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The innovation of enterprises and cooperation between science and business in the didactic aspect

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Abstract

Motivation: Key variables influencing enterprise innovation often include size, revenue dynamics, and technological class. Research also highlights the role of supply chain relations and geographic distance. However, there is a lack of studies addressing the impact of science–business cooperation in didactic and practical aspects on innovative activity.
Aim: This article examines whether such cooperation stimulates innovation in industrial enterprises and compares its influence with other established determinants.
Methods: The study applied logit modelling to analyze collected data and determine the direction and strength of selected independent variables' impact on innovation-related dependent variables.

Results and Added Value: Findings indicate that cooperation between science and business contributes positively to innovation. Specifically, product innovation was supported by professional internships for students and academic staff within enterprises, as well as company-organized meetings and presentations facilitating knowledge transfer. In contrast, barriers to product innovation included entrepreneurs' low evaluation of academic staff competencies and the ineffectiveness of certain knowledge transfer mechanisms.
Regarding process innovation, study visits by students and lecturers to enterprises, combined with effective transfer mechanisms, played a significant stimulating role.
The study concludes that didactic and practical cooperation between science and business effectively supports both product and process innovations. Its impact is comparable to that of knowledge transfer methods and enterprise ownership forms typically associated with high innovative capacity. This represents the key added value of the research, emphasizing the relevance of structured collaboration in shaping enterprise innovation strategies.

Keywords: product innovations; process innovations; didactic-practical aspects of cooperation between science and business, logit modelling

JEL: O31; O33; O38; L14; C35

1. Introduction

The positive impact of innovation on the development of enterprises and entire economies in regional, national or global terms has long been positively verified by economists and historians. This issue has been the subject of research since the industrial revolution in the 19th century (Smith 2016, pp. 18–19). The involvement of enterprises in innovation activity has a positive impact on the improvement of their work efficiency and the increase of the wealth of countries (Kuznets, 1966, p. 75). A feedback can be observed between the innovation activity of enterprises and the level of economic development. Higher innovation activity of enterprises affects higher economic growth, while higher economic growth stimulates the innovation activity of individual enterprises. Contemporary research has identified a huge and complex set of factors specific to individual enterprises, sectors or entire national economies (Yildiz, Murtic, Klofsten & Richtnér 2021, pp. 102–130; Mendoza-Silva 2021, pp. 707–734; Costa Cavalcante, 2024, pp. 60–76.). The literature review showed that the innovation activity of enterprises is influenced by numerous variables, which include, for example: enterprise size, market conditions, technological class, links in supply networks, available sources of financing, enterprise location and many other variables.

A separate research area widely described in the literature is the issue of cooperation between the spheres of science and business, whether in isolation from other conditions or within the triple or quadruple helix.

While university–business cooperation has been extensively studied in the context of technology transfer, commercialization, and R&D collaboration, a parallel stream of research has also examined education-driven cooperation, including work-integrated learning, student mobility, and curriculum co-creation.

However, despite this growing body of literature, relatively little quantitative evidence exists at the firm level on how such educational and practice-oriented forms of cooperation translate into innovation outcomes, particularly in industrial enterprises operating in catching-up economies.

Therefore, the contribution of this article lies not in identifying an entirely unexplored field, but in providing firm-level empirical evidence on the relationship between didactic–practical university–business cooperation and product and process innovation in the specific regional context of Poland.

The article consists of six parts: introduction, literature review, methodological aspects of the conducted research, results, discussion, and conclusions.

The literature review presents an overview of the conditions influencing the innovative activity of industrial enterprises, as described in the literature. The issue of cooperation between enterprises and research institutions is addressed as well.

The methodological aspects of the conducted research describe the procedure for determining the number and structure of enterprises selected for the study. Furthermore, the research method that allowed for drawing conclusions is characterized and the dependent and independent variables included in the study are listed.

The next section presents the obtained results regarding the conditions for new product and process innovations.

The "Discussion" section compares the obtained conclusions with those published in other authors' works.

The final section presents the conclusions drawn from the article, its limitations, and areas that deserve further development in future publications.

To summarize this introduction, it should be emphasized that the impact of collaboration between industrial enterprises and universities on innovative activity in both the educational and practical aspects is an extremely important issue and one often overlooked in the literature. Demonstrating a positive relationship between these variables could translate into greater attention to issues related to collaboration between both entrepreneurs and university staff, which is still not very common in Poland.

2. Literature review

2.1. Determinants of innovative activity

The issue of determinants of innovation activity of enterprises has already been discussed quite widely in the literature on the subject. Individual studies described in the publications differed in terms of taking into account different dependent and independent variables, as well as the geographical area in which the study was conducted. For example, Bhattacharya and Bloch (2004, pp. 155–162) examined how enterprise size, market structure, profitability, enterprise revenues and R&D activity influenced product innovations in small and medium-sized enterprises located in Australia. This study also took into account technological classes divided into low and high technologies. Similar studies were also conducted by De Jong and Vermeulen (2006, pp. 587–609) among small enterprises located in the Netherlands.

Love and Roper (1999, pp. 43–64) showed that R&D activity, technology transfer and the creation of network connections as substitutes for each other, and do not mutually support innovative activity. They also noted that the strengthening of a monopoly in a sector does not favor the innovative activity of enterprises, and the increase of the size of the enterprise has a positive effect on the creation of network connections by these entities. However, these authors did not notice the relationship between the size of the enterprise and R&D activity and technology transfer.

Determinants of innovation activity among Japanese technology-based start-ups were analyzed by Lynskey (2004, pp. 169-196). He showed that the number of patents and new product implementations depend on the availability of the company's own funds and venture capital funds, as well as the links between the science and business spheres. The author also included in the study the influence of CEO characteristics, such as education and the ability to establish contacts with employees from the science sphere, on selected dependent variables.

Aspects related to the influence of networks, distribution and internal R&D on product and process innovations were drawn to by Capitano, Coppola and Pascucci (2010, pp. 503–518). Their study was conducted among Italian companies producing food products. A similar study among small companies was conducted by Frey, Iraldo and Testa (2013, pp. 352–364).

Interesting conclusions also result from the work of Prokop and Stejskal (2019, pp. 134–46), who showed that the determinants influencing product and process innovations differ depending on the size of the enterprise. They suggest that small enterprises should focus primarily on internal R&D, while medium-sized enterprises should focus on acquiring knowledge through

training. The role of training in supporting innovative activities, divided into product, process, organizational and marketing innovations, was also indicated in their work by Carvalho, Costa and Caiado (2013, pp. 583–600).

Also noteworthy is the work of Divisekera and Nguyen (2018, pp. 157––167), who examined the conditions influencing the occurrence of service and marketing innovations in the tourism services sector. In the case of these types of innovation, two groups of factors played the most important role. The first group was related to the expenditures incurred on: establishing cooperation, improving the quality of available human capital and acquiring new information technologies. The second group of factors included: foreign ownership of the enterprise, the strength of the impact of competition, the size of the enterprise and the environment in which the enterprise operates. The determinants of the innovative activity of service enterprises were also studied by Jose Madeira Silva, Simoes, Sousa, Moreira, Wagner Mainardes (2014, pp. 404–416) and Hue (2019, pp. 247–267).

The role of socio-cultural and demographic conditions in stimulating innovative activity was pointed out by Grego-Planer and Kuś (2020, pp. 137––148). These relationships were also dealt with in their works by Munjal and Kundu (2017, pp. 1–11).

The specificity of conditions influencing the implementation of innovative activities of Polish enterprises was studied, among others, by Sudolska and Łapińska (2020, pp. 1–20), Sachpazidu-Wójcicka, (2017, pp. 287–299) and Świadek and Gorączkowska (2020, pp. 811–831).

2.2. Cooperation between entities from the sphere of science and business

The issue of cooperation between universities and businesses first appeared in the literature as a subject of scientific interest in 1995 and has been continuously developed since then. Issues discussed within this framework include: technology transfer and the ability of enterprises to absorb knowledge acquired from universities, the diffusion of cooperative links between science and business in regions, and the impact of cooperation between enterprises and universities on the financial results of enterprises (Mascarenhas, Ferreira & Marques, 2018, pp. 708–718). Cooperation between science and business is also analyzed from the perspective of regional or national innovation systems, the triple or quadruple helix, and in the context of the entrepreneurial university (Pereira, Franco, 2023, pp. 676-–690).

Cooperation between universities and businesses is an important factor in regional development. However, despite numerous support programs implemented by public administration, such interactions between businesses and universities are extremely weak, especially in developing countries (Şerbanica, 2011, pp. 29–44; Merritt, 2015, pp. 568–588).

This is primarily due to two reasons: first, universities carry out scientific research inspired by the interests of scientists, that are not necessarily related to the needs of enterprises, and second, most enterprises do not have the research and development potential to engage in talks with scientists on a partnership level. Other barriers hindering cooperation between enterprises and universities include: 1) lack of knowledge among entrepreneurs about the research areas carried out by university researchers and insufficient information about university programs that can support cooperation between universities and business entities (Pereira, Franco, 2022, pp. 37–50); 2) low scientific potential of universities, especially those located in underdeveloped regions (Cui, Li, 2022, pp. 915–930). Furthermore, research has shown that even when scientists do not perceive any barriers limiting cooperation with enterprises, such cooperation will still not occur unless factors stimulating it appear (Galán-Muros, Plewa, 2016, pp. 369–382).

The issue of institutional barriers limiting effective university–industry cooperation has been examined in recent studies, including those by Khachatryan, Hakobjanyan, Nikoghosyan, and Keryan (2024), which point to weak institutional capacity and limited engagement of firms in collaborative activities. These constraints are particularly evident in the educational dimension of cooperation, where insufficient alignment between academic curricula and firms' needs, as well as limited involvement of enterprises in curriculum co-development, reduce the effectiveness of joint training initiatives.

Cooperation between universities and enterprises in both the didactic and practical dimensions is currently one of the key challenges in the process of orienting higher education to the needs of the labor market (Pavlin, 2016, pp. 25–39). Its important element is defining the role of entrepreneurs in shaping the competences of graduates and setting directions for the development of academic teaching in the perspective of practical education.

In this context, work-integrated learning (WIL) should be a fundamental area of cooperation between academia and business. Its importance stems from the fact that it provides graduates with the necessary industry experience for the successful implementation of innovations (Rampersad, 2015, pp. 203–227).

WIL partnerships pose many challenges in practical application. These difficulties stem from the need to redistribute knowledge-power relations between the university and the host organization. Research (Choy & Delahaye, 2011, pp. 157–172) indicates that effective work-integrated learning, which addresses both the needs of individuals and workplaces, relies on learning partnerships where curricular and pedagogical roles are genuinely shared. The fact that such partnerships are integral to effective work-integrated learning, while also being highly problematic, justifies the need for further research into the dynamics and mechanisms of university-organization collaborations.

Recent studies have further systematized education-driven university–business cooperation, emphasizing its role in student mobility, curriculum development, and lifelong learning (Orazbayeva et al., 2020). Moreover, Zhang et al. (2022) highlight the importance of cognitive and institutional drivers shaping faculty engagement in such cooperation.

Complementary evidence suggests that university–industry collaboration contributes not only to improved innovation performance but also to the development of firm-level human capital and organizational capabilities (Liu, 2025).

3. Methods

Data were collected using a standardized questionnaire administered through direct contact with enterprises. The questionnaire consisted primarily of closed-ended questions, allowing for binary coding of variables.

The respondents were typically individuals responsible for managerial or operational decision-making within the firm (e.g., owners, managers, or department heads), ensuring adequate knowledge of innovation activities and cooperation practices.

According to data from the Central Statistical Office, there were 36,456 industrial enterprises operating in the Lubuskie and Lower Silesian Regions in 2022. Based on commonly available research sample selection calculators, it was determined that assuming a maximum error of 5%, a confidence level of 95% and a fraction size of 0.5, the minimum research sample should be 380 units.

Knowing the size of the research sample, its structure was then determined. For this purpose, two stratification criteria were adopted: location (Lubuskie and Dolnośląskie Regions) and company size (micro, small, medium and large). Data necessary to determine the key for structuring the research sample were obtained from the website of the Local Data Bank of the Central Statistical Office. This key is presented in Table 1.

After multiplying the data from the table above by the size of the research sample (380 enterprises), the structure of the entire research sample was established and is presented in the Table 2.

In order to collect the required number of survey questionnaires, in accordance with the structure presented above, an address database of all enterprises classified in section C of PKD 2007 was purchased from the Central Statistical Office. In addition to contact/address data, this database contained information on the number of employees and the location of the enterprise. This information allowed for the classification of enterprises into one of eight groups according to Table 2. Next, enterprises were randomly selected for the survey within each of these groups.

The collection of survey questionnaires took place at the turn of 2022––2023, while the period for which the data was collected was 2019–2021. The study was carried out by employees of the Department of Innovation and Entrepreneurship at the University of Zielona Góra in cooperation with students attending their classes. In order to verify the reliability of the surveys collected by students, the employees of the department conducted interviews verifying the authenticity of the submitted surveys. The inclusion of students in the research process is suggested by Lundvall (2007, pp. 95–119), who draws attention to the difficulties in financing scientific research in developing countries. Behrens and Gray (2001, 179-199) and Baldini (2008, pp. 289–311) also wrote about the role of students and the benefits they gain from participating in scientific research.

The response rate in the study was 2%. While relatively low, this level is not un-common in firm-level surveys, particularly those addressed to enterprises and involving detailed questionnaires. With regard to missing data, questionnaires that were returned incomplete were excluded from the analysis.

Prior to the main data collection, the questionnaire was pilot-tested on a small group of firms to ensure clarity and consistency.

Ethical standards were maintained throughout the research process. Participation of students in data collection was voluntary and supervised by academic staff. All respondents were informed about the purpose of the study and assured of anonymity and confidentiality. No sensitive firm-level data allowing identification were disclosed.

The dependent and independent variables adopted in the study were binary (0 and 1). The dependent variables included the occurrence of product and process innovations that were new at least on the scale of the enterprise. Kafetzopoulos and Psomas (2015, pp. 104–130) point out that both types of innovations should be examined together, which is the case in this article. The occurrence of such innovations was marked with the value 1. The absence of such innovations in the studied enterprises was marked with the value 0. The independent variables were marked in a similar way.

In the case of independent variables, the selection of variables for modeling was based on a literature review and the guidelines included in the Oslo Manual (OECD, 2018). These variables were divided into six groups. The first group concerned the sources of financing for the innovation project, which included: existing internal capital of the enterprise, co-financing from regional public funds, co-financing from national public funds, co-financing from EU funds, bank loans and other sources. sources. The second group concerned tax reliefs related to R&D activities and operational activities. The third group of independent variables included the types of entities with which industrial enterprises could cooperate, i.e.: suppliers, competitors, recipients, Polish Academy of Sciences units, universities, domestic and foreign research and development units and other entities operating within

one capital group. The fourth group of variables included aspects related to cooperation with universities, but in the didactic and practical area. This group of variables included the fact of a study visit of students, internships of students and academic staff, professional internships and conducting classes by entrepreneurs with students.

The fifth group of independent variables concerned knowledge transfer mechanisms occurring in the cooperation process. These mechanisms included exchange, informal channels, formal employee meetings and presentations, joint courses, and delivery of a finished product, prototype, or technical documentation.

The last group of variables concerned barriers that made it difficult or even impossible to establish cooperation. It included the following variables: lack of need for technical changes on the part of enterprises, lack of financial resources, insufficient competences of enterprise employees, insufficient competences of academic employees, lack of knowledge of the university's offer, insufficient public support, too strong bureaucracy and fear of losing the secret related to the technical aspects of the product or process that is the subject of cooperation.

In the study, the following control variables were adopted: enterprise size divided into small, medium and large enterprises; the form of enterprise ownership divided into ownership: domestic, foreign and mixed; sales range divided into local, regional, national and international; technological class of the enterprise divided into: low, medium-low, medium-high and high technologies.

The computational part of the study was based on logit modeling. The choice of this method resulted from the binary form of the variables adopted for the study. As a consequence of conducting logit modeling, the odds ratios were determined, which provided information about the probability of occurrence of the dependent variable. Assuming a value greater than one for the odds ratios meant that the probability of the expected event occurring with a given independent variable was higher than the probability of this event occurring with the remaining independent variables included in the same group of variables. In the case of accepting a value less than 1 for the odds ratio, the interpretation of probability is reversed.

Statistica 13 software (TIBCO Software Inc., Palo Alto, CA, USA, 2017) has been used for analysis. It should be emphasized that not all variables included in the study met the condition of statistical significance. The variables that were used in the estimation process in the model are presented in Table 3.

The formal form of the equations for the models presented later in this paper is presented below:

$$Int\_nprod = \alpha_0 + \alpha_1 Dom\_cap_i + \alpha_2 Reg\_Sale_i + \alpha_3 BC_i + \alpha_4 Stud\_app_i + \alpha_5 meet\_pres_i + \alpha_6 com\_cour_i + \alpha_7 del\_fin\_prod_i + \alpha_8 Unf\_Op\_Aca_i + \alpha_9 LP\_supp_i + \alpha_{10} Low\_tech_i + u_i, \quad (1)$$

$$Int\_nproc = \alpha_0 + \alpha_1 Mix\_cap_i + \alpha_2 For\_cap_i + \alpha_3 Mainly\_EA_i + \alpha_4 Study\_visit_i + \alpha_5 meet\_pres_i + \alpha_6 han\_doc_i \alpha_7 del\_fin\_prod_i + \alpha_6 Loss\_TS_i + u_i \quad (2)$$

In the context of the literature review conducted above, the research hypothesis was formulated as follows:

H0: Innovation-active enterprises are more open to the environment and relatively more often cooperate with universities in the didactic and practical aspects.

To verify the main hypothesis, partial hypotheses were also formulated:

H1: Cooperation between the sphere of science in the didactic and practical aspect and the sphere of business has a positive impact on the innovative activity of enterprises in the area of new product and process innovations

H2: The impact of cooperation in the didactic and practical aspect is comparable to the impact of traditional knowledge transfer mechanisms and other key determinants of innovation activity of enterprises.

H3: Not every knowledge transfer mechanism stimulates the innovation activity of enterprises.

H4: Not all barriers to cooperation in the field of innovation included in the study turn out to be factors that destimulate innovation activity.

The selection of the Lower Silesian and Lubuskie regions was intentional. These regions differ in terms of economic development, industrial structure, and innovation potential, while at the same time remaining geographically proximate. Lower Silesia represents a more industrialized and innovation-active region, whereas Lubuskie is characterized by a smaller industrial base and lower innovation intensity. This contrast allows for capturing variability in cooperation patterns and innovation behavior within a relatively homogeneous national context.

4. Results

4.1. *Product innovations*

The models (1) and (2) explaining the conditions influencing the implementation of new products and processes in Polish industrial enterprises from the Lower Silesian and Lubuskie Regions are presented in Tables 4 and 5.

When analyzing the obtained results, it is worth noting that the above model does not contain variables that, despite being included in the estimation process, were rejected in the further research process as statistics insignificant. These variables include, among others, control variables regarding the size of the enterprise and the fact of cooperation in the field of innovation with various partners from the sphere of science and business. The absence of these variables means that for cooperating enterprises neither the size of the enterprise nor cooperation with a specific group of partners are important when implementing a completely new product into production.

The first group of factors, which was identified as having a significant impact on the implementation of new products, concerned knowledge transfer mechanisms. Within this group, the dependent variable is positively influenced by the delivery of a finished product to the contractor and joint meetings and presentations. The chance of implementing new products into production in the first case increased 2.17-fold, and in the second 1.56-fold.

In turn, the organization of joint courses and training by the company in cooperation with external partners contributed to a 39% reduction in the chances of implementing new products.

Credit activity carried out by the banking sector also has a stimulating effect on the introduction of new products into production by enterprises. When enterprises use this type of financing, then the chances of introducing a new product into production increase more than twice.

Student/professional internships, which are carried out at industrial enterprises, also have a positive effect on the dependent variable. In such a situation, the chances of implementing a new product into production increase by 57%. The reasons for this state of affairs may be different. On the one hand, it should be remembered that the participants of the internships are pupils or students, i.e. young people who approach the problems posed in an unconventional way, which results from their creativity or sometimes from a lack of appropriate knowledge. The questions they ask force entrepreneurs to redefine the problem, which can lead to interesting and constructive conclusions. On the other hand, the implementation of professional and student internships in an enterprise is a manifestation of more or less formalized cooperation between an entity from the business sphere and the science sphere. The more areas this cooperation covers, the greater the chances of product innovations. More frequent contact between enterprises and educational and scientific units translates into easier transfer of knowledge from the science sphere to the business sphere. It should also be remembered that after completing their education, young graduates can find employment in companies where they completed their internships, thus facilitating the transfer of knowledge to the sphere of science and business. Such a transfer of knowledge is particularly valuable in the case of graduates of technical and engineering faculties.

Interesting conclusions can be drawn based on the analysis of another determinant, which is the barrier of "low support from public administration for innovative activity of enterprises". The obtained odds ratio of 1.67 means that the chances of implementing product innovations in enterprises that believe that support from public administration for this type of activity is too low are 67% higher than in enterprises that have a different opinion on this subject. This means that this opinion does not constitute a real barrier for enterprises and despite the fact that they express the above opinion, they still carry out work related to the implementation of new products into produc-

tion. The situation indicates the weakness of the Polish system of supporting enterprises in implementing innovative solutions and the bad opinion of this system among entrepreneurs.

The conducted research also showed that the implementation of product innovations by industrial enterprises was stimulated by the implementation of activities based on low technologies. The probability of implementing new products into production in this group of enterprises is 35% higher than in enterprises using higher technologies in their basic activity. This relationship is characteristic of developing countries, in which sectors related to low technologies dominate (e.g. food, furniture or construction materials industry) and medium-low technologies (e.g. production of rubber and plastic products, production from other non-metallic raw materials, production of metals and finished metal products). In such conditions, implementing a new product into production is relatively simple, due to the specificity of this type of products.

Among the factors that constitute a barrier to implementing product innovations, false perceptions and stereotypes about the academic staff of Polish universities should be mentioned first. The probability of product innovations in the group of entrepreneurs who presented such views was 72% lower than the probability of product innovations in the group of entrepreneurs who did not share such an opinion.

Another barrier to implementing new product innovations turned out to be the regional sales range. The chances of product innovations occurring in the group of enterprises characterized by such a sales range were 46% lower than in enterprises with a larger range. With such a sales range, enterprises are not very interested in new technologies, which results in lower chances of implementing them. The spatial scope of enterprises' activities limited to the level of the region indicates that the industrial enterprises studied rarely engage in modern activities and mainly implement a survival strategy.

The last factor that had a destimulating effect on the implementation of new products was the fully domestic form of ownership of the enterprise. In this group of enterprises, the chances of implementing new products into production were 43% lower than the chances of implementing new products in enterprises with a greater or lesser share of foreign capital.

4.2. Process innovations

The determinants of the introduction of new processes in enterprises identified during the study are presented in the Table 5.

Based on the parameters presented in Table 5, it can be stated that the most important factor in implementing process innovations is the form of enterprise ownership. The chances of process innovations occurring in the group of enterprises with mixed and fully foreign forms of ownership are

90% and 68% higher, respectively, than in enterprises with other forms of ownership.

Factors related to knowledge transfer mechanisms, such as the transfer of technical documentation related to manufacturing methods, delivery of the finished product, and meetings and presentations, also have a comparable impact on process innovations. The chances of implementing new processes in companies that used the above-mentioned knowledge transfer mechanisms were 77, 60, and 50% higher, respectively, than the chances of implementing new processes in companies that used other knowledge transfer mechanisms. The results obtained indicate that only extensive cooperation between the parties and mutual goodwill will facilitate the implementation of new processes. Other knowledge transfer mechanisms, such as informal channels, joint courses, and employee exchanges, turned out to be insufficient to support process innovations.

Study visits by students and lecturers also stimulate the implementation of new processes in companies. This determinant increases the chances of implementing process innovations by as much as 62% compared to entities that do not organize such visits.

Contacts with average educational institutions can also affect the innovativeness of enterprises. This results from the need for entrepreneurs to seek new impulses also from weak and unknown networks. Innovative learning is about balancing the chaos of new ideas with traditional views and experience. The ability to combine new solutions with traditional knowledge is a basic competence of innovative entrepreneurship.

Another factor stimulating the implementation of process innovations was the barrier hindering the establishment of cooperation, namely the fear of losing business secrets. The chances of implementing process innovations in companies that feel such fear are 62% higher than in companies that do not have such fears. The reasons for such a relationship may be of two types. First, companies that are known by such fears have reasons for it, i.e. they have unique knowledge related to contractors or technologies. In such a case, this fear is a consequence of the recent implementation of a process innovation. The second reason for the occurrence of the relationship in question may be related to an attempt to escape forward. Companies fear that their technological secrets will be discovered, which is why they are looking for even newer solutions, i.e. working on further process innovations.

Of the factors included in the model, only one turned out to be a real barrier that hindered the implementation of process innovations – dominant share of export activity in sales. With such a sales reach, the chances of implementing process innovations were 61% lower than in the case of companies with a smaller sales reach.

5. Discussion

Comparing the results obtained with the results presented in the literature, it should be mentioned first that the variables concerning the size of the enterprise and the fact of cooperation in the field of innovation with various partners from the sphere of science and business did not show statistical significance. In this respect, the results obtained are consistent with the results of the study conducted by Goedhuys and Veugelers (2012, pp. 516–529), Sanchez et al. (2013, pp. 339–349), Love and Roper (1999, pp. 43–64) and Oerlemans and Pretorius (2006, pp. 589–593). However, they do not coincide with the views presented by Schumpeter (1950, pp. 108–109), Bachmann, Kataichi (2025) who believed that the size of the enterprise affects innovation activity.

In the case of variables concerning knowledge transfer mechanisms, their impact on the implementation of new products was not the same. The implementation of new products was stimulated by delivering a finished product to the contractor and joint meetings and presentations. The results obtained were consistent with the views presented in the works of Rahmouni (2013, pp. 914–930) and El Elj (2012, pp. 183–197) on the implementation of product innovations. On the other hand, the implementation of new products was negatively influenced by the organization of joint courses and trainings by the company in cooperation with external partners. This issue was raised in his research by Becker (1964, pp. 299–320), who established that companies invest in training and courses only when they can gain direct benefits from training an employee. In this approach, training and courses can be treated as a consequence of product and process innovations, not their cause.

The conducted research also showed that the implementation of new products into production was positively influenced by co-financing of this activity by means of bank loans. Recent empirical studies confirm the strong and positive role of external financing in supporting firms' innovation activity. In particular, access to bank credit alleviates financial constraints, enabling firms to undertake risky and capital-intensive innovation projects. Evidence suggests that firms with better access to credit are more likely to introduce product innovations and invest in R&D activities, as external financing reduces liquidity constraints and facilitates the commercialization of new products (Prystrom, Wierzbicka 2015, p. 65; Nikolova, Rodionov, Mottaeva 2016, pp. 246–252).

Student/professional internships, which are carried out in economic entities, also have a positive impact on the dependent variable. In the literature on the subject, there are references according to which this relationship is the result of an unconventional and creative approach to new topics and issues by students and pupils (Doroshenko, Shutenko, Shutenko, Ospishchev 2016, pp. 909–914). It should also be remembered that these internships

are a manifestation of more or less formalized cooperation between the enterprise and the university. The more often this cooperation occurs, and its area becomes more diverse, the more chances for knowledge transfer between these entities increase. A similar tone was expressed in the works of Romanovich, Sevostyanov, Romanovich, Sevostyanov (2014, pp. 273–276), Bozeman and Boardman (2013, pp. 88–120) and Terkan (2014, pp. 239–246).

The results concerning the positive impact of internships and study visits suggest that policy instruments supporting education-driven university–industry cooperation may be particularly effective in strengthening firms' innovation capacity. Unlike traditional instruments focused on R&D subsidies, these forms of cooperation contribute to the development of practical skills, improve knowledge absorption capacity, and facilitate the alignment between educational outcomes and labor market needs.

Therefore, the findings of this study imply that innovation policy should place greater emphasis on supporting structured forms of didactic cooperation between universities and firms, including dual education models, internship programs, and joint curriculum development initiatives. Strengthening these instruments may enhance not only human capital formation but also the overall effectiveness of the innovation system.

At the same time, the results indicate that the mere availability of policy instruments is not sufficient. Their effectiveness depends on institutional quality, coordination mechanisms, and the degree of engagement of both firms and academic institutions. This suggests that improving the institutional framework of cooperation may be as important as increasing the scale of financial support.

When reviewing the results obtained, the positive relationship between the implementation of a new product into production and a factor that seemed to be a barrier to stimulating innovative activity deserves special attention. This factor is low public support for the innovative activity of enterprises. The positive relationship between these variables means that the surveyed enterprises, despite complaining about poor support from public administration, still carry out this type of activity.

From the perspective of innovation policy, the obtained results should be interpreted in a broader institutional context rather than solely as firm-level behavioral patterns. In particular, the positive relationship between innovation activity and the perception of insufficient public support may reflect structural weaknesses in the design and implementation of innovation policy instruments in Poland (Wojnicka-Sycz, Sycz, 2016, pp. 1–23).

Existing studies and policy reports indicate that the Polish innovation system is characterized not only by limited effectiveness of direct financial support instruments, but also by relatively weak linkages between universities and industry, especially in the area of human capital development and practical education. In this context, firms may rely more heavily on internal

capabilities and informal cooperation mechanisms, while simultaneously expressing dissatisfaction with public support systems. This conclusion is in line with the views presented in the works by Janiszewska and Janiszewski (2020, pp. 51–73) and Łukaszewska (2018, pp. 181–197).

The weakness of the Polish innovation system is evidenced by another variable related to the implementation of low-tech activities by enterprises. This relationship is characteristic of developing countries, where sectors related to low and medium-low technologies dominate. In this type of economy, implementing a new product into production is relatively simple, due to the specificity of this type of product. The issue of innovativeness of enterprises in countries dominated by low-tech economies was analyzed by, among others, Aboal and Garda (2016, pp. 435–454) and Crespi and Zuniga (2012, pp. 273–290).

Among the factors that constitute a barrier to implementing product innovations, false ideas and stereotypes about the academic staff of Polish universities should be mentioned first. The issue of prejudices and stereotypes on the part of entrepreneurs about the staff employed at Polish universities was described, among others, in studies prepared by the Ministry of Science and Higher Education (MNiSzW, 2006, p. 3), Bąk and Kulawczyk (2009, p. 20), the Western Institute (2012, p. 25) and Kuna-Marszałek and Lisowska, (2013, p. 34). The issue of the communication gap between science and business was addressed, among others, by Klevorick, Levin, et al. (1995, pp. 185––205) and Hellman (2007, pp. 624–647).

Another identified barrier that hindered the implementation of new product innovations was the regional sales range. The obtained results were consistent with the conclusions presented in the works of Capitano, Coppola and Pascucci (2010, pp. 503–518), Świadek (2018, pp. 725–740) and Grillitsch, Tavasassoli, Obschonka (2026).

The last factor considered in the study, which had a destimulating effect on the implementation of new products into production, was the fully domestic form of ownership of the enterprise. In Polish conditions, this group of enterprises was only slightly interested in implementing new products into production. This is a serious problem from a systemic perspective. The result obtained means that among enterprises from the Lower Silesian and Lubuskie Regions, a necessary condition for implementing new products into production is having foreign capital in their structure. The obtained results are confirmed by studies included in the works of Świadek (2012, pp. 5–23) and El Elj (2012, pp. 183–197).

Based on the research conducted, it could be observed that in the case of implementing process innovations, the most important factor was the form of enterprise ownership. In the case of this type of innovation, the results obtained are consistent with the views presented in the works of, among others, Świadek (2012, pp. 5–23) and Jaklic, Damijan, Rojec (2008, pp. 1–18).

The conducted research showed that factors related to knowledge transfer mechanisms, such as the transfer of technical documentation related to manufacturing methods, delivery of the finished product, and meetings and presentations, had an equally intensive impact on process innovations. The issue of the impact of knowledge transfer mechanisms on innovations was described, among others, by: Malik and Bergfeld (2015, pp. 1129–1142), Rambe and Kahaol (2022, pp. 741–773) and Cinar, Altuntas and Alan (2021, pp. 2179–2207).

The study confirmed that study visits by students and lecturers increased the chances of implementing process innovations. This means that combining educational activities with business practice strengthens the competitive position of enterprises and allows enterprises to enter the open innovation system (Choi, Markham 2019, pp. 1–15). The ability of current and future employees to learn and improve their qualifications is particularly important for entities operating in technologically advanced sectors. This is even more important if innovation is approached as an informal learning process. Employees or future employees learn by sharing knowledge within work teams, and employers learn to create networks of collaborators and advisors (Cofré -Bravo, Klerkx & Engler 2019, pp. 53–64). The ability to combine new applications with traditional knowledge is the basis for innovative entrepreneurship (Gielen, Hoeve & Nieuwenhuis 2003, pp. 90–106).

Of course, we cannot forget about the fact that the relationship between enterprises and educational institutions is feedback. Cooperation with enterprises influences the adaptation of the offer of schools and universities to the requirements of the labor market, which in the long term translates into further benefits for enterprises in the form of the possibility of acquiring better educated employees (Pocol, Stanca, et al. 2022, pp. 1–12). Contacts with average educational institutions can also affect the innovativeness of enterprises. This results from the need for entrepreneurs to search for new impulses also from weak and unknown networks. Innovative learning is about balancing the chaos of new ideas with traditional views and experience. The ability to combine new solutions with traditional knowledge is a basic competence of innovative entrepreneurship.

Among the factors included in the model, only the variable "dominant share of export activity in sales" turned out to be a destimulating determinant. This may indicate that for companies serving mainly foreign markets, the most important thing is to have an attractive product range that will be of interest to foreign contractors. Due to the competitive advantage of Polish companies resulting from lower production costs related to cheaper labor, searching for other ways to optimize production processes, i.e. implementing process innovations, is less popular. A similar relationship was identified in the work of El Elj (2012, pp. 183–197).

6. Conclusions

The innovative activity of industrial enterprises depends on many factors. Different conditions determine the implementation of product and process innovations. The only common element concerns the mechanisms of knowledge transfer, in particular the delivery of a finished product to the cooperator and the organization of joint presentation meetings.

A common feature of implementing product and process innovations was also the positive impact of cooperation with schools in the didactic and practical field. Implementing professional internships or study visits of pupils, students and teachers in enterprises clearly contributed to increasing the probability of innovations occurring in these entities. This conclusion positively verifies the adopted main research hypothesis and the first and second auxiliary hypotheses. It should be emphasized that this thread is currently quite rarely discussed in contemporary literature on the subject.

Recent research (e.g., Costa Cavalcante, 2024) confirms that non-technological factors, including human capital development and institutional quality, play a growing role in shaping innovation performance, which is consistent with the findings of this study.

This study contributes to the existing stream of research on education-driven university–business cooperation by providing firm-level evidence from a catching-up economy. Rather than filling a completely unexplored gap, it extends previous research by linking educational forms of cooperation with measurable innovation outcomes in industrial enterprises.

An unusual relationship turned out to be the stimulating influence on innovation activity of factors that were supposed to constitute a barrier to innovation activity. We are talking here about factors related to too low public support and fears of losing trade secrets. In the case of the first relationship, it can be stated that the current system of support for innovation activity by the Polish public administration is unsatisfactory for entrepreneurs.

The paradoxical finding that firms reporting insufficient public support are more likely to innovate should be interpreted in the broader context of the Polish innovation system. Previous reports (e.g., OECD) have consistently pointed to structural weaknesses, including limited effectiveness of public support instruments and weak science–business linkages. In this context, the observed relationship may reflect a compensatory behavior of firms that rely more on internal capabilities and informal cooperation mechanisms. In the case of the second relationship, it turns out that enterprises choose the strategy of escaping forward. This means that entrepreneurs, fearing that as a result of cooperation they will lose exclusivity on the use of certain technological solutions, implement new process innovations. They do not share these latest innovations with partners with whom they have cooperated so

far. Thanks to this, they still maintain a technological advantage over other market participants, including previous cooperators. This conclusion constitutes a positive verification of the fourth auxiliary hypothesis.

The actual barriers that made it difficult to implement product and process innovations can be divided into two groups: obvious and non-obvious barriers. Obvious barriers include the national ownership of the company and the regional sales range. These variables have been described quite often in the literature on the subject. Another obvious barrier is the variable concerning the unfavorable opinion about academics among entrepreneurs. The negative perception of academic staff competencies among entrepreneurs may stem from several factors, including a mismatch between academic curricula and market needs, as well as limited practical experience of university staff. This suggests that strengthening practice-oriented education and increasing staff engagement in industry projects could help reduce this barrier. This issue would require in-depth research in the future, especially in an international context.

Less obvious barriers that hindered the implementation of product and process innovations included: the dominant share of export activity in the company's sales and the implementation of courses and trainings together with cooperators. This last conclusion resulting from the conducted research constitutes a positive verification of the third auxiliary hypothesis.

The conducted research provided valuable information on the impact of cooperation in the didactic and practical aspect between the sphere of science and business. It confirmed that this cooperation is as important as other key determinants influencing product and process innovations. It is worth emphasizing that this cooperation has a positive impact on both types of innovation included in the study.

A significant limitation of the study is the dominance of microenterprises in the sample (340 out of 380 observations), which reflects the actual population structure but limits the possibility of conducting meaningful comparative analyses across firm size categories. Future research should consider disproportionate stratified sampling combined with analytical weighting to ensure better representation of medium and large enterprises.

This study is in line with the trend of views emphasizing the important role of the didactic and practical area of activity of universities, which nowadays seems to be omitted in the literature on the subject. Most publications focus mainly on the area of scientific activity of universities and cooperation in this area with entities from the business sphere. The thread that is omitted is that one of the goals of universities is to supply the market with highly qualified employees, thanks to whom Polish enterprises will have a chance to compete or cooperate with entities operating on a global scale.

The few studies on the issue of cooperation in the didactic and practical area of higher education institutions with business entities constitute

a premise for further analyses in this area. Areas that are particularly worth investigating in the future include, among others: determinants that favor establishing cooperation in the didactic and practical area between the science and business spheres, the role of business environment institutions in stimulating this process and the role of fiscal instruments in stimulating this type of activities.

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Appendix

Table 1. Key to selecting the number of industrial enterprises for the study, taking into account stratification according to their size and location

Region \ Company size	Micro	small	medium	Big	Together
Lubuskie	24.61%	1.82%	0.57%	0.09%	27%
Lower Silesia	64.71%	6.08%	1.70%	0.41%	73%
Together					100%

Source: Own study based on data from the Central Statistical Office.

Table 2. Structure of the research sample

Region \ Company size	Micro	Small	medium	Big	Together
Lubuskie	94	7	2	0	103
Lower Silesia	246	23	6	2	277
Together	340	30	8	2	380

Source: Own study based on data from the Central Statistical Office.

Table 3. Definitions of variables used in equations

Variables	Description
	Variable dependent
Int_NProd *Int_Nproc*	1: new product introduction; 0: no new product introduction; 1: new process introduced; 0: no new process introduced
	Variables independent
	Sources of financing for innovative projects:
BC	1: bank loan; 0: no bank loan
	Cooperation in the didactic and practical aspect:
Study visit	1: study visits of students/lecturers to enterprises; 0: no study visits of students/lecturers to enterprises
Stud_app	1: student internships; 0: no student internships
	Knowledge transfer mechanisms:
meet_pres	1: Meetings and presentations; 0: no meetings
com_court	1: Joint courses; 0: no joint courses or trainings
han_doc	1: Documentation transferred; 0: No documentation transferred
del_fin_prod	1: Delivery of finished product; 0: no delivery of finished product
	Barriers to establishing cooperation:
Unf_Op_Aca	1: unfavorable opinion of academic staff; 0: favorable opinion of academic staff competence of academic staff
LP_supp	1: Too little public support; 0: Adequate support from public administration
Loss_TS	1: Fear of losing company secrets; 0: No fear of losing company secrets
	Variables checklist
	Form of company ownership:
Dom_cap	1: domestic form of ownership; 0: other than domestic form of ownership of enterprise
For_cap	1: foreign form of ownership; 0: other than foreign form of ownership of the enterprise
Mix_cap	1: mixed form of ownership; 0: other than mixed form of ownership of the enterprise
	Company sales scope:
Reg_Sale	1: regional sales coverage; 0: non-regional
Mainly_EA	1: mainly export; 0: other scope than export
	Technological class of the enterprise (according to PKD 2007):
Low_tech	1: low tech; 0: other than low tech

Source: Own study based on own research.

Table 4. Conditions for introducing a completely new product in industrial enterprises (model 1)

Independent value	Odds Ratio
Dom_cap	0.57 *
Reg_Sale	0.54 **
BC	2.02 ***
Stud_app	1.57 **
Meet_pres	1.56 **
Com_cour	0.61 **
Del_Fin_prod	2.17 ***
Unf_Op_Aca	0.28 *
LP_supp	1.67 *
Low_Tech	1.35 *
Sample	380
Likelihood Quotient	57.65
R^2 Cox Snell	0.097
R^2 Nailerke	0.13
Wald χ^2	57.64
p-value	0.00
Hosmer- Lemeshow test:	
chi square	1.56
p-value	0.29

*** – statistical significance at 1%; ** – statistical significance at 5%; * – statistical significance at 10%.

Source: Own calculation based on questionnaire research.

Table 5. Conditions for introducing completely new processes in cooperating enterprises (model 2)

Independent value	Odds Ratio
Mix_cap	1.90 **
For_cap	1.68 *
Mainly_EA	0.39 **
Study_visit	1.62 *
Meet_pres	1.50 *
Han_doc	1.77 **
Del_fin_prod	1.60 **
Loss_TS	1.62 *
Sample	380
Likelihood Quotient	49.60
R^2 Cox Snell	0.084
R^2 Nailerke	0.129
Wald χ^2	49.6
p-value	0.00
Hosmer- Lemeshow test:	
chi square	1.58
p-value	0.27

*** – statistical significance at 1%; ** – statistical significance at 5%; * – statistical significance at 10%.

Source: own calculation based on questionnaire research.