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The Impact of Industrial Robot Use on Exports in European Countries – an Empirical Analysis

Introduction

Export is the shipping of goods and services to another country for sale or trade. The earnings from such goods and services increase the gross domestic product of nations. Besides, export increases employment, production, and revenues. Export has a positive effect on the current accounts and foreign exchange reserves of countries. Therefore, countries need to develop new production and export methods. The world's largest exporting countries are China, the United States of America, and Japan.

Schumpeter mentions the effects of new production techniques on the economy in the creative destruction hypothesis. According to Schumpeter (1942, p. 83), innovation may occur via factors such as follows:
1) new goods must be improved,
2) new production techniques must be improved,
3) new logistic methods must be improved,
4) new markets must be created.

According to the creative destruction hypothesis, if a country does not become an innovator, the country can lose its international competitiveness ability. Innovation may take place if new production techniques are employed by countries (Schumpeter 1939).

Nowadays, robots are employed gradually in manufacture as a new production technique. This situation will sustain in the future, too. Many companies prefer to use robots because using robots enhances productivity in the industry and

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strengthens the international competitiveness of countries. Industrial robots are employed in many branches of industry, such as electronics, food, automotive.

The robot system is flexible and provides various benefits because the same robot system can be used for different targets or goods. The labor necessity is decreased with robot using in industry. Besides, industrial robots work quicker than laborers. Robots increase the productivity by close to 50 percent (MHI, 2018). Robots have a production cost advantage of 60 percent and the initial investment costs are paid back, on average, in a year. Nowadays, robots become a part of production in every sector. Robotic production provides international competitiveness to countries by reducing production errors, producing more products in a shorter time, and increasing the quality of products (IHA, 2015).

The study aims to examine the impacts on industrial export of industrial robot amount. In the studies in literature, productivity and production costs are analyzed. Also, the studies in the literature explain that using industrial robots affects productivity and production costs positively. However, there are not sufficient studies related to the impact of using industrial robots on the manufacturing industry. This is an important deficiency in the available literature. This is a pioneering study on the subject because there are no studies in the literature that contain the same theme, method, countries, and periods. The study hypothesizes that using industrial robots affects the industrial exports of countries positively. As regards the method, the panel data analysis is used in this study.

1. Literature review

The industrial robot issue is "a new topic." Therefore, there are few studies related to the matter in literature. Kinkel et al. (2015) analyzed the impact of robot applications on the European manufacturing industry. According to the empirical analysis, using industrial robots raises productivity in the manufacturing processes. The positive effect occurs in European high wage countries especially. Sirkin et al. (2015) states that industrial robots increase productivity while they decrease manufacturing costs. Thus, countries raise global competitiveness. We can categorize the countries as aggressive, fast, and slow. European countries are classified in the slow-countries category. This circumstance will affect the global competitiveness of European countries negatively in the next years. McKewen (2016) explains that the user of the industrial robot increases the success of the economy because industrial robots become faster and cheaper as compared to the workforce for companies. Besides, industrial robots raise the global competitiveness of countries. Roehricht (2016) explains that investing in the industrial robot sector is essential for exporting countries of today because industrial robots increase productivity and reduce production costs. Exporting countries will lose their exporting positions if they do not invest in the industrial robotic sector in the next ten years. Hong (2017) writes that the government of South Korea gives excellent care to the robot industry; the government tries to assure that the country becomes a leading exporting country in the robot industry. Ndubuisi and Avenyo (2018) explained that robotization affects export positively. Eker and Eker (2018) stated that the use of industrial robots increases production. However, it does not shorten working times. According to Liu (2019), robotization increases efficiency and production in developing countries. Nevertheless, it will cause low skilled workers to become unemployed.

2. Methodology

The panel data analysis method is used in this study. In statistical analyses, the data can be divided into three categories, as time series, horizontal cross-section, and mixed data consisting of a combination of these two data types. If the same cross-sectional unit is tracked over time, such mixed data is called panel data (Gujarati 1999). The panel data analysis covers some units, such as households, firms, or countries, within a specified period. The panel data analysis often utilizes reciprocal data from different countries (Baltagi 2005, p. 237; Hsiao 2003, p. 3). The panel data analysis method is based on time-series observations. There are two dimensions: time-series, and cross-section. Panel data analysis has a hierarchical structure, which can be explained as follows (Hsiao 2006, p. 1–6):

a) the panel data analysis method offers the opportunity to determine the correct model parameters;
b) the panel data model can solve problems related to the regression results;
c) the panel data method is suitable to control by the set dynamics;
d) the panel data method is ideal for solving complex behavioral models.

An ordinary panel data model is written as (Hsiao 2003):

$$Y_{it} = \alpha_{it} + \beta_{it} X_{it} + u_{it} \quad (i = 1, ..., N; \;\; t = 1, ..., T), \tag{1}$$

where Y is the dependent variable in the model, X represents independent variables, α – constant parameters, β – slope parameter, u – error, i – units (individuals, households, vendors, or countries), t represents some time variables (such as day, month, or year).

Panel unit root tests are applied in the first stage to determine the stability of the data. Breitung, Hadri, Im-Pesaran, and Shin (IPS), Levin, Lin and Chu, Fisher, and Harris-Tzavalis unit root tests are used widely by researchers. Levin and Lin (1992) developed unit root tests for the model:

$$\Delta y_{i,t} = p y_{i,t-1} + \delta_t + \alpha_i + \theta_t + \varepsilon_i, \quad (i = 1, ..., N; \;\; t = 1, ..., T), \tag{2}$$

The model contains time trend and individual effects. Levin and Lin (1992) test indicates the H_0 hypothesis and H_1 hypothesis as:

$$H_0: p_1 = p_2 = \ldots = p_N = p = 0; \qquad H_1: p_1 = p_2 = \ldots = p_N = p < 0. \tag{3}$$

Levin, Lin and Chu (2002) developed a unit root test that is called LLC. The test proposes these hypotheses as follows: null hypothesis (H_0) – each time series contains a unit root; the alternative hypothesis (H_1) – each time series is stationary. $\sqrt{NT/T} \rightarrow 0$ is the condition for LLC; N is a monotonic function; NT is the cross-sectional dimension (Kunst 2011, p. 1). The LLC analysis may be defined as follows (Barbieri 2006, p. 6):

$$\Delta y_{it} = py_{it-1} + \alpha_{0i} + \alpha_{1it} + u_{it}, \quad (i = 1, ..., N; \; t = 1, ...,T), \tag{4}$$

where α_{1it} is time trend. Also α_i (individual impacts) is included, and u_{it} is presumed to be independently scattered across individuals:

$$u_{it} = \sum_{j=1}^{\infty} \theta_{ij} u_{it-1} + \varepsilon_{it}. \tag{5}$$

There are many estimation methods used in simultaneous equation systems. One of them is the two-stage least squares method. This was one of the methods used by Henri Theil and Robert Basmann to estimate the systems of simultaneous equations they have developed as a particular form of the generalized least squares method (Gujarati 2006).

The basic idea of all simultaneous equation systems estimation methods is to purify the internal variable, which is a random variable, from the effect of the error term and to try to minimize this deviation, called simultaneous equation deviation. In this respect, the internal equations in the equation examined are created according to all external variables in the model. Then, by estimating the reduced pattern parameters, the estimation values of the internal variables in the reduced form equation are found. The panel simultaneous equation system is estimated with constant and random effects assumptions in consideration of the unit impact while the panel data analysis is running. For the two-step least-squares method, the first equation of the panel simultaneous equation system is as follows (Haavelmo 1944):

$$Y_1 = \alpha_1 + \alpha_2 Y_2 + u_1, \tag{6}$$

$$Y_2 = \beta_1 + \beta_2 Y_1 + u_{12}. \tag{7}$$

In the equation system given above, there is a bidirectional cause-effect relationship between Y_1 and Y_2 variables. These variables affect each other mutually. In both equations, error terms and independent variables are not independent of each other. Therefore, the equations here cannot be solved individually. Such equations should be treated together (Haavelmo 1944). Two-stage least squares method is a very preferred method due to its ease of application because it is sufficient to know the external variables in the model for parameter estimates.

3. Data and models

Industrial robot data were taken from the international federation of robotics. The data cover the period between 2006 and 2018. Data of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Romania, Slovakia, Spain, Sweden, and the United Kingdom are used in the study, which is available for the relevant period.

All value data are in constant prices and annual. Data of GDP (gross domestic product), export, and global competitiveness are taken from the "World Development Indicators" database of the World Bank. GDP data are in constant 2010 US dollars. Total exports are measured in billions of the US dollars. Data on employment are taken from Eurostat.

There are few studies related to this issue in the literature. The studies which do exist are usually descriptive research, while empirical works are few, if any. This article, which is an empirical study, addresses this absence related to the industrial robot topic. The relationships between the number of industrial robots, global competitiveness, exports, employment, and GDP are examined with the help of the following equations:

$$\mathrm{AIR}_{it} = \beta_{10} + \beta_{11}\mathrm{GDP}_{it} + \beta_{12}\mathrm{GC}_{it} + \beta_{13}\mathrm{EMP}_{it} + \varepsilon_{1it} + u_{1it}, \quad (8)$$

$$\mathrm{EXP}_{it} = \beta_{20} + \beta_{21}\mathrm{AIR}_{it} + \beta_{22}\mathrm{GC}_{it} + \beta_{23}\mathrm{EMP}_{it} + \varepsilon_{2it} + u_{2it}, \quad (9)$$

where AIR – amount of industrial robots, GC – global competitiveness, GDP – gross domestic product, EXP – export, EMP – employment. In the study, internal variables are GC and EXP, while external variables are AIR, EMP, and GDP. In the first phase of the two-step least-squares method, the structural form is transformed into a collapsed form. In other words, internal and external variables are gathered together, and internal variables in all models are used to predict external variables:

$$\mathrm{AIR}_{it} = \lambda_{10} + \lambda_{11}\mathrm{GDP}_{it} + \lambda_{12}\mathrm{EMP}_{it} + \lambda_{13}\mathrm{GC}_{it} + \varepsilon_{1it} \rightarrow \mathrm{AIR}_{it'}, \quad (10)$$

$$\mathrm{EXP}_{it} = \lambda_{20} + \lambda_{21}\mathrm{AIR}_{it} + \lambda_{22}\mathrm{EMP}_{it} + \lambda_{23}\mathrm{GC}_{it} + \varepsilon_{2it} \rightarrow \mathrm{EXP}_{it'}, \quad (11)$$

In the second step, the estimated values of EXP and GC, which are the external variables obtained in the first stage, are used as variables in the structural form of the simultaneous equation system, and the following equations are estimated:

$$\mathrm{AIR}_{it} = \beta_{10} + \beta_{11}\mathrm{GDP}_{it} + \beta_{12}\mathrm{EMP}_{it} + \varepsilon_{1it} + u_{1it}, \quad (12)$$

$$\mathrm{EXP}_{it} = \beta_{20} + \beta_{21}\mathrm{AIR}_{it} + \beta_{22}\mathrm{EMP}_{it} + \varepsilon_{2it} + u_{2it}, \quad (13)$$

The two-step least squares method is estimated via the panel fixed effect test in order to see the cumulative effect of countries. The outcomes of the analysis are discussed in the estimation results section.

4. Empirical results

The stability of the variables is examined via the LLC and Breitung unit root tests. The variables are stable according to the LLC unit root test but are not for the Breitung unit root test as levels. Therefore, the first differences were employed for EXP, AIR, GDP, and GC variables.Thus, EXP, AIR, GDP, and GC have become stable values.

Hausman test applies to estimate parameters with fixed effect and random effect models used in panel data to see individual effects. In this stage, it is neces-

Table 1
Results of unit root tests

Variables		LLC		Breitung	
		statistic	*p*-value	statistic	*p*-value
Level	LAIR	–5.2393**	0.0000	1.8500	0.9678
	LGDP	–6.1170**	0.0000	1.3990	0.9191
	LEXP	–4.8308**	0.0000	3.7165	0.9999
	LGC	–6.1472**	0.0000	–0.6345	0.2629
First difference	AIR	–8.7015**	0.0000	–6.5474**	0.0000
	GDP	–19.9200**	0.0000	–3.7604**	0.0001
	EXP	–7.5845**	0.0000	–4.2307**	0.0000
	GC	–12.5927**	0.0000	–4.4086**	0.0000

LLC: Levin–Lin–Chu unit root test; Breitung: Breitung unit root test.
** Statistically significant at 5% level.
Source: own calculations, using Stata.

Table 2
Results of Hausman test

Dependent variable	AIR	EXP
Prob > chi2	0.8774	0.4515
Result	random	random

Source: own calculations, using Stata.

Table 3
Estimated results of the two-step least squares (AIR equation)

AIR	Coef.	Std. err.	$P > \|z\|$	[95% conf. interval]	
GDP	4.84307**	1.3501360	0.000	2.196856	7.4892920
EMP	–0.04459	0.0705907	0.528	–0.1829512	0.0937593
Const.	1.14800	2.1528590	0.594	–3.071518	5.3675360
Prob > chi2	0.0014		R^2	0.29	

** Statistically significant at 5% level.
Source: own calculations, using Stata.

Table 4
Estimated results of the two-step least squares (EXP equation)

EXP	Coef.	Std. err.	$P > \|z\|$	[95% conf. interval]	
AIR	0.049986**	0.0122906	0.000	0.0258975	0.0740759
EMP	0.030492	0.0024648	0.216	–0.001781	0.0078802
Const.	–0.05841	0.0634673	0.357	–0.182811	0.0659753
Prob > chi2	0.0001		R^2	0.49	

** Statistically significant at 5% level.
Source: own calculations, using Stata.

sary to decide which of these two models (fixed effect, random effect) is valid. For this, the Hausman test is applied.

Hausman test's prob > chi2 value for AIR is 0.877. In other words, 0.877 > 0.05, the random effect as dominant hypothesis is accepted, and the random effect model is preferred. Also, prob > chi2 value for EXP is 0.451, and 0.451 > 0.05, again, the random effect as dominant hypothesis is accepted, and the random effect model is chosen (Table 2).

EMP variable is not significant statistically. Also, GDP affects AIR positively. If GDP increases 1 unit, AIR increases 4.84 unit. According to the result of the analysis, the amount of industrial robots increases when the GDP of the European countries increases (Table 3).

EMP variable is not significant statistically. Also, AIR affects EXP positively. If AIR increases by 1 unit, EXP increases by 0.04 unit. According to the result of the analysis, the exports of the European countries increases with the number of industrial robots (Table 4).

Conclusion

In the study, the impacts of industrial robot amount on global competitiveness and export for the period of 2006–2018 for 17 European countries are investigated. The two-step least squares method is applied in the context of the simultaneous equations system. The result of the analysis shows that the industrial robot using affects export of European countries positively. This result is consistent with the creative destruction hypothesis because using of industrial robots increases exports of the European countries while raises the productivity of companies. In other words, firms can produce more goods at a low cost via robots in a short time. Therefore, developed countries are investing in the robot industry. Even China, Japan, and South Korean have placed on the top among the countries which invest in the robot industry.

Today, the positive impact of robots on export has been discerned by China, South Korea, and Japan. Therefore, these countries are investing millions of US dollars in the industrial robotic sector. Countries can be divided into three groups (aggressive, fast, and slow) as regards their attitude to the investments in the industrial robot sector. China, Japan, and South Korea belong to the aggressive group while European countries fall into the slow group. Many factors contribute to the increase in the manufacturing costs. The developed countries try to decrease the production cost because the countries do not wish to lose their leading positions in world exports.

European policymakers should allocate more resources for R&D and industrial robot production if they do not want to lose their export positions and reduce the welfare level of people in the next decades.

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THE IMPACT OF INDUSTRIAL ROBOT USE ON EXPORT IN EUROPEAN COUNTRIES – AN EMPIRICAL ANALYSIS

Summary

In this paper, the relationship between the volume of export and the number of industrial robots in the selected European countries is examined by using the simultaneous equation models. Panel data of Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Romania, Slovakia, Spain, Sweden, and the United Kingdom are used. The study covers the period of 2006-2018, for which the required data are available. The article is a unique empirical study related to the subject because the literature on this topic is quite scarce. According to the results of the analysis results, there is a positive relationship among the number of industrial robots used and the volume of exports. One can therefore assume that the use of industrial robots contributes to the growth of exports, mainly by the decrease of production costs which improves international competitiveness of industrial products. Therefore, European policymakers should support using robots in manufacturing and other sectors of the economy. In this way, Europe can strengthen its position in the world trade against strong competition from China, the United States, and Japan.

Keywords: export, robots, empirical analysis, European Union

JEL: F14, F17, F18, O31, O52

WPŁYW ZASTOSOWANIA ROBOTÓW PRZEMYSŁOWYCH NA EKSPORT KRAJÓW EUROPEJSKICH – ANALIZA EMPIRYCZNA

Streszczenie

W artykule badana jest za pomocą zestawu równań ekonometrycznych zależność między wielkością eksportu a liczbą robotów przemysłowych w wybranych krajach europejskich. Wykorzystano tu dostępne dane panelowe z okresu 2006–2018 obejmujące następujące kraje: Austria, Belgia, Czechy, Dania, Finlandia, Francja, Hiszpania, Holandia, Niemcy, Norwegia, Polska, Rumunia, Słowacja, Szwecja, Węgry, Włochy i Wielka Brytania. Artykuł jest unikalną analizą empiryczną w tym zakresie, ponieważ literatura na ten temat jest dość uboga. Wyniki analizy pokazują, że zależność pomiędzy liczbą stosowanych robotów przemysłowych a wielkością eksportu jest dodatnia. Można więc przypuszczać, że zastosowanie robotów przemysłowych przyczynia się do wzrostu eksportu, głównie poprzez obniżkę kosztów produkcji, która zwiększa konkurencyjność międzynarodową wyrobów przemysłowych. Dlatego politycy europejscy powinni wspierać wykorzystanie robotów w przemyśle i innych działach gospodarki. W ten sposób Europa może umocnić swą pozycję w handlu światowym i sprostać silnej konkurencji ze strony Chin, Stanów Zjednoczonych i Japonii.

Słowa kluczowe: eksport, roboty, analiza empiryczna, Unia Europejska

JEL: F14, F17, F18, O31, O52

ВЛИЯНИЕ ПРИМЕНЕНИЯ ПРОМЫШЛЕННЫХ РОБОТОВ НА ЭКСПОРТ ЕВРОПЕЙСКИХ СТРАН – ЭМПИРИЧЕСКИЙ АНАЛИЗ

Резюме

В статье с помощью эконометрических уравнений исследуется зависимость между объемом экспорта и количеством промышленных роботов в избранных европейских странах. Были использованы доступные панельные данные за период 2006-2018 гг. относящиеся к следующим странам: Австрия, Бельгия, Чехия, Дания, Финляндия, Испания, Голландия, Германия, Норвегия, Польша, Румыния, Словакия, Швеция, Венгрия, Италия и Великобритания. Статья представляет собой уникальный эмпирический анализ, так как литература на эту тему является довольно скудной. Результаты анализа указывают, что зависимость между количеством промышленных роботов и объемом экспорта положительна. Следовательно, можно предполагать, что применение промышленных роботов способствует росту экспорта, главным образом путем понижения издержек производства, что влечет за собой рост международной конкурентоспособности промышленных изделий. Поэтому европейские политики должны поддерживать использование роботов в промышленности и в других сферах экономики. Действуя таким образом Европа сможет укрепить свою позицию в мировой торговле и выдержать сильную конкуренцию со стороны Китая, Соединенных Штатов и Японии.

Ключевые слова: экспорт, роботы, эмпирический анализ, Евросоюз

JEL: F14, F17, F18, O31, O52