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Study on the influence of foreign direct investment on innovations in enterprises in Poland using the ECM panel model

In many theories of economics and empirical research, foreign direct investment (FDI) is perceived as a potential technology transfer channel bringing tangible benefits to FDI exporting countries and host countries. In light of some theories, such as Vernon's product life cycle theory or Dunning's pull factor theory, and the results of empirical research, the impact of inward FDI flows inhibits the development of innovation or has a neutral effect on innovation in the host country. In the era of the growing internationalisation of enterprises, and the search for opportunities for enterprises to compete on the domestic and foreign markets, innovation is becoming one of the most important elements of building a competitive advantage. Innovation and new technologies are also of fundamental importance for Polish enterprises that want to compete effectively. The question is, to what extent FDI in Poland favours this process, and to what extent limits it? In the empirical studies conducted so far for the Polish economy in the field of the relationship between the inflow of FDI and innovation, there are not many models that would allow to describe the cause-effect relationship between the discussed categories. The authors of this article attempt to fill this research gap. The main goal was to examine the directions and intensity of the impact of foreign direct investment on the level of innovation of enterprises in the main sectors of the economy in Poland. The study used, among others, panel data models with error correction mechanism (ECM) and the Granger causality test. The results confirmed the positive impact of foreign direct investment on the innovativeness of enterprises both in the industrial sector and in the service sector. Moreover, the impact of FDI on the innovativeness of enterprises in the industrial sector turned out to be stronger than the impact on the innovativeness of companies from the service sector.

Keywords: innovation, foreign direct investment (FDI), ECM, Granger causality

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1. Introduction

According to various economic theories and empirical studies carried out to date, the inflow of foreign direct investment is one of the key factors in the development of innovation in the host countries. This applies to developing countries but not exclusively. Inward FDI flows have an influence on innovations of enterprises thanks to the mechanism of technology and knowledge transfer between the investor's country and the host country of FDI. Unlike typical portfolio investments, this form of investment is aimed at building a new business entity from scratch or at taking some shares in the existing enterprise which enables its control. To ensure the proper development of an enterprise created with inward FDI, transfers of the relevant production and technological solutions, know-how, management organisation techniques and marketing techniques are necessary to improve the efficiency of an enterprise, its innovations and competitiveness. Thus, foreign direct investment may affect innovations and competitiveness of enterprises both in the material and non-material spheres. The former includes obtaining modern machinery by beneficiaries of FDI, while the latter is about gaining technical, organisational and managerial expertise, improving the quality of human capital by providing training and courses for staff at various levels. FDI also contributes to the general improvement of company management by adapting the most efficient techniques of financial planning, improving work efficiency and better cost control. These elements, combined with greater availability of foreign capital, are conducive to or even decisive for companies' innovations. The potential effects of the development of innovations on the enterprise's environment should also be mentioned here as the implemented product or organisational innovations are usually later followed and imitated by other domestic companies, and this contributes to the development of other industries and the entire economy of the host country of FDI.

It should also be emphasised that the spillover effects linked to the adaptation of new technologies and to qualified staff (who start working for other companies), or to the creation of cooperating logistics chains with vertical links, depend on the capacities of economy sectors of the FDI host country to absorb new production and organisational solutions, and on the nature of FDI. If foreign direct investment projects are focused on access to sales markets, the investor usually tries to limit the spillover effect of technologies because technology transfer is meant to be beneficial only to the company's operations. When FDI is focused on low prices of production factors, then cooperation links with local companies are required and the diffusion of technologies to the sector and beyond becomes faster. Nevertheless, there are theoretical concepts, such as Vernon's product life cycle theory (Vernon, 1966), which assume at some stage of the investment process even inhibiting or at least delaying the impact of inward FDI flows on innovation. However, Dunning's pull factor theory (Dunning, 1995) suggests that a feedback effect is possible, i.e. that it

is innovations in the host country that attract foreign investors. According to this theory, investors are looking for investment opportunities in companies that have more modern technologies than are owned by the investing company. These technologies are then sent by the investor to the parent company. Ultimately, therefore, foreign investors do not incur R&D expenditure in the country hosting the FDI. There are also theories that assume a mixed impact of FDI on innovation, where the benefits and disadvantages of the inflow of FDI may balance each other in some way (Yang et al., 2013). In light of the theoretical concepts mentioned here, as well as empirical research reviewed later in this article, the impact of inward FDI on innovation is not always one-way and does not always brings benefits. The debate in the literature on the subject continues on this topic and concerns also the countries of Central and Eastern Europe, including Poland as inward FDI beneficiaries. The question is to what extent do inward foreign direct investment projects in Poland support this process, and to what extent do they limit it? Poland is a country with great economic potential, attractive for foreign investors, where the share of inward FDI stocks in GDP exceeds 40%[1], so the assessment of the direction and strength of the impact of FDI on innovation seems fully justified. The studies conducted so far show that the inflow of FDI to Poland increases the innovativeness of the economy. However, in general, research on the relationship between FDI and innovation does not take into account the close cause-effect relationship, but only includes independent analyses of the inward FDI structure and innovation indicators. Yet, the results of the research conducted so far lack models that will make it possible to describe the cause-effect relationship between the discussed categories for the Polish economy.

This article is the author's attempt to bridge this gap by analysing the influence of foreign direct investment on innovations of enterprises in Poland in cause and effect terms. For this purpose, panel data models with error correction mechanism and the Granger causality test were applied. Such research methodology allows for determining the actual direction and strength of the impact of FDI on innovations in companies from the major sectors of the economy.

2. Theoretical concepts of the relationship between FDI and innovation

The debate on the relationship between inward FDI flows and innovation in the literature concerns three various theoretical concepts. They assume that the impact of FDI on innovation can be positive, negative or neutral. The positive impact of FDI on innovation is the most motivated one. These theories emphasise the importance of channels, such as transfers of new technologies and knowledge from the investing country to the FDI host country, through which the improvement of innovation occurs (Aghion et al., 2009; Bertschek, 1995; Caves, 1974). According to these

[1] Source: www.nbp.pl (download date: 17.02.2022)

concepts, the entry of foreign investors increases competitiveness and thus stimulates production efficiency and generates additional economies of scale for local companies, enabling them to improve their productivity. Along with the increase in productivity, the company has additional financial resources that can be spent on innovation and R&D (Aghion et al., 2001). According to Blomström and Kokko (1998), the competitiveness of enterprises, in turn, improves the allocative and technical efficiency of companies and stimulates innovation, therefore FDI is expected to improve the innovativeness of companies. The positive impact of FDI on local companies is twofold: it has a positive effect on the companies that support them, and secondly, it has a positive impact on other local companies in the same economy or sector. In addition to excellent knowledge transfer, host firms also benefit enormously from FDI in strengthening their capital base. Thanks to additional capital resources, such companies can afford to employ highly qualified and creative staff, which can be used in the implementation of innovative solutions in the production and management process (Glass, Saggi, 2002). The positive impact of FDI on innovation may also be the result of increased demand for the products of local companies (Rodrigue-Clare, 1996). If their production companies are not able to keep up with the growing demand, they can implement innovative solutions allowing for more efficient production. Knowledge transfer driven by FDI can help here.

Attention should also be paid to the imitation effect, bringing benefits to local companies in the country hosting FDI (Salomon, 2006). The spillover effect in terms of innovation is possible, among others, thanks to the transfer of employees between companies. Some researchers believe that the inflow of FDI inhibits the innovativeness of the economy in the host country. In his theory of product life, Vernon (1966) claims that Multinational Enterprises (MNEs) spend more on innovation in their operations in the early stages of the company's life cycle, and that moving to host countries in the mature stage involves less R&D spending.

There are also concepts according to which MNEs look for such destinations for their FDI, in which local companies will only be responsible for such stages of production that do not require advanced technology or knowledge transfer (e.g. for final processing or distribution), and the stages requiring it will be implemented in parent companies (Yang et al., 2013). Then, the innovation benefits for the FDI-powered company will be limited. On the other hand, according to Dunning's theory (Dunning, 1995), one of the motives behind FDI is the reverse transfer of technology and knowledge – from the host country to the investor's country. Then, investors are interested in taking over the technological solutions used in the beneficiary's country and adopting them in the parent company. Such a situation will not bring benefits in terms of innovation in the economy of the host country.

The third group of theoretical concepts assumes that the impact of FDI on innovation is mixed or neutral. Dunning (1993) considered the relationship between the inflow of FDI and benefits for companies and for the entire economy, and showed

that if local firms benefit from the inflow of FDI, then the whole economy does not benefit, and vice versa. Blind and Jungmittag (2004) proved that the way FDI influences innovation depends on the type of FDI: in the case of greenfield investments, the benefits of FDI are the greatest. Yet, the benefits of mergers and acquisitions depend on whether the investing enterprise or the enterprise that is the target of the investment has more advanced innovations. According to another concept, the degree of benefit from innovation will depend on the size of the technological gap between the investor's country and the FDI host country – the greater the gap, the greater the impact on innovation (Blind, Jungmittag, 2004).

3. Review of empirical literature

Polish and foreign literature has seen research on the relations between FDI and innovation ratios for a long time, but mostly in the context of broader considerations on the influence of FDI on the economy in general. In the case of the Polish economy, the research results usually confirm the beneficial impact of FDI on the innovations of enterprises by industries, regions or countries (Stiebale, Reize, 2010; Wiśniewska, 2001). These conclusions are drawn based on the analysis of dynamics of the inflow of FDI and the analysis of available innovation ratios for economy sectors or countries with the omission of the modelling of cause-effect relations. World literature including empirical research often uses econometric modelling to describe these relations. Public and private expenditure on research and development, the number of patent applications, productivity of production factors, export volume of technologically advanced goods, and the inflow of foreign direct investments are the subjects of modelling. Researchers usually use regression models, panel data models, dynamic econometric models and VAR models. The research refers to whole economies, regions or sectors of the economy. Table 1 provides an overview of the major research findings on the relationship between FDI and innovation.

For example, the positive impact of FDI on innovations in the Chinese economy measured by the number of patent applications was confirmed, e.g. by Cheung and Lin (2004), Hsu and Yu-En (2015). Iacovone et al. (2009) came to similar conclusions when examining the investments of Walmart in the Mexican market. The same kind of influence on the innovations of the West German economy was confirmed by Bertschek (1995) who analysed 1,270 companies in the industry sector. Similar conclusions for the German economy were also obtained by Stiebale and Reize (2010). Temiz and Gökmen (2014) showed that FDIs are the driving force of economic growth and development both in developed and developing countries. Ghazel and Zulkhibri (2015), as well as Khachoo and Sharma (2016) in their separate studies, noted that FDI is an effective catalyst in the innovation capacity of host companies. Moreover, Khachoo and Sharma (2016) showed that greater benefits from the development of innovation caused by the inflow of FDI are visible in companies operating in identical industries.

Table 1

Overview of the study results of the relationship between FDI and innovation

Type of relationship	Study area	Research tools	Relevant studies
Positive	Germany	Probit model	Bertschek (1995)
	Taiwan	Negative binomial model, logit model, Principal Component Analysis (PCA)	Lin, Lin (2009)
	China	GMM estimator	Liu, Zou (2008)
	India	Poisson model, negative binomial model	Khachoo, Sharma (2016)
	Developing countries	Negative binomial model	Ghazel, Zulkhibri (2015)
	China	Fixed Effect (FE) and Random Effect (RE) models	Cheung, Lin (2004)
	Germany	Tobit model	Stiebale, Reize (2010)
	Mexico	Logit model	Iacovone et al. (2009)
	Asian countries	Gravity model, GMM estimator	Hsu, Yu-En (2015)
	Turkey	VAR model	Temiz, Gökmen (2014)
	Poland	Synthesis of the results of various studies	Wiśniewska (2001)
Negative	Spain	Poisson regression model, negative binomial regressions, GMM regression	Garcia et al. (2013)
	Central and Eastern Europe	Tobit model	Maaso et al. (2013)
	Sub-Saharan Africa	Stochastic frontier analysis (SFA)	Barasa et al. (2018)
Mixed, neutral	13 different countries	Dynamic panel data model	Potterie, Lichtenberg (2001)
	Czechoslovakia	Linear regression model	Kinoshita (2000)
	Spain	GMM estimator	Rosell-Martinez, Sanchez-Sellero (2012)
	China	Tobit model	Girma et al. (2005)
	54 developing countries	Panel threshold model	Loukil (2016)
	Southeast Asia	Fixed Effect (FE) and Random Effect (RE) models	Sivalogathasan, Wu (2014)

Source: author's own study.

However, some researchers proved that the benefits of FDI in terms of innovations refer only to the sectors and companies which invest in research and development (R&D). Such results were obtained by e.g. Kinoshita (2000) for the Czech market, whereas Rosell-Martinez and Sanchez-Sellero (2012) demonstrated that in Spain FDI flows to research sectors and to sectors experiencing an intense development. Similar results for the Chinese economy were obtained by Girma et al. (2006), who performed econometric modelling based on the sample of 30,000 companies. The same researchers confirmed that research and development are the major component elements of enterprise innovations, so the inflow of FDI can be endogenous and the spillover effects can be limited. A similar unequivocal influence of FDIs on the innovations of the economy was found by Loukil (2016), who concluded that below a certain threshold of technological development FDI projects can have an adverse effect on innovations in companies accepting innovations whereas above the same threshold, FDI has a positive impact on innovations of companies in developing countries.

The negative effects of the inflow of FDI for the innovativeness of local companies were confirmed by Garcia et al. (2013), and Barasa et al. (2018), who showed that foreign technology has a negative impact on the technological efficiency of companies in host countries. Similar conclusions were reached by Maaso et al. (2013), who found that the inflow of FDI is not conducive to innovation in host countries. Such an unequivocal influence of FDI on innovations in enterprises worldwide and the research gap in the application of advanced quantitative tools in research incline researchers interested in the Polish economy to further develop research on this matter.

4. Research methodology

The modelling of dependencies between foreign direct investment and innovations in businesses used data on the inflow of FDI to individual provinces in Poland, whereas expenditure on research and development by provinces and the number of patent applications in individual provinces were assumed as innovation ratios. These types of variables are most often adopted in studies on the innovativeness of economies, as they reflect fairly accurately the level of innovativeness of the economy (expenditure on research and development represents the side of capital expenditure on innovation, and the number of patents filed – the effects of innovation). All data were cross-sectional and time-based, and panel models of error correction mechanism (ECM) were used in the research. This is a combination of econometric tools known from the analysis of time series with the panel data analysis. On the one hand, the application of this approach was dictated by the nature of the data, but on the other hand, by the need to take into account the impact of the historical values of variables (autoregressive processes) on their current values and finally the search for a long-term relationship between FDI and enterprise innovation. The proposed

approach allows for the determination of the time-independent balance path for cointegrated economic processes along with short-term deviation from balance. This research methodology requires the examination of the existence of a unit root of the relevant time series (Baltagi, Kao, 2000).

The starting point in the testing of the stationarity of time series in panel models with error correction mechanism is the AR process:

$$y_{it} = \delta_i y_{t-1} + \alpha_i X_{it} + \varepsilon_{it}, \tag{1}$$

where: y_{it} – dependent variable, $i = 1, 2, \ldots, N$, n – number of units in the cross-section (of objects) or time series, $t = 1, 2, \ldots, T$ – number of periods during which objects are observed, X_{it} – endogenous variables which take account of trends and fixed effects, ε_{it} – error term.

In this model, the fulfilment of condition $|\delta_i| < 1$ by parameter δ_i suggests stationarity of the time series, whereas condition $|\delta_i| = 1$ means the existence of a unit root, hence non-stationarity of the series. Stationarity tests of variables for dynamic panel models usually are based on the assumption that parameter δ_i is identical in all cross-sections or that it can change its values arbitrarily within cross-sections (Im et al., 2003). In the former case, the Breitung test is used (2000), while in the latter the Fisher tests were based on ADF tests. This study used both groups of tests.

The key element of the modelling of innovation ratios and foreign direct investment is the analysis of the existence of a cointegrating relation between the time series of variables which form equations:

$$\ln P_{it} = \beta_{i0} + \beta_{i1} \ln FDI_{it} + u_{it}, \tag{2}$$

$$\ln RD_{it} = \gamma_{i0} + \gamma_{i1} \ln FDI_{it} + v_{it}, \tag{3}$$

where: P_{it} – number of patent applications in i-th object (here: province) during period t, RD_{it} – expenditure on R&D in i-th object during period t, u_{it}, v_{it} – error terms which are uncorrelated white noise processes.

Engle and Granger (1987) proved that a linear combination of two or more nonstationary time series can be stationary. If there is such a stationary linear combination, then the time series are cointegrated and this combination is the cointegration equation. The equation can be interpreted as long-term dependence between variables. For panel data models, the Johansen procedure (Maddala, Wu, 1999) and the Pedroni (1999) procedure were are used. The Engle-Granger procedure tests the stationarity of residuals in the model with variables with stationary increments (Kao, 1999). The Johansen procedure, in turn, applies empirical probabilities to combine individual, independent results where each panel unit is treated individually and allows for defining individual cointegration. The Johansen test is based on trace statistics of the matrix and maximum eigenvalue. The application of the Johansen procedure allows for determining at least r cointegration vectors.

In this research, both types of tests were used to detect cointegration. For stationary variables, it is possible to build ECM models and thus estimate short-term dependencies. A single-equation model of error correction for stationary increments of variables used in analyses of short-term dependencies for panel data may be written in the following form:

$$\Delta y_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{1j} \Delta y_{i,t-j} + \sum_{j=1}^{q} \alpha_{2j} \Delta x_{i,t-j} + \gamma ECT_{i,t-1} + \varepsilon_{it}, \tag{4}$$

where: $ECT_{i,t-1}$ – error-correction term representing a long-term relationship, p, q – orders of lagged differences in variables (selected using the Schwarz information criterion), $y_{it} \in \{\ln P_{it}; \ln BR_{it}\}; x_{it} \in \{\ln BIZ_{it}\}$, ε_{it} – error term of the model.

Granger's analysis of variable causality was conducted using the Dumitrescu and Hurlin (2012) approach, which provides for the heterogeneity of panel data models. In this case, the basis is the model

$$y_{it} = \alpha_0 + \sum_{k=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-t} + \varepsilon_{it}. \tag{5}$$

When testing the causality of variable X in relation to Y, the tested hypothesis was that the autoregressive structure of process X equals zero (H_0: $\beta_i = 0$ for $I = 1, 2, .., N$), as opposed to the hypothesis that β_i parameters differ from zero in each cross-section of panel data. The following test statistics using means from Wald test statistics determined separately for each cross-section is calculated below

$$\hat{Z}_{N,T}^{HNC} = \sqrt{\frac{n}{2K}} \left(\bar{W} - k \right), \tag{6}$$

where: n – number of observations, k – lag order of variables in the model, $\bar{W}$ – mean value of Wald statistics from all panels.

With the null hypothesis being true, statistic (6) has an asymptotic standard normal distribution. The results of the statistics calculated based on the appropriate vector autoregressive model (VAR) enable the examination of causality of FDI variables and innovation ratios. Data for calculations were retrieved from the databases of the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

5. Results of empirical research

Cross-sectional and time-based data considering the variables mentioned below were taken into consideration in the analysis of the influence of foreign direct investments on innovation of enterprises: *FDI* – inflow of foreign direct investment

in PLN million[2], *RD* – research and development expenditure in enterprises in PLN million[3], *P* – number of patent applications filed by businesses with the Patent Office of the Republic of Poland[4]. The values of variables were observed in 16 individual provinces during the period 2010-2019, whereas the calculations were performed individually for businesses from the industry sector and the services sector. The study applied logarithm variables. In accordance with the methodology of the construction of ECM models, the stationarity of the following time series of variables was analysed first: $\ln P_{it}$, $\ln BR_{it}$, $\ln FDI_{it}$ for $i = 1,2,...,16$, and $t = 1,2,\ldots,10$. Table 2 presents the results of panel unit root tests (p-value is given in brackets).

Table 2

The results of panel unit root tests

Sector	Test	$\ln P_{it}$	$\ln RD_{it}$	$\ln FDI_{it}$	$\Delta ln P_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln FDI_{it}$
Industry	Fisher PP	15.145 (0.058)	9.541 (0.125)	12.658 (0.084)	30.145 (0.000)	27.212 (0.001)	42.104 (0.000)
	Breitung	-1.245 (0.214)	0.875 (0.321)	1.0234 (0.624)	-2.784 (0.009)	-2.889 (0.012)	-3.745 (0.000)
Services	Fisher PP	13.876 (0.092)	16.057 (0.065)	10.337 (0.074)	42.108 (0.000)	34.508 (0.000)	37.604 (0.000)
	Breitung	-0.544 (0.107)	1.024 (0.233)	0.983 (0.544)	-3.745 (0.012)	-4.714 (0.000)	-4.204 (0.001)

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

In light of the results of the conducted stationarity tests, it should be concluded that the first differences in the analysed variables are stationary. Each of time series was thus integrated of order I(1). Furthermore, it was verified whether there is cointegration between the relevant variables. For this purpose, the Johansen procedure (Table 3), and the Pedroni and the Kao tests (Table 4) were used.

Based on the results presented in Tables 3 and 4, it should be concluded that all the tests indicate the existence of cointegration between variables, except for the ADF Pedroni panel test which shows the absence of cointegration between expenditure on R&D among enterprises in the services sector and the inflow of FDI to the same sector. However, because the Kao panel test and the panel data test using the Johansen procedure suggest the existence of cointegration, in this case the decision was made that there is cointegration in all the analysed dependencies.

[2] Source: the National Bank of Poland (https://www.nbp.pl/), Orbis database (https://www.bvdinfo.com/en-gb/our-products/data/international/orbis)

[3] Source: Main Statistical Office of Poland (www.gus.gov.pl)

[4] Source: Patent Office of the Republic of Poland (https://uprp.gov.pl/pl)

Table 3

The results of panel cointegration tests using the Johansen procedure

Sector	Cointegration relationships	Statistical hypothesis	Max-Eigen Stat.
Industry	$\ln P_{it}=\beta_{i0}+\beta_{i1}\ln FDI_{it}+u_{it}$	H_0: Absence of cointegration	52.354 (0.000)
		H_1: At most one cointegrating vector	4.214 (0.451)
	$\ln RD_{it}=\gamma_{i0}+\gamma_{i1}\ln FDI_{it}+v_{it}$	H_0: Absence of cointegration	42.055 (0.000)
		H_1: At most one cointegrating vector	6.851 (0.342)
Services	$\ln P_{it}=\beta_{i0}+\beta_{i1}\ln FDI_{it}+u_{it}$	H_0: Absence of cointegration	61.874 (0.000)
		H_1: At most one cointegrating vector	5.983 (0.624)
	$\ln RD_{it}=\gamma_{i0}+\gamma_{i1}\ln FDI_{it}+v_{it}$	H_0: Absence of cointegration	74.365 (0.000)
		H_1: At most one cointegrating vector	2.124 (0.650)

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

Table 4

The results of panel cointegration – the Pedroni and the Kao tests

Sector	Cointegration relationships	Test	
		Pedroni ADF	Kao ADF
Industry	$\ln P_{it}=\beta_{i0}+\beta_{i1}\ln FDI_{it}+u_{it}$	-3.358 (0.002)	-6.251 (0.000)
	$\ln RD_{it}=\gamma_{i0}+\gamma_{i1}\ln FDI_{it}+v_{it}$	-1.441 (0.054)	-3.324 (0.032)
Services	$\ln P_{it}=\beta_{i0}+\beta_{i1}\ln FDI_{it}+u_{it}$	-4.205 (0.000)	-7.521 (0.000)
	$\ln RD_{it}=\gamma_{i0}+\gamma_{i1}\ln FDI_{it}+v_{it}$	-3.657 (0.003)	-5.797 (0.000)

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

In view of this, when the Fully Modified Least Squares (FMOLS) method was used, long-term relations between variables *FDI* and *RD* as well as *FDI* and *P* were estimated in accordance with models (2) and (3). The results given in Table 5 are

statistically significant and the obtained models of cointegration equations imply fairly good adjustment to empirical data (coefficients of determination are given in the last column of the table). When analysing the obtained parameters, it can be concluded that in the long run the impact of foreign direct investments on innovations in enterprises in the industrial sector is stronger than in the services sector. A 1% increase in the inflow of FDI to the industrial sector causes an increase in the number of patent applications by approximately 0.308%, and an increase in R&D expenditure in the same sector by approximately 0.645%. The same increase in the inflow of FDI to enterprises in the services sector has an influence on the increase in the number of patent applications in this group of businesses by approximately 0.208%, and increases R&D expenditure by approximately 0.386% on average. What is notable, is that the fact that long-term elasticity of R&D expenditure in relation to FDI is higher than the elasticity of the number of patent applications both in the industrial sector and the services sector. Therefore, from the long-term perspective, the inflow of FDI supports companies' innovation by higher R&D expenditure to a greater extent than by the number of invention patents.

Table 5

The results of estimation of long-term relations in models (2) and (3) with the use of the FMOLS estimator

Sector	Model	Parameter	Coefficient	R^2
Industry	$\ln P_{it} = \beta_{i0} + \beta_{i1} \ln FDI_{it} + u_{it}$	β_{i0}	1.364 (0.002)	0.856
		β_{i1}	0.308 (0.001)	
	$\ln RD_{it} = \gamma_{i0} + \gamma_{i1} \ln FDI_{it} + v_{it}$	γ_{i0}	-0.961 (0.024)	0.943
		γ_{i1}	0.645 (0.006)	
Services	$\ln P_{it} = \beta_{i0} + \beta_{i1} \ln FDI_{it} + u_{it}$	β_{i0}	2.671 (0.000)	0.971
		β_{i1}	0.208 (0.003)	
	$\ln RD_{it} = \gamma_{i0} + \gamma_{i1} \ln FDI_{it} + v_{it}$	γ_{i0}	1.220 (0.004)	0.826
		γ_{i1}	0.386 (0.007)	

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

In order to analyse the short-term relations between FDI and innovation ratios, the ECM panel model was estimated with the use of the LSDV estimator. Based on the results of the estimation of model (4), the parameters of elasticity for short-term

dependencies and the parameters of the error-correction term are presented in Tables 6 and 7. The parameters of the models were generally statistically significant at the significance level of 0.05, which allows for the generalisation of the conclusions based on the calculations.

A short-term 1% increase in the inflow of FDI in the industrial sector during the previous period caused an increase in R&D expenditure during the current period by approximately 0.079% *ceteris paribus*, whereas a negative parameter next to the

Table 6

The results of estimation of short-term elasticity for R&D expenditure in the ECM panel models

Sector	Explanatory variable	Parameter	Coefficient
Industry	$\Delta \ln FDI_{i,t-1}$	α_{21}	0.079 (0.012)
	$ECT_{i,t-1}$	γ	-0.062 (0.096)
Services	$\Delta \ln FDI_{i,t-1}$	α_{21}	0.041 (0.048)
	$ECT_{i,t-1}$	γ	-0.052 (0.057)

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

Table 7

The results of estimation of short-term elasticities for number of patents in ECM panel models

Sector	Explanatory variable	Parameter	Coefficient
Industry	$\Delta \ln FDI_{i,t-1}$	α_{21}	0.188 (0.032)
	$ECT_{i,t-1}$	γ	-0.113 (0.101)
Services	$\Delta \ln FDI_{i,t-1}$	α_{21}	0.107 (0.029)
	$ECT_{i,t-1}$	γ	-0.073 (0.034)

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

correction term provided for the balance during the previous period; approximately 9.6% of imbalance in comparison to the long-term growth path was corrected by a short-term adjustment process. In the services sector, the short-term relationship between R&D expenditure and the inflow of FDI was weaker than in the industrial sector; an increase in the inflow of FDI during the previous period by 1% caused an increase in R&D expenditure during the current period by approximately 0.041% on average, *ceteris paribus*. The error correction mechanism was slower here: 5.2% of deviations from a long-term growth path were corrected using the error correction mechanism.

Based on the results given in Table 7, it can be concluded that an increase in the inflow of FDI to the industrial sector by 1% in the previous year implied an increase in the number of patent applications during the current year by approximately 0.188% *ceteris paribus,* and approximately 11.3% of imbalance of deviations from the long-run relationship was corrected by a short-term correction process regulated by the error correction mechanism.

In the services sector, a short-term reaction to the inflow of FDI observable in the number of patent applications filed was again weaker in the industrial sector; a 1% increase in the inflow of FDI during the previous year caused an increase in the number of patent applications during the current period by approximately 0.107% on average, *ceteris paribus*, while adaptation to a short-term growth path took longer than in the industrial sector (7.3% of deviation from the long-term relationship was corrected here by the process of short-term adaptations). The Granger analysis of causality was an important element of the analysis of dependencies between FDI and innovations. The results of the panel causality test assuming the heterogeneity of panel model data (Dumitrescu, Hurlin, 2012) are given in Table 8.

Table 8

Results of the panel causality test of variables *RD*, *P* and *FDI*

Sector	Causality direction	Z_{NT}^{HNC}
Industry	*FDI* =>*RD*	4.823***
	RD =>*FDI*	2.012**
	FDI =>*P*	3.982***
	P =>*FDI*	1.058
Services	*FDI* =>*RD*	3.088***
	RD =>*FDI*	2.235**
	FDI =>*P*	4.214***
	P =>*FDI*	2.124**

Note: The significance of results at level 0.01; 0.05 and 0.1 is marked: ***, **, *.

Source: author's own study based on data from the Main Statistical Office of Poland, the National Bank of Poland, Orbis, and the Patent Office of the Republic of Poland.

Based on the results given in Table 8, it can be concluded that the inflow of FDI was a cause in the Granger's sense (at significance level of 0.01) of both R&D expenditure and of the number of patent applications filed. Such causality was observed both in the industrial sector and in the services sector while the causality in the direction from *FDI* to *RD* was stronger in the industrial sector, whereas the causality in the direction from *FDI* to *P* was stronger in the services sector than in the industrial sector. Furthermore, the presence of a statistically significant feedback reaction should be noted; R&D expenditures also provided a cause for the inflow of FDI in the industrial and services sectors, whereas the number of patent applications was a significant cause of the inflow of FDI in the services sector (dependencies significant at the significance level of 0.05). The reverse mechanism showed that not only the inflow of FDI contributes to innovation, but also innovation in enterprises can be an important magnet attracting foreign direct investment.

Conclusions

Direct foreign investment brings new technologies and innovative solutions in the sphere of production and organisation. However, as research shows the benefits FDI brings to innovations in specific industries depend on the capacity of these industries to absorb new technological solutions, the efficiency of the spillover effect, and other factors. For this reason, the examination of the issue for various economies, including the Polish economy, seems justified, especially that scientific analyses relating to the relation between FDI and innovation in Poland have so far lacked the modelling of cause-effect relations between the values discussed here.

The results presented in this paper confirm the hypothesis of the positive influence of foreign direct investment on innovation of enterprises both in the industrial and services sectors. These results are consistent with the results obtained by other researchers of the economies of developed and developing countries (Wiśniewska, 2001; Bertschek, 1995; Ghazel, Zulkhibri, 2015; Hsu, Yu-En, 2015). The influence of FDI on innovation of the industrial sector turned out to be stronger than the influence on innovation of companies from the services sector, which was proven in cointegration models and the Granger causality test. In the long run, the greater influence of FDI on expenditure than on the number of patent applications was visible, whereas in the short term the change in the number of patent applications turned out to be a stronger response to the inflow of FDI than the change in R&D expenditure. The correction mechanism of deviation from long-term relationship appeared to be stronger in the case of the industrial sector than in the services sector. This may result from the fact that in Poland the industrial sector absorbs FDI more easily than the services sector and is characterised by smaller inertia. Yet, a bidirectional causality of FDI-innovation was also observed, which indicates that the innovations introduced by enterprises are also important determinants for incoming FDI, both for the services and the industrial sectors. Therefore, it should be concluded

that in order to further narrow the technological gap in Poland and develop innovations, the intensification of development processes of a knowledge-based economy is important and should attract FDI even more. In addition, internal strengthening of enterprise innovation will, as has been proven, be an important element to support the inflow of FDI. However, it should be emphasised that the effect of strengthening innovation depends not only on the specific industry, but also on the type of FDI (greenfield vs. brownfield, wholly-owned vs. joint-ventures, vertical vs. horizontal). Investigating the detailed dependencies in this area requires further research. This study does not exhaust the whole spectrum of dependencies between FDI and enterprise innovation. Processes in knowledge-based economies are quite dynamic and relations between FDI and innovations will change. Therefore, it will become necessary to continue and expand such research by including other variables which represent new technologies. This will enable the constant monitoring of the direction and strength of the relation between FDI and innovation.

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