
The Long-run Relationships between Number of Patents and Economic Growth

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Abstract:

Purpose: The aim of the article was to determine whether there was a long-term relationship between the level of economic growth and development of Germany and the number of granted patents and the so-called valuable patents. The empirical analysis was based on available statistical data for the period of 1872–1913. Econometric methods were used, including stationary test using ADF and KPSS tests, Johansen cointegration test.

Findings: The research results showed that all analysed time series were non-stationary, and were integrated of order $I(1)$. The Johansen's test results excluded any long-term relationship between the growth and economic development of Germany, and the number of granted patents, including valuable patents.

Practical Implications: The adoption of the patent law by the Reichstag (1877) was an important step in the protection of intellectual property of the united Germany, so it was reasonable to determine whether there was a correlation between the analysed variables. The hypotheses about long-term interdependence could not be confirmed, which may have an impact on further studies of the factors of economic growth in the Second German Reich.

Originality/Value: It was particularly important to examine whether the number of granted patents (including valuable patents) had a positive effect on Germany's long-term economic growth and development (and the other way around). The obtained results are an extension of the author's research to date, in this respect by providing some contribution to the development of cliometrics (not very popular in Europe). The research results will allow, in the next stage, to further search for determinants of Germany's economic growth, including determining interdependence in the short term, using the impulse response function.

Keywords: Cliometrics, Johansen test, economic growth (and development) of the German Reich, patents.

JEL classification: A12, N13, O47.

Paper Type: Research study.

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1. Introduction

In economic literature, the factors determining economic growth are, among others, population growth, development of the financial sector, macroeconomic conditions, trade policy, socio-political environment, but also expenditure on R&D, their size as well as the entity and subject structure (Snowdon and Vane, 2005). Intellectual property rights (IPR), since its conception in its first historical forms, has been the subject of controversial discussions regarding its economic legitimacy, however, it cannot be ignored in the analyses of economic growth, especially in the period of industrialization (Machlup and Penrose, 1950). Patents, widely regarded as the most important element of IPR, guaranteeing an appropriate return on investment for innovators and creators (Greenhalgh and Rogers, 2007).

In the industrialization process of Germany, started in the mid-nineteenth century, changes in human capital, the level of expenditure on research and development became an important element, and the measurable indicator in this respect was the number of granted patents that were the most important input factor for the development of innovation in the economy. The Patent Act adopted by the Reichstag on May 25, 1877 (Das Reichspatentgesetz) was certainly an important step for the German economy, which was important in building the “made in Germany” brand and also contributing to the development of innovation. It should be added that in the initial stage of industrialization, Germany (German countries), without incurring expenditure on research and development, effectively imitated foreign (e.g. English, Belgian) experience in the sphere of development of individual branches of the national economy, e.g. in railways (Myszczyzyn, 2013; 2019). As a result of Germany’s economic development, the awareness of legal protection of intellectual property increased over time, which under certain conditions led to an increase in the competitiveness of the domestic economy, while protecting it from competition. However, at the beginning of the 1870s, the need for patent protection in Germany seemed to have no future (Boch, 1999).

The economic success that Germany had at the turn of the 19th and the beginning of the 20th century, despite the fact that the country belonged to the poor in mineral resources, should encourage the search for its sources. In retrospect, it can be said that the increase in factor productivity (TFP) played a special role in the process of accumulating national wealth. Metz and Watteler (2002) indicate that in 1870-1973, the share of TFP growth in Germany’s economic growth was about 42%, Burhop specifies that in 1851-1913 it was about 25% for industrial production (Burhop, 2010).

Patent protection also led to increased interest on the part of the business sector to incur funds for research and development (Streb, Wallusch, and Yin, 2007). The adoption of the act meant the state’s readiness to pursue an active economic policy, and the creation of new rules on patents was crucial for the increase in activity in the

area of new technologies, while supporting the development of creative thought and innovation, especially in railways, the so-called “new industries”.

The main aim of the article was to identify causality and its direction between the level of economic growth and development in Germany and the number of received patents, taking into account the so-called valuable patents. Taking into account analyses and papers devoted to explaining economic theories assuming the hypothesis about the positive impact of intellectual property rights on economic growth, the author verified the H1 and H2 research hypotheses (Thumm, 2000; Leger, 2007; Bielig, 2013) as follows:

H1: In the long run, an increase in the number of granted patents, including valuable patents had a positive impact on the level of economic growth and development of German Reich.

H2: In the long term, the growth and economic development of the German Reich had a positive impact on the increase in the number of granted patents, including the so-called valuable patents for the economy.

An important element of the research is the use of still little-known, latest estimates of the level of economic growth of the German Reich developed by Burhop and Wolff (2005) for the number of granted patents (Federico, 1964; Statistisches Jahrbuch für das Deutsche Reich (1880-1916)) and the number of patents valuable for the economy (Streb, Baten, and Yin, 2006) together with an attempt to increase the achievements in the field of cliometrics. The author also used the times series of the national net product per capita (NNP per capita). The author’s previous research on the correlation between the level of economic growth in Germany and the granted patents using the Granger causality test showed no correlation. Annual data from 1872-1913 was analysed.

2. Literature Review

Although the codification of patents and copyrights, as well as the regulation of privileges already appeared in the 15th century, research on the relationship between patent protection and economic growth only began at the end of the 20th century, which was the result of scientific work from the new theory of endogenous economic growth (Azevedo, Silva, and Afonso 2012; Romer 1990; 1994). Research results reflect a diverse assessment of the impact of intellectual property rights (including patents) on innovation processes and economic growth. In their studies of changes in patent protection legislation, researchers note that the purpose of protection is to promote innovation and economic growth. At the same time, they note that there is little credible evidence that patents are indeed the tool by which this goal is achieved. Sanctioned intellectual property rights increase returns on innovation, but at the same time may hinder the spread of technology and subsequent innovations ((Nordhaus, 1969; Scherer, 1972; Green and Scotchmer, 1995).

As emphasized by Aurora and others (2008): “*studies analyzing the impact of IPRs [IP rights] on innovation and growth have yielded mixed and, at times, difficult-to-interpret results*”.

Burhop (2010), analysing the transfer of patent applications in Germany (1877-1913), concludes that patent transfer has positively influenced the allocation of knowledge in the economy and may have been a source of economic growth and increase in productivity. Hu and Png (2013), examining the impact of patent law on economic growth, conclude that patent regulations and their enforcement are important for economic growth, but also taking into account dozens of countries in their studies, they add that stronger patent rights have less impact on economic growth in underdeveloped economies and countries with less patent saturation. They suggest that patent law should be adapted to specific conditions in the country in conjunction with its economic development (development of individual industries)ⁱ. At the same time, they put forward the thesis that there is little explicit empirical evidence to support the claim that the increase in patent protection in the sphere of patents indeed stimulates economic growth.

Ginarte and Park (1997), used the patent right index to study the impact of patent legislation on economic growth, investment and research and development expenditure. They did not find a link between stronger patent law and economic growth. However, they add that among the richer countries (but not the poorer ones), stronger patent rights, however, positively affected the level of investment and the R&D sphere. Josheski and Koteski (2011) in their research on the number of patents and the level of economic growth of the G7 countries (quarterly data for the period of 1963–1993) confirmed (Granger test) the positive effect of the number of patents on the level of economic growth, while in the short term this relationship was negative.

Hasan and Tucci (2010) in panel studies for 58 countries (1980-2003) conclude that the countries in which companies with access to high-quality patents thrived reported higher economic growth. They add that countries that increased the level of patent protection were participants in simultaneous economic growth. Dinopoulos and Segerstrom (2010) claim that stronger protection of intellectual property rights will not only not accelerate economic growth, but also will not accelerate the transfer of international technology, because only patent holders benefit, i.e., corporations based in the most technologically advanced countries of the world, including the USA.

Sinha (2008) studied the cointegration between the number of patents and economic growth in Japan and South Korea (1963-2005). He confirmed the two-way causality between real GDP growth and the increase in the number of patents for Japan. In the case of South Korea, one-way cointegration from real GDP growth towards an increase in the number of patents has been confirmed.

The latest research results for Turkey (1990–2015) using VAR cointegration tests and modelling have shown that both exports of advanced technologies and patents accelerate economic growth in both the short and long term (Dereli, 2019). The author has thus confirmed one-way interdependence. In addition, it indicates, among others, that Algan *et al.* (2017) examined the relationship between the share of research and development expenditure in GNP, the number of patents and GDP per capita using the Granger causality test (1996–2015) and found a one-way causal relationship from the level of GDP per capita towards the number of patents in short term (Algan, Manga, and Tekeoğlu, 2017).

In principle, a review of the literature in this regard could be summarized that empirical evidence regarding the impact of intellectual property rights, in particular patents on the economic growth of modern countries is not unequivocal. One can only conclude that there is no complete consensus in this respect. It should be added that despite the above, it is rather difficult to find works in the field of interdependence research, including those related to the functioning of patent law at the end of the 19th and the beginning of the 20th century.

3. Data

The author based not only on the number of patents for Germany and used estimates in the field of patents valuable for the economy. It should be added that in the period analysed by the author, over 278,000 patents were registered in Germany, where the number of valuable patents estimated by Streb *et al.* was about 31,8% the average share of high value patents in the sum of all patents granted in the years 1877–1918 was 11.14%, and in the period analysed by the author 11.46% (Streb, Baten, and Yin, 2006). In 1872–1913, the average annual growth rate of received patents was 5.4%, although it is noticeable that the largest increase occurred just before the outbreak of World War I. The number of granted patents increased from around 950 in 1872 to nearly 4,500 in 1879, to reach almost 10,500 in 1901, while 13,500 in 1913. At that time, the percentage of valuable patents increased, and so at the end of the 1870s, the percentage was 3–4%, reaching around 10% in the 1890s, and the percentage rose to over 23% in 1913.

The amendment to the German Patent Act (1891) also concerned the extension of protection in the field of raw materials, reported for example by German chemical industry, resulted in an increased number of patents received within a year by almost 19% (Fleischer, 1984). The first corporate research and development laboratories were established in the early 1870s and a similar phenomenon was observed only in the USA at that time. This mainly concerned the chemical and pharmaceutical industries. An important element of patent protection were patent fees, which were relatively high in Germany; for 15-year protection one should pay 5,300 of marks (M), for example, in England this fee was about 3,100 M. High fees in the German patent system allowed to quickly separate patents with significant economic effect

from those of low value, which only contributed to the increase in quality (Burhop, 2010).

To sum up the analysed period in the development of patent law in Germany, it is worth distinguishing individual waves of technological growth that determined the structure of patents obtained: 1) railway wave (1877-1886), 2) dye wave (1887-1896), 3) wave of the chemical industry development (1897-1902), 4) the wave of electrical engineering (1903-1918) (Streb, Baten, and Yin, 2006).

In the analysed period of rapid economic growth in Germany, expenditure on education and the purchase of patents were an important factor affecting labour productivity, as they theoretically affect technical and organizational progress, and thus the increase in labour productivity. According to the correlation account carried out by Hoffmann for the years 1878-1913, a 1% increase in granted patents meant a 0.35% increase in labour productivity (Wallusch, Streb, and Yin, 2007). A detailed analysis of the economic growth of the German states, and later the German Reich, including problems with its estimates, was included in the author's works (Myszczyzyn, 2013; 2019).

It should be noted that in the years 1872-1913 the average annual level of economic growth for the German Reich amounted to:

- NNP estimated by Hoffmann (1965) 2.61%;
- adjusted values calculated by Burhop and Wolf (2005) were: a) NNP IHM 2.64%; b) NNP EH 2.54%; c) NNP IH 3.12%; d) NNP OH 2.61%; e) compromise NNP 2.69%;

In real terms, NNP estimated by Hoffmann increased from 19,133 billion M. (1872) to 52.44 billion M. (1913) (Compromise NNP from 17.89 billion M. to 53.7 billion M.). NNP per capita estimated by the author, measuring the level of economic development increased from 493,99 M. (1872) to 806,05 M. (1913) (Compromise NNP per capita from 450,73 M. to 825,41 M.). The high rate of economic growth meant a number of economic and social changes, including the strengthening of capitalist relations, united Germany became one of the economic powers of the world.

4. Methodology

An extremely important issue in economic analyses is the need to combine conclusions regarding short-term dynamics and long-term balance. The cointegration relation equation can be used to present the state of long-term balance. Cointegration is usually assessed using the Engle-Granger test or the Johansen method (Granger, 1981; Johansen, 1988). However, regardless of the method, each of them requires that the analysed variables be integrated to the same order. It is known that most of the variables used in economic models are characterized by non-

stationary waveforms, which can lead to the establishment of apparent relationships (spurious regression) and lead to erroneous conclusions. The theory of cointegration formulated by Granger and developed by Engle and Granger eliminates the main obstacle in modelling non-stationary series (Granger, 1981; Granger and Engle, 1987; Granger, 1991).

According to the theory, two processes y_t, x_t are cointegrated of the order (d, b) , $(y_t, x_t \sim CI(d, b), d \geq b \geq 0)$, if:

- the order of integration d of both processes (y_t, x_t) is the same;
- there is a linear combination of these processes $u_t = \beta_1 x_t + y_t$, which is integrated of order $d-b$.

Therefore, it can be written that when $Y_t \sim I(d)$ and $X_t \sim I(d)$, then Y_t i $X_t \sim CI(d, b)$, if $y_t - \beta x_t \sim I(d - b)$, where $b > 0$.

This means that the regression equation:

$$y_t = \beta x_t + u_t \tag{1}$$

makes sense, because y_t and x_t do not move too much apart over time, and this means that there is a long-term balance between them.

The advantage of the Engle and Granger's approach is its simplicity (Majsterek, 2014), but also the method has several disadvantages:

- 1) this procedure is based on a two-stage estimation. In the first step, we generate the rest from the long-term balance relationship, which, in the second step, are the basis for the next regression. So if the regression of the balance equation was affected by error, it is varied over to the second stage;
- 2) the Engle and Granger's approach assumes that the estimation of the relationship of long-term equilibrium requires a clear distinction which of the variables will appear as the explanatory variable and which will be the explained one (Kusideł, 1997; Kusideł, 2001).

The Johansen method should be considered a breakthrough in cointegration studies, because he proposed the study of long-term balance relationships based on vector autoregressive models – (VAR) in the form, where:

$$x_t = A_0 + A_1 x_{t-1} + A_2 x_{t-2} + \dots + A_k x_{t-k} + \epsilon_t \tag{2}$$

where:

x_t – vector with dimensions $(n \times 1)$ containing variables included in the model

$$\text{VAR } x_t = [x_{1t} \quad x_{2t} \quad x_{nt}]'$$

$$A_0 \text{ – an } (n \times 1) \text{ vector of intercepts } A_0 = [a_{01} \quad a_{02} \quad a_{0n}]'$$

A_i – ($i=1, 2, \dots, p$) ($n \times n$) coefficient matrices

ϵ_t – an ($n \times 1$) vector of unobservable i.i.d. zero mean error term (white noise).

In order to use the VAR model for cointegration testing, it should be transformed into a VECM error correction model. After transformations, we get the formula:

$$\Delta x_t = A_0 + \sum_{i=1}^{k-1} \pi_i \Delta x_{t-i} + \pi_2 x_{t-2} + \dots + \pi x_{t-k} + \epsilon_t \quad (3)$$

where:

$$\pi_i = \sum_{i=1}^{k-1} A_i - I_1$$

$$\pi_i = \sum_{i=1}^{k-1} A_j - I$$

Johansen proved that for the study of cointegration, one can use the matrix row π , which is equal to the number of independent cointegrating vectors, in particular:

- if the row π is 0, then all elements of this matrix must be zero and model 3) is a typical VAR model in the first differences and there is no linear combination of variables that is stationary,
- if the matrix π is of the full order, then the series of the vector x_t are stationary,
- if the matrix π is of the first order, there is only one cointegrating vector and the expression πx_{t-p} is an error correction factor. In other cases, i.e. $1 < \pi < n$ there are many cointegrating vectors.

Therefore, it can be concluded that the Johansen method allows the determination of the number of cointegrating compounds – so it is free from the disadvantages that the Engle–Granger algorithm is burdened with. Regardless of the method used, a necessary condition in the study of economic time series is testing for the order of integration of time series using the so-called unit root test.

For this purpose, you can use, e.g., the following tests: Dickey-Fuller, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Dickey and Fuller, 1979; Kwiatkowski, Phillips, Schmidt, and Shin, 1992). The cointegration study was carried out for the variable groups:

- I. The level of economic growth, the number of granted patents and valuable patents (for the economy):
 - 1) economic growth data for Germany – net national product level (NNP (million M.));

- 2) number of granted patents and number of valuable patents.
- II. The level of economic development, number of granted patents and valuable patents (for the economy):
- 1) data on the economic development of Germany (NNP per capita (M.))
 - 2) number of granted patents and number of valuable patents.

In case I 1), the author examined six time series:

- a) net national product (NNP) estimated by Hoffmann (1_NNP_Hoff) (Hoffmann, 1965);
- b) corrected by Burhop and Wolff (2005): Compromise NNP (1_NNP_Comp), NNP EH (expenditure method) (1_NNP_EH), NNP IH (income method) (1_NNP_IH), NNP IHM (income method) (1_NNP_IHM), NNP OH (product method) (1_NNP_OH).

In case II 1), the author examined six time series:

- a) 1_NNP_PC_Hoff);
- b) NNP per capita: (1_NNP_PC_Comp., 1_NNP_PC_EH, 1_NNP_PC_IH, 1_NNP_PC_IHM, 1_NNP_PC_OH).

For I 1) and II 2), the number of granted patents: (1_Pat), the number of valuable patents (1_Pat_HV) (Federico, 1964; Statistisches Jahrbuch für das Deutsche Reich (1880-1916); Streb, Baten, and Yin, 2006).

Following generally accepted practice, data was logged in individual time series (prefix 1_ before variables) in order to “smooth” them (Enders, 2010; Marona and Bieniek, 2013). The research consisted of the following stages: 1) graphic analysis of analysed variables; 2) calculation of Pearson correlation coefficients; 3) unit root tests (tests: ADF and KPSS); 4) determining the order of integration of the analysed variables,

– for integrated variables I(1), estimating the number of cointegrating vectors (Johansen test); 5) analysis of the obtained results. The research was carried out using the GRETL program v. 2018a.

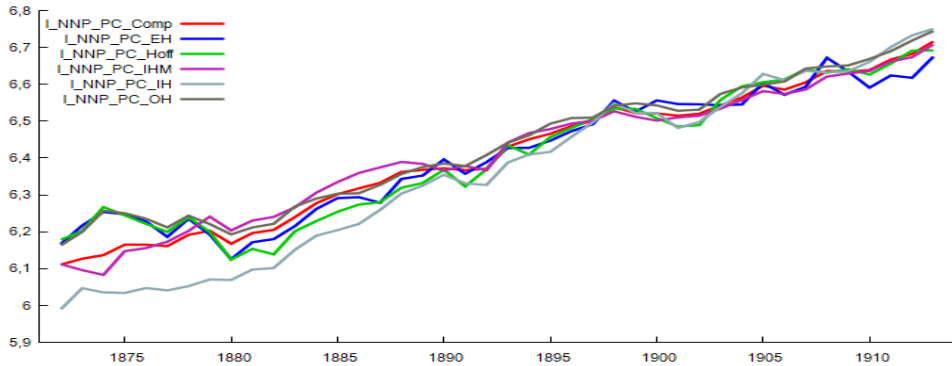
5. Research Results

At the initial stage of the study of individual time series, the course has been presented on the graph:

- NNP per capita (Figure 1);
- the number of granted patents and valuable for economy patents (Figure 2).

A cursory analysis of the above figures leads to the conclusion that the analysed variables are non-stationary. In the next step, the Pearson correlation coefficient was calculated between the variables I 1) and 2) and with II 1) and 2).

Figure 1. The level of NNP per capita of the German Reich (1872-1913).

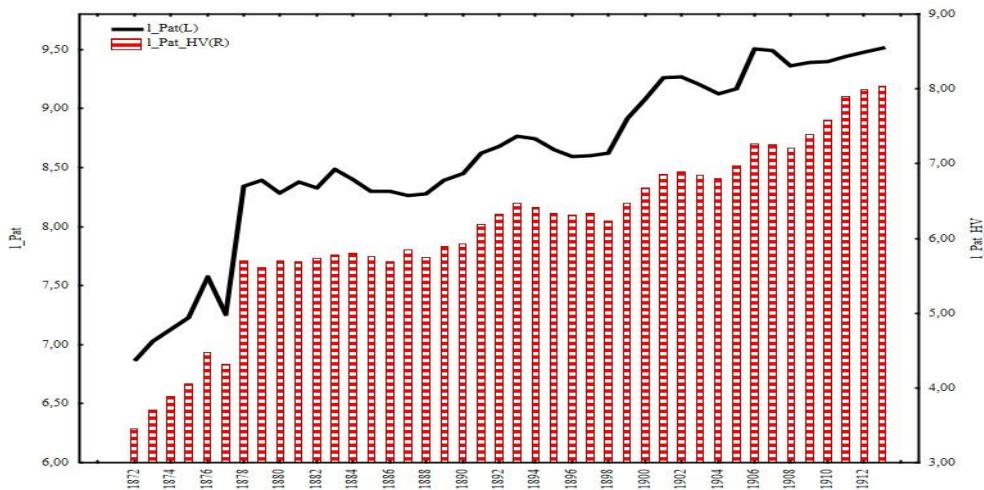


Source: Author's calculations based on: Burhop, Wolff, 2005, Hoffmann, 1965, Statistisches Jahrbuch für das Deutsche Reich (1880-1916).

Correlation coefficients take high values for two groups of variables:

- between economic growth and the number of granted patents; the lowest correlation coefficient was 0.8446 (l_NNP_Hoff and l_Pat), for the corrected NNP values the lowest one was: 0.9464 (l_NNP_EH), and the highest one 0.9524 (l_NNP_IHM);
- between the level of economic development and the number of granted patents; the lowest correlation coefficient was 0.8182 (l_NNP_PC_Hoff and l_Pat), for the corrected NNP values the lowest one was: 0.8357 (l_NNP_PC_EH), and the highest 0.9208 (l_NNP_IHM).

Figure 2. Number of granted patents (1872-1913) (l_Pat) against the background of the number of valuable patents (l_Pat_HV)



Source: Author's calculations based on: Federico, 1964, Streb, Baten, Yin 2006, Statistisches Jahrbuch für das Deutsche Reich (1880-1916).

Despite such high correlation coefficients, great care should be taken in drawing conclusions before conducting stationary tests (spurious regression). The order of integration of the studied time series was initially examined using the augmented Dickey – Fuller test (ADF). Table 1 presents the results of the ADF test for the analysed variables. The conclusion is that all analysed time series are non-stationary, which is quite typical for economic quantities. At the significance level of $\alpha = 5\%$, there were no grounds to reject the H_0 hypothesis. Hence, the author examined the test results for the first differences. Time series for the first differences for all variables are stationary, which gives the reason to conclude that the variables are integrated of order I(1).

Table 1. *The results of the ADF test for the tested variables (1872-1913).*

| Variable | ADF test for the tested variables | ADF test for the for the first differences | Conclusion |
|---------------|-----------------------------------|--|------------|
| I_NNP_Comp | 0,9902 | 1,406e-006 | I(1) |
| I_NNP_EH | 0,9853 | 1 9,28e-008 | I(1) |
| I_NNP_IHM | 0,9745 | 3,944e-007 | I(1) |
| I_NNP_IH | 0,9810 | 8,912e-006 | I(1) |
| I_NNP_OH | 0,9957 | 8,208e-005 | I(1) |
| I_NNP_Hoff | 0,9830 | 3,718e-006 | I(1) |
| I_NNP_PC_Comp | 0,9524 | 2,96E-06 | I(1) |
| I_NNP_PC_EH | 0,9443 | 1,32E-07 | I(1) |
| I_NNP_PC_HM | 0,9112 | 6,95E-07 | I(1) |
| I_NNP_PC_IH | 0,943 | 9,61E-06 | I(1) |
| I_NNP_PC_OH | 0,9762 | 1,00E-04 | I(1) |
| I_NNP_PC_Hoff | 0,9413 | 4,07E-06 | I(1) |
| L_Pat | 0,2055 | 5,820e-08 | I(1) |
| I_Pat_HV | 0,3661 | 1,057e-007 | I(1) |

Source: Authors' calculations.

The author has critically assessed the order of integration of variables with an inverse hypothesis test; the KPSS test was used. The unit root tests carried out using the ADF and KPSS tests have proved that all the analysed variables are non-stationary series and are integrated of order I(1) (for $\alpha = 0.05$).

Therefore, in order to investigate whether there are any stationary linear relationships between two pairs of non-stationary variables, cointegration tests were used according to the Johansen procedure (1988). The statistics of the trace statistic and the maximum eigen value were used for $\alpha = 0.05$. Sample calculation results for NNP per capita and the number of granted patents and valuable patents are presented in Table 2.

The result of the Johansen test for all analysed variables (Table 2), similarly to the variables concerning the level of economic growth and patents indicate that there is no cointegrating vector. The π order is 0, i.e. there is no linear combination of analysed variables that is stationary. All pairs of variables are typical VAR models

for the first differences of these variables. This premise enables the construction of the VAR model, and determination of (only) short-term trends, or also testing the impulse response function, however, the first equations for the analysed variables should be calculated in advance. As it turns out, high Pearson correlation coefficients were not sufficient evidence that there was a correlation between variables.

Table 2. The results of the Johansen cointegration test - pairs of variables (NNP per capita, I_Pat , I_HV_Pat).

| Hypothesized No. | Eigenvalue | Trace statistic | p-value | Max Eigenvalue Statistic | p-value |
|-------------------------|------------|-----------------|----------|--------------------------|----------|
| I_NNP_PC_Comp, I_Pat | | | | | |
| $r_0=0$ | 0,20161 | 9,2684 | [0,3475] | 9,2316 | [0,2735] |
| $r_0 \leq 1$ | 0,00089 | 0,0368 | [0,8478] | 0,03686 | [0,8478] |
| I_NNP_PC_EH, I_Pat | | | | | |
| $r_0=0$ | 0,18555 | 8,7493 | [0,3961] | 8,4151 | [0,3459] |
| $r_0 \leq 1$ | 0,00811 | 0,3342 | [0,5632] | 0,33425 | [0,5632] |
| I_NNP_PC_IH, I_Pat | | | | | |
| $r_0=0$ | 0,20239 | 9,4074 | [0,3352] | 9,2716 | [0,2703] |
| $r_0 \leq 1$ | 0,00330 | 0,13573 | [0,7126] | 0,13573 | [0,7126] |
| I_NNP_PC_OH, I_Pat | | | | | |
| $r_0=0$ | 0,18031 | 8,3092 | [0,4402] | 8,1519 | [0,3717] |
| $r_0 \leq 1$ | 0,00383 | 0,1573 | [0,6917] | 0,1573 | [0,6917] |
| I_NNP_PC_Hoff, I_Pat | | | | | |
| $r_0=0$ | 0,18289 | 8,3220 | [0,4389] | 8,2814 | [0,3589] |
| $r_0 \leq 1$ | 0,00099 | 0,0405 | [0,8404] | 0,04057 | [0,8404] |
| I_NNP_PC_EH, I_Pat_HV ~ | | | | | |
| $r_0=0$ | 0,15490 | 7,3327 | [0,5460] | 6,9002 | [0,5094] |
| $r_0 \leq 1$ | 0,01049 | 0,4324 | [0,5108] | 0,43248 | [0,5108] |
| I_NNP_PC_Comp I_Pat_HV | | | | | |
| $r_0=0$ | 0,18358 | 8,4929 | [0,4215] | 8,3159 | [0,3555] |
| $r_0 \leq 1$ | 0,00431 | 0,17693 | [0,6740] | 0,1769 | [0,6740] |
| I_NNP_PC_IHM, I_Pat_HV | | | | | |
| $r_0=0$ | 0,24392 | 12,477 | [0,1363] | 11,464 | [0,1335] |
| $r_0 \leq 1$ | 0,02441 | 1,0131 | [0,3142] | 1,0131 | [0,3142] |
| I_NNP_PC_IH, I_Pat_HV | | | | | |
| $r_0=0$ | 0,17585 | 8,2462 | [0,4467] | 7,9295 | [0,3945] |
| $r_0 \leq 1$ | 0,00769 | 0,31667 | [0,5736] | 0,31667 | [0,5736] |

| I_NNP_PC_OH, I_Pat_HV | | | | | |
|-------------------------|---------|---------|----------|--------|----------|
| $r_0=0$ | 0,16263 | 7,3208 | [0,5473] | 7,2770 | [0,4656] |
| $r_0 \leq 1$ | 0,00107 | 0,0438 | [0,8342] | 0,0438 | [0,8342] |
| I_NNP_PC_Hoff, I_Pat_HV | | | | | |
| $r_0=0$ | 0,16661 | 7,5353 | [0,5233] | 7,4723 | [0,4437] |
| $r_0 \leq 1$ | 0,0015 | 0,06306 | [0,8017] | 0,0630 | [0,8017] |

Source: Authors' calculations.

5. Concluding Remarks

The adoption of the patent act in 1877 and its amendment in 1891 meant the readiness of the state to pursue an active economic policy, and the creation of new rules on patents was crucial for the increase in activity in the area of new technologies, while supporting the development of creative thought, innovation, especially in railways, so-called “new industries”. Despite high fees in the German patent system, almost 280,000 patents were registered in the analysed period, including almost 32,000 patents of great importance for the economy. Before the outbreak of World War I, Germany effectively expanded new industries, strengthening the made in Germany brand.

Studies using the Johansen test and before the Granger test did not confirm the long-term correlation (no cointegration vector) between the level of economic growth and development of Germany and the number of granted patents, including valuable patents, which only confirms the thesis that there is no clear relationship between intellectual property rights and economic development. Therefore, an error correction model (VECM) cannot be built. Perhaps the obtained results confirm the research of Burhop and Wolff (2013) that, despite the political integration of the German Reich, the technology market was not integrated, and the internal borders of German states effectively hindered the transfer of technology, like the external borders. This does not exclude short-term relationships, but also means the possibility of analysing interrelationships using the abovementioned data as increases (VAR models).

Thus, the obtained test results do not confirm the H1 and H2 hypotheses about the long-term correlation of the time series of the considered variables, at the same time being the starting point for further studies using a larger number of variables and using the VAR model tests and impulse response functions (IRF).

References:

- Algan, N., Manga, M., Tekeoğlu, M. 2017. Teknolojik Gelişme Göstergeleri ile Ekonomik Büyüme Arasındaki Nedensellik İlişkisi: Türkiye Örneği. International Conference on Eurasian Economies, 332-338.

- Arora, A., Ceccagnoli, M., Cohen, W.M. 2008. R&D and the patent premium. *International Journal of Industrial Organization*, 26, 1153-1179.
- Azevedo, M.L., Silva, S.T., Afonso, O. 2012. Intellectual Property Rights and Endogenous Economic Growth – Uncovering the Main Gaps in the Research Agenda, Technological Change. Aurora A.C. Teixeira, IntechOpen, DOI: 10.5772/37768. <https://www.intechopen.com/books/technological-change/-intellectual-property-rights-technological-change-and-economic-growth-uncovering-the-main-gaps-in-t>
- Bielig, A. 2013. Die Rolle des Geistigen Eigentums in der Wirtschaft. Theorie und Praxis. Warsaw School of Economic, Warsaw, 151-152.
- Boch, R. 1999. Das Patentgesetz von 1877. Entstehung und wirtschaftsgeschichtliche Bedeutung. In: Studien zur Technik-, Wirtschafts- und Sozialgeschichte, 11, Wyd. P. Lang, Frankfurt am Main
<https://monarch.qucosa.de/api/qucosa%3A19561/attachment/ATT-0/>
- Burhop, C., Wolff, G.B. 2005. A compromise estimate of German net national product 1851-1913, and its implications for growth and business cycles. *Journal of Economic History* 65, 621.
- Burhop, C. 2010. The Transfer of Patents in Imperial Germany. *The Journal of Economic History*, 70(4), 921-939.
- Burhop, C., Wolff, G.B. 2013. The German Market for Patents during the “Second Industrialization,” 1884–1913: A Gravity Approach. *Business History Review*, 69-93.
- Dereli, D.D. 2019. The relationship between high-technology exports, patent and economic growth in Turkey (1990-2015). *Journal of Business, Economics and Finance (JBEP)*, 8(3), 173-180.
- Dickey, D.A., Fuller, W. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427-431.
- Dinopoulos, E., Segerstrom, P. 2010. Intellectual property rights, multinational firms and economic growth. *Journal of Development Economics*, 92, 13-27.
- Enders, W. 2010. *Applied Econometric Time Series*. Wiley, New York.
- Engle, R.F., Granger, C.W.J. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2), 251-276.
- Federico, P.J. 1964. Historical Patent Statistics 1791-1961. *Journal of the Patent Office Society* (46)2, 89-171.
- Fleischer, A. 1984. Patentgesetzgebung und chemisch-pharmazeutische Industrie im Deutschen Kaiserreich (1871-1918). Deutscher Apotheker Verlag, Stuttgart.
- Ginarte, J.C. Park, W.G. 1997. Determinants of patent rights: a cross-national study. *Research Policy*, 26, 283-301.
- Granger, C.W.J., Engle, R.F. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing, *Econometrica*, 55(2), 251-276.
- Granger, C.W.J. 1981. Some Properties of Time Series Data of Their Use in Econometric Model Specification. *Journal of Econometrics*, 67, 173-188.
- Granger, C.W.J. 1991. Developments in the study of cointegrated economic variables. In: R.F. Engle, Granger, C.W.J., Long-Run Economic Relationship, Readings in Cointegration. Oxford, Oxford University Press.
- Greenhalgh, C., Rogers, M. 2007. The value of intellectual property rights to firms and society. *Oxford Review of Economic Policy*, 23(4), 541-567.
- Green, J.R., Scotchmer, S. 1995. On the division of profit in sequential innovation. *Rand Journal of Economics*, 26, 20-33.
- Hasan, I., Tucci, C.L. 2010. The innovation-economic growth nexus: global evidence. *Research Policy*, 39, 1264-1276.

- Hoffmann, W. 1965. *Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts*, Berlin, Springer-Verlag.
- Hu, A.G.Z., Png, I.P.L. 2013. Patent rights and economic growth: evidence from cross-country panels of manufacturing industries. *Oxford Economic Papers*, 124.
- Johansen, S. 1988. *Statistical Analysis of Cointegration Vectors*. *Journal of Economic Dynamics and Control*, 12(3).
- Josheski, D., Koteski, C. 2011. The causal relationship between patent growth and growth of GDP with quarterly data in the G7 countries: cointegration, ARDL and error correction models. MPRA, Paper No. 33153.
- Kusideł, E. 2001. *Modelowanie wektorowo-autoregresyjne VAR. Metodologia i zastosowanie w badaniach ekonomicznych*. Wyd. Absolwent, Łódź.
- Kusideł, E. 1997. *Badanie kointegracji na podstawie wektorowo-autoregresyjnych modeli ekonometrycznych. Podejście Johansena*, Łódź, 3.
- Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y. 1992. Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root. *Journal of Econometrics*, 54, 159-178.
- Léger, A. 2005. *Intellectual Property Rights and their impacts in developing countries. An empirical analysis of Maize Breeding in Mexico*. ICAR Discussion Paper, 5/2005.
- Machlup, F., Penrose, E.E. 1950. The Patent Controversy in the Nineteenth Century, *The Journal of Economic History*, 10, 1-29.
- Majsterek, M. 2014. Modelowanie systemów skointegrowanych. *Aspekty teoretyczne*, *Bank i Kredyt* 45(5), 433-466.
- Maddala, G.S. 2006. *Ekonometria*. Wydawnictwo Naukowe PWN, Warszawa.
- Marona, B., Bieniek, A. 2013. Wykorzystanie modelu VECM do analizy wpływu bezpośrednich inwestycji zagranicznych na Gospodarkę Polski w latach 1996-2010. *Acta Universitatis Nicolai Copernici, Oeconomia XLIV*, nr 2, 333-350.
- Metz, R., Watteler, O. 2002. Historische Innovationsindikatoren Ergebnisse einer Pilotstudie. *Historical Social Research*, 27(1), 4-99.
- Myszczyński, J. 2013. *Wpływ kolei żelaznych na wzrost gospodarczy Niemiec 1850-1913*. Wydawnictwo Uniwersytetu Łódzkiego, Łódź.
- Myszczyński, J. 2019. *Wykorzystanie analizy klastrowej w ocenie wpływu kolei żelaznych na wzrost gospodarczy Niemiec*, Wyd. Zachodniopomorski Uniwersytet Technologiczny w Szczecinie, Szczecin.
- Nordhaus, W.D. 1969. *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change*. MIT Press, Cambridge, MA.
- Romer, P.M. 1994. The origins of endogenous growth. *Journal of Economic Perspectives*, 8(1), 3-22.
- Romer, P.M. 1990. Endogenous technological change. *Journal of Political Economy*, 98, 71-102.
- Scherer, F.M. 1972. Nordhaus' theory of optimal patent life: a geometric reinterpretation. *American Economic Review*, 62, 422-427.
- Sinha, D. 2008. Patents, Innovations and Economic Growth in Japan and South Korea: Evidence From Individual Country and Panel Data. *Applied Econometrics and International Development*, 8(1), 1-23.
- Snowdon, B., Vane, H.R. 2005. *Modern Macroeconomics. Its Origins, Development and Current State*. Edward Elgar Publishing, Cheltenham, Northampton.
- Statistisches Jahrbuch für das Deutsche Reich 1880-1916*. Berlin, Herausgegeben vom Kaiserlichen Statistischen Amt.

- Streb, J., Baten, J., Yin, S. 2006. Technological and geographical knowledge spillover in the German Empire 1877–1918. *Economic History Review*, LIX, 2, 347-373.
- Streb, J., Wallusch, J., Yin, S. 2007. Knowledge spill-over from new to old industries: The case of German synthetic dyes and textiles (1878–1913). *Explorations in Economic History*, 44, 203-223.
- Thumm, N. 2000. Intellectual Property Rights. National systems and harmonisation in Europe. *Contribution to Economics*, Heidelberg.

Notes:

ⁱ *Our findings lend empirical support to arguments that patent laws be tailored to the particular circumstances of country and industry.*