1.

Figure 2. Percentage of service firms with expenditures on innovation activities in Poland (2018-2022). Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

The findings indicate that, with the exception of 2019, the percentage of industrial and service firms with expenditures on innovation processes is increasing in the majority of Polish NUTS-2 regions. This is also evident in the conditions of severe constraints experienced by firms in the covid perspective (especially in 2020). This may be related to the need to invest in innovative solutions in order to adapt to extraordinary demands of the market environment. This is in line with the results of the study by Heinonen and Strandvik (2020), which suggest that conditions of severe constrains can shift firms' innovation processes. The results show above-average percentage of service firms involved in innovation activities. This is especially seen for the year 2021 in the majority of Polish NUTS-2 regions. This may be due to the need to implement the solutions imposed on the service sector. The increase in the percentage of industrial and service firms with expenditures on innovation activities is also observed in the majority of NUTS-2 regions in Poland in the post-covid perspective. This may indicate the need for Polish firms to further increase their competitive advantage.

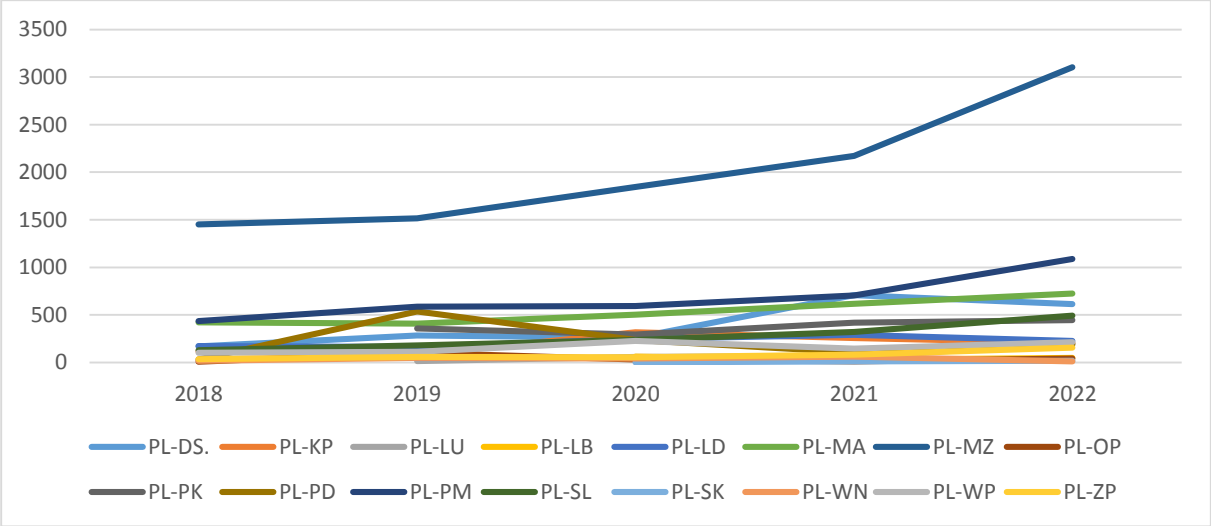
In terms of total expenditures on innovation activities, the results suggest that industrial firms in the majority of Polish NUTS-2 regions have more resources for innovation processes than service firms (Figures 3-4). This can be observed for the whole period 2018-2022.



Legend: like in Figure 1.

Figure 3. Total expenditures on innovation activities by industrial firms (PLN) per inhabitant in Poland (2018-2022).

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



Legend: like in Figure 1. Lack of data: 2018 − PL-LU, PL-PK, PL-SK; 2019 − PL-LB, PL-SK.

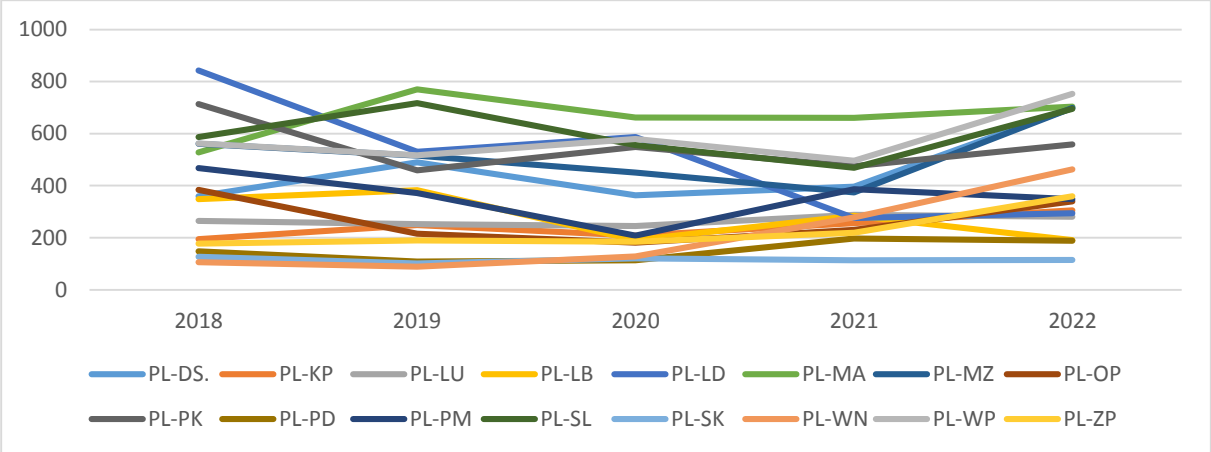
Figure 4. Total expenditures on innovation activities by service firms (PLN) per inhabitant in Poland (2018-2022).

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

Simultaneously, it should be emphasized that service firms in the majority of Polish NUTS-2 regions show significantly higher growth in total innovation expenditures compared to industrial firms. This is particularly observed in 2019 and 2020, which may be due to the need to increase the competitive advantage of this sector and its adaptation to the needs caused by the covid pandemic (2020). This is consistent with the results of the study by Dominiak and Rachwał (2022) on the short term-impact of the covid pandemic on industrial sector in Poland. This situation continues (albeit to a lesser extent) in 2021, where a stronger upward trend in total expenditures on innovation activities is observed for service firms than for industrial firms.

For both the industrial and the service firms, there is a noticeable increase in expenditures on innovation activities in the post-covid period in the majority of Polish NUTS-2 regions. This may indicate firms' focus on development rather than survival. It may lead to an improvement in their competitive advantage and, through the simultaneous effect, also impact on regional and national competitiveness. Such results are consistent with the studies provided by Hossain (2020), Schilling (2020), Sheng et al. (2020) and Netz et al. (2022) that firms through the crisis may characterise the innovation capacity to adapt to changes and be more resilient.

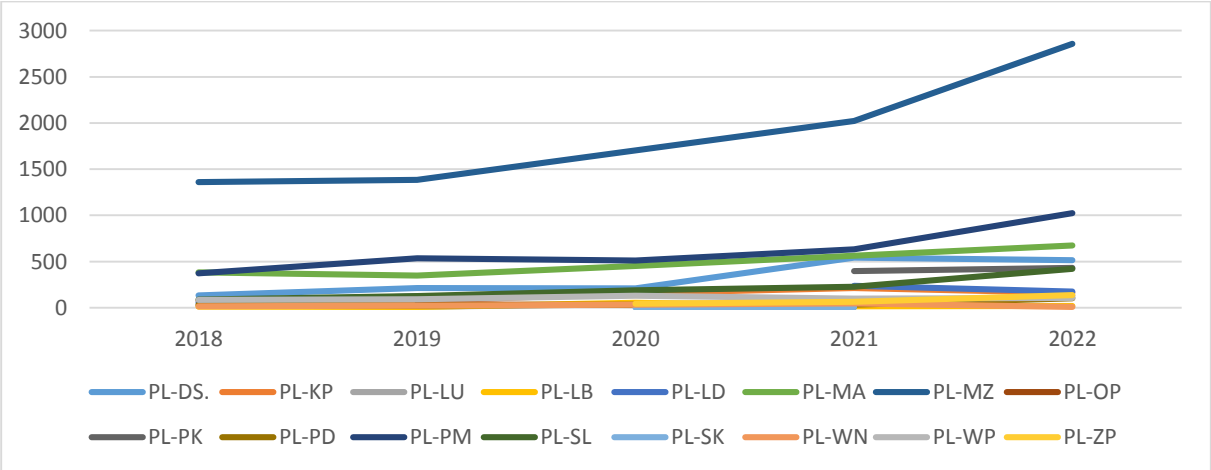
When considering the use of firms' own funds for innovation, the results indicate that both industrial and service firms in most Polish NUTS-2 regions predominantly financed innovation activities from their own resources in 2018-2022 (Figures 5-6).



Legend: like in Figure 1.

Figure 5. Own funds for innovation activities of industrial firms (PLN) per inhabitant in Poland (2018-2022).

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



Legend: like in Figure 1. Lack of data: 2018 – PL-OP, PL-PK, 2019 – PL-SK, PL-ZP, 2020 – PL-LD, PL-PK, 2022 – PL-OP, PL-SK.

Figure 6. Own funds for innovation activities of service firms (PLN) per inhabitant in Poland (2018-2022).

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

According to the results, such a feature can also be observed for the covid perspective, when firms have to face conditions of high constraints. In this respect it is important to note that firms were willing to increase the level of own resources for innovation activities. This is consistent with the findings of Wojnicka-Sycz et al. (2022), who point to an increase in innovation processes as a result of the need to face new environmental requirements. This is especially seen for service firms from the majority of Polish NUTS-2 regions and may indicate the need to develop innovation processes in order to adapt to severe constraints. This is in line with the empirical evidence provided by Dominiak and Rachwał (2022), who indicate the changes in the service sector caused by the covid pandemic. With regard to industrial firms, the results show a decrease in the allocation of own resources to innovation activities in 2020 and 2021 (for the majority of Polish NUTS-2 regions). This may suggest that this sector tends to focus on survival rather than increasing competitive advantage in the covid perspective. The results for the post-covid perspective suggest an increased involvement of own resources in innovation activities for both sectors for most Polish NUTS-2 regions, which may imply to a turn towards strengthening innovation processes and thus contribute to strengthening the competitive advantage of regions and country.

4.2. The zero unitarization method and multivariate analysis

The outcomes of the zero unitarization method and multivariate analysis show a relatively high diversity between Polish NUTS-2 regions in terms of expenditures on innovation activities in the covid and post-covid perspectives (Table 2).

Table 2.
Expenditures on innovation activities of Polish firms at the NUTS-2 level in 2018-2022 (multivariate analysis)

2018			2019			2020			2021			2022		
No.	**Co.**	**SM**	**No.**	**Co.**	**SM**	**No.**	**Co.**	**SM**	**No.**	**Co.**	**SM**	**No.**	**Co.**	**SM**
1	PL-MZ	0.762	1	PL-MZ	0.806	1	PL-MZ	0.821	1	PL-MZ	0.757	1	PL-MZ	0.976
2	PL-LD	0.535	2	PL-MA	0.602	2	PL-MA	0.634	2	PL-MA	0.639	2	PL-MA	0.546
3	PL-MA	0.382	3	PL-SL	0.465	3	PL-WP	0.434	3	PL-DS.	0.434	3	PL-DS.	0.522
4	PL-PM	0.330	4	PL-LD	0.458	4	PL-SL	0.428	4	PL-PK	0.446	4	PL-SL	0.478
5	PL-SL	0.305	5	PL-DS.	0.398	5	PL-DS.	0.360	5	PL-PM	0.3910	5	PL-WP	0.476
6	PL-WP	0.272	6	PL-PK	0.387	6	PL-PM	0.229	6	PL-WP	0.360	6	PL-PK	0.383
7	PL-DS.	0.180	7	PL-PM	0.374	7	PL-KP	0.139	7	PL-SL	0.3703	7	PL-PM	0.313
8	PL-LB	0.128	8	PL-WP	0.324	8	PL-LU	0.126	8	PL-LD	0.211	8	PL-WN	0.216
			9	PL-KP	0.121	9	PL-LB	0.077	9	PL-KP	0.173	9	PL-ZP	0.168
9	PL-KP	0.080	10	PL-LU	0.098	10	PL-OP	0.056	10	PL-LU	0.148	10	PL-KP	0.123

Cont. table 2.

						11	PL-ZP	0.052	11	PL-LB	0.144	11	PL-LD	0.118
10	PL-ZP	0.056	11	PL-PD	0.097	12	PL-PD	0.036	12	PL-WN	0.128	12	PL-LU	0.096
									13	PL-PD	0.091			
11	PL-PD	0.021	12	PL-OP	0.092	13	PL-WN	0.028	14	PL-OP	0.081	13	PL-PD	0.023
									15	PL-ZP	0.077			
12	PL-WN	0.004	13	PL-WN	0.023	14	PL-SK	0.009	16	PL-SK	0.000	14	PL-LB	0.020

Legend: like in Figure 1. Lack of data: like in Figure 4, Figure 6.

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

This is in line with the stated hypothesis and indicates that in both the covid and post-covid perspectives there are similar characteristics related to the diversity between Polish NUTS-2 regions regarding expenditures on innovation processes. In this respect, for both perspectives, the observed differences in expenditures on innovation activities between Polish NUTS-2 regions indicate diversity in fostering innovation. While innovation activities is treated as an important driver of competitive advantage, such diversity may have consequences for the competitiveness of firms, regions and country. Simultaneously, the results of the study show that despite the occurrence of conditions of severe constraints related to covid, the highest diversity between Polish NUTS-2 regions in expenditures on innovation processes can be seen almost between the very same regions in 2018-2022. In this context, the highest diversity in this area is observed between Masovian Voivodship, Lesser Poland Voivodship and Warmian-Masurian Voivodship, Świętokrzyskie Voivodship, Lubusz Voivodship. This suggests that regardless of the covid perspective no significant changes have occurred in the distance between the regions with the highest and the lowest levels of expenditures on innovation activities. This is in line with the results of the study by Kozioł-Nadolna (2022), which indicates that there was no significant reduction in firms' innovation activities during the covid pandemic. According to the results, Masovian Voivodship and Lesser Poland Voivodship emphasise the relatively highest level of expenditures on innovation processes compared to other Polish NUTS-2 regions, both in the covid and post-covid perspectives. This suggests that the Voivodships concerned possess a high potential to enhance innovativeness and competitiveness. On the contrary, compared to the other Polish NUTS-2 regions, the relatively lowest level of expenditures on innovation activities in characterises Warmian-Masurian Voivodship, Świętokrzyskie Voivodship, Lubusz Voivodship, Podlaskie Voivodship and Opole Voivodship in 2018-2022. This may lead to a reduction in the ability of firms, and consequently the regions, to innovate and improve their competitiveness.

5. Conclusions

This article adds to the discussion on the drivers and sources of firms' innovation activities by providing an insight into how expenditures on innovation processes differ across Polish NUTS-2 regions. A special focus is given to the covid and post-covid perspectives in order to understand the attitude of Polish firms towards innovation under conditions of high constraints. The results find that despite the occurrence of conditions of severe constraints caused by the covid pandemic, the highest diversity in terms of expenditures on innovation is observed between almost the very same Polish NUTS-2 regions in 2018-2022. Such an occurrence may be due to regional differences in the conditions for innovation activities of firms. Remarkably, the covid pandemic noticeably encourages Polish firms, especially in the service sector, to increase their expenditures on innovation processes. This may be connected with the need to increase the competitive advantage of this sector and to adapt it to the needs caused by the pandemic.

The findings of this study provide implications for policy makers and practitioners. Given that firms' innovation activities is seen as a key driver of competitiveness, not only of firms, but also of regions and countries, it is necessary to further strengthen the conditions for fostering innovation processes of firms. Public institutions should play an important role in this respect. The pro-innovation attitude of industrial and service firms is also crucial.

Some limitations can be identified, which may provide a basis for future research. This study concentrates on total innovation expenditures in order to capture all sources through which Polish firms improve their innovation processes under highly constrained conditions. It also focuses separately on firms' own resources for innovation in order to understand the extent to which Polish firms were willing to finance innovation activities from their own resources under severe conditions. It would be useful to see whether the results are similar for other variables describing expenditures on firms' innovation activities. It would also be worthwhile to examine the reasons for maintaining the highest diversity between Polish NUTS-2 regions in expenditures on innovation processes that can be seen almost between the very same regions despite the conditions of severe constraints caused by the covid pandemic.

References

1. Brodny, J., Tutak, M. (2022). Assessing the Level of Innovation of Poland from the Perspective of Regions between 2010 and 2020. *Journal of Open Innovation: Technology, Market, and Complexity, 8(4),* 190, doi: 10.3390/joitmc8040190
2. Decyk, K. (2023). Innovative Activity of the Service Sector of the EU Member States. *Journal of the Knowledge Economy*, doi: 10.1007/s13132-023-01143-w
3. Dominiak, J., Rachwał, T. (2022). Changes in industry and services sectors in Poland during the Covid-19 pandemic. *Quaestiones Geographicae, 41(4)*, pp. 41-56, doi: 10.2478/quageo-2022-0040
4. Fritsch, M., Titze, M., Piontek, M. (2020). Identifying cooperation for innovation—a comparison of data sources. *Industry and Innovation*, *27, 6*, pp. 630-659, doi:10.1080/13662716.2019.1650253
5. Gajewski, P., Kutan, A.M. (2023) COVID-19 Pandemic and Enterprise Financial Performance: Aggregate, Regional, and Sectoral Evidence from Poland. *Eastern European Economics, 61, 5*, pp. 491-516, doi: 10.1080/00128775.2023.2226657
6. Grillitsch, M., Martynovich, M., Fitjar, R.D., Haus-Reve, S. (2021). The black box of regional growth. *Journal of Geographical Systems, 23*, pp. 425-464, doi: 10.1007/s10109-020-00341-3
7. Heinonen, K., Strandvik, T. (2021). Reframing service innovation: COVID-19 as a catalyst for imposed service innovation. *Journal of Service Management, 32(1)*, pp. 101-112, doi: 10.1108/JOSM-05-2020-0161
8. Hossain, M. (2020). Frugal innovation: Conception, development, diffusion, and outcome. *Journal of Cleaner Production, 262*, 121456, doi: 10.1016/j.jclepro.2020.121456
9. Isaksen, A., Jakobsen, S.-E. (2017). New path development between innovation systems and individual actors. *European Planning Studies*, *25*(3), pp. 355-370, doi: 10.1080/09654313.2016.1268570
10. Kiselakova, D., Stec, M., Grzebyk, M., Sofrankova, B. (2020). A Multidimensional Evaluation of the Sustainable Development of European Union Countries – An Empirical Study. *Journal of Competitiveness, 12(4),* pp. 56-73, doi: 10.7441/joc.2020.04.04
11. Kozioł-Nadolna, K. (2022). Innovation strategies used by companies in Poland during the pandemic. *Procedia Computer Science, 207.* 26th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2022), pp. 3192-3201, doi: 10.1016/j.procs.2022.09.377
12. Kukuła, K., Bogocz, D. (2014). Zero unitarization method and its application in ranking research in agriculture. *Economic and Regional Studies, 7(3),* pp. 5-13.

13. Lehnert, P., Pfister, C., Backes-Gellner, U. (2020). Employment of R&D personnel after an educational supply shock: Effects of the introduction of Universities of Applied Sciences in Switzerland. *Labour Economics*, *66*, 101883, doi: 10.1016/j.labeco.2020.101883
14. Lubacha, J. (2021). The role of cooperation in the innovation activity of enterprises: the case of Polish regions. *Journal of Urban and Regional Analysis, 13(1),* pp. 19-34, doi: 10.37043/JURA.2021.13.1.1
15. Netz, J., Reinmoeller, P., Axelson, M. (2022). Crisis-driven innovation of products new to firms: The sensitization response to COVID-19. *R and D Management, 52(2),* pp. 407-426. doi:10.1111/radm.12522
16. Schilling, M.A. (2020). *Strategic Management of Technological Innovation.* Boston: McGraw Hill.
17. Sheng, J., Amankwah-Amoah, J., Khan, Z., Wang, X. (2020). COVID-19 Pandemic in the New Era of Big Data Analytics: Methodological Innovations and Future Research Directions. *British Journal of Management, 32(4),* pp. 1164-1183, doi: 10.1111/1467-8551.12441
18. Wojnicka-Sycz, E., Piróg, K., Tutaj, J., Walentynowicz, P., Sycz, P., TenBrink, C. (2022) From adjustment to structural changes – innovation activity of enterprises in the time of COVID-19 pandemic. *Innovation: The European Journal of Social Science Research*. doi: 10.1080/13511610.2022.2036951
19. Wyrwa, D. (2022). Expenditure on research and development as a factor stimulating innovativeness of European Union economy. *Scientific Papers of Silesian University of Technology. Organization & Management [Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarzadzanie], 163*, pp. 715-725, doi:10.29119/1641-3466.2022.163.44
20. Zygmunt A. (2020a). *Intramural expenditures on R&D by types of costs in Poland: Evidence from NUTS-2 regions.* Proceedings of 35th International Business Management Association Conference (IBIMA), ISBN: 978-0-9998551-4-1, 1-2 April 2020, Seville, Spain, pp. 12335-12363.
21. Zygmunt, A. (2022b). The effect of research and development personnel on innovation activities of firms: Evidence from small and medium-sized enterprises from the Visegrad Group countries. *Entrepreneurial Business and Economics Review, 10(3),* pp. 105-121, doi: 10.15678/EBER.2022.100307
22. Zygmunt, J. (2020). *Supporting entrepreneurship from public funds during the major economic disruptions: Polish evidence*. Proceedings of 36th International Business Management Association Conference (IBIMA), ISBN: 978-0-9998551-5-7, 4-5 November 2020, Granada, Spain, pp. 2141-2148.