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USE OF ECONOMETRIC MODELLING TO EVALUATE THE IMPACT OF THE RAILWAYS ON ECONOMIC GROWTH OF GERMAN REICH (1879–1913)

In this article the modelling is based on the statistical data related to the years 1879–1913, characterizing the German economy. The obtained results prove that, the railway sector had a significant effect on the economic growth of the German Reich in 1879–1913 measured through GDP and GDP per capita. Other important factors include imports and emigration.

Keywords: *railway; German Reich; econometric model; GDP per capita; emigration.*

Януш Мищишин

ВИКОРИСТАННЯ ЕКОНОМЕТРИЧНОГО МОДЕЛЮВАННЯ ДЛЯ ОЦІНЮВАННЯ ВПЛИВУ ЗАЛІЗНИЦЬ НА ЕКОНОМІЧНЕ ЗРОСТАННЯ ГЕРМАНСЬКОГО РЕЙХУ (1879–1913)

У статті проведено економетричне моделювання на основі статистичних даних щодо Германського рейху за 1879–1913 роки. Отримані результати доводять надзвичайну важливість залізниць для економічного розвитку даної держави, розвиток вимірювався через показники ВВП та ВВП на душу населення. Крім того, відмічено значний вплив двох інших факторів – обсягів імпорту та еміграції.

Ключові слова: *залізниці; Германський рейх; економетрична модель; ВВП на душу населення; еміграція.*

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Януш Мищищин

ИСПОЛЬЗОВАНИЕ ЭКОНОМЕТРИЧЕСКОГО МОДЕЛИРОВАНИЯ ДЛЯ ОЦЕНКИ ВЛИЯНИЯ ЖЕЛЕЗНЫХ ДОРОГ НА ЭКОНОМИЧЕСКИЙ РОСТ ГЕРМАНСКОГО РЕЙХА (1879–1913)

В статье проведено эконометрического моделирование на основе статистических данных о Втором Германском рейхе за 1879–1913 годы. Полученные результаты доказывают чрезвычайную важность развития железных дорог для экономического развития данного государства, измеряемого через показатели ВВП и ВВП на душу населения. Кроме того, отмечено значительное влияние двух других факторов – объёмов импорта и эмиграции.

Ключевые слова: *железная дорога; Германский рейх; эконометрическая модель; ВВП на душу населения; эмиграция.*

Introduction. The assumption that technological innovations, including those in transport, constituted one of the driving forces of economic growth in the 19th century, appears to be undisputed. Railways as one of the important inventions of that era, were often the subject for research carried out by economists, although the alternative research methods for studying their impact on the overall economy have been developed not earlier than in the 1960s (Fishlow, 1965; Fogel, 1962).

In his analyses of the role of railway industry in the take-off of capitalist economies, W. Rostow (1990: 55) pointed that "introduction of the railroad has been historically the most powerful single initiator of take-offs. It was decisive in the

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United States, France, Germany, Canada, Russia". Even in the 1950s, the railway significance at the stage of the start of economies to self-development was not questioned. In 1959, Ch. Savage argued that the role of railways in economic development of the USA could not be underestimated (Savage, 1959).

The works of R. Fogel (1962) and later by A. Fishlow (1965) turned out to be a breakthrough. Those researchers proved – using, among others, the concept of social savings – that the importance of railways in the US economic growth had not been as great as widely accepted.

On the wave of criticism of the previous methods, the paradigm of the New Economic History (NEH) has been created. The main objective of these new methods is to verify the well-known claims and commonly held truths, using econometric methods.

It should be noted, however, that cliometrics, despite its heyday in the US and the UK, continues to be little popular on European continent overall (Dumke, 1986; Eddie, 1997; Tilly, 1997).

The value and usefulness for verifiability purposes of scientific achievements of R. Fogel, D. North, A. Fishlow, as well as economic success achieved by Germany, are the main reasons for taking that issue as a subject for research in this paper.

The following hypothesis has been put forward: the railways, despite low social savings, constituted one of many important factors of economic growth in Germany. Social savings of the railway sector in Germany, estimated by the author in his habilitation thesis, proved to be relatively low and amounted to: 2.08–2.32% GDP, and after taking into account the consumer surplus, their amount was 1.53–1.58% of the GDP (in 1909) (Myszczyszyn, 2013).

The author pursues the following objectives:

- presentation and analysis of other significant factors affecting economic growth and development in Germany in the analysed period of 1879–1913;
- demonstration of the econometric modelling usefulness for economic research, in particular, for studies on economic growth and development in Germany in the last two decades of the 19th century and until the outbreak of the World War I;
- the impact of railway lines expansion after 1879 (after the period of general nationalization) and by the outbreak of the World War I upon the economic growth in Germany;
- comparing the results with the author's previous papers.

To verify the research hypothesis, the author has collected statistical data characterizing German economy and has built an econometric model.

Statistical data have been acquired from various sources, including among others: the statistical yearbooks of the German Empire for the period of 1873–1916, the yearbooks of Kingdom of Prussia for the period of 1870–1917, contemporary statistical sources, including the statistics compiled by W. Hoffman (1965), A. Maddison (2002), R. Fremdling (1985), B.R. Mitchell and by many other authors (Myszczyszyn, 2013).

German economic growth in 1879–1913. To determine the economic growth rate, the author used the statistics on GDP and GDP per capita. Having analyzed the above two measures for the unified Germany, rapid growth of both of those parameters over the years 1879–1913 occurs to be noticeable.

Overall GDP grew much faster than per capita; in 1879 it amounted to 18.08 bln marks (M), while being 845 bln M in 1913–1956. The average annual GDP growth rate during that period was 3.01%, which meant the product doubled within approximately 24 years.

GDP per capita, which is a better measure for determining social welfare, grew much slower; it was 475 bln M in 1879 and it reached 873.76 bln M in 1913, the average annual growth rate was 1.73%. That was due to rapid population growth in Germany.

There occurred to be a specific uneven growth of GDP per capita in the countries associated within the German Customs Union, and later within the unified Reich; relatively slow growth in the 1850s (the average of 1.2% annually), very rapid growth in the 1870s (up to 14.5% annually), finished with a strong decline in the late seventies. The downward trend prolonged to the early eighties of the 1880s – the economy recorded the average annual decline of GDP by 2.46%. Gradual increase in GDP per capita occurred in 1883–1913 – the average increase was 1.63% annually.

Apart from the progress in agriculture, industrial development, including heavy industry, changes in economic structure, the following were the characteristic for the period under review: promotion of culture and education – increase in the number of pupils and students, institutional development, involvement of public sector in economic processes and the increase of national identity. German economy competed effectively with the English power. On the other hand, free movement of people and goods, in connection with radical improvements in transportation and communication facilities as the sources of innovation, affected the convergence of national economies and globalisation processes (Myszczyszyn, 2014).

As noted by J. Foreman-Peck (1991), the process of economic development was also supported by: the gold standard adopted by most states, the most favoured nation clause for the trade in the 1860–1870s (the free trade era), development – apart from the development of railway lines – of inland waterways, maritime transport, a range inventions, like telegraph etc. All of those accelerated rapid diffusion of economic development in different European countries.

The assumptions for modelling. Model of GDP per capita. To determine the relationship between the endogenous variable (GDP per capita), and the independent variables describing the state of German economy, the author has analyzed, among others, the following: length of railway lines, the share of the people employed in agriculture within the national economy, the percentages of pupils and students, the outflow of emigration, the level of investment in the economy (as % of GDP), the level of international trade (imports and exports), the level of industrial production. The author has referred, among others, to the single-equation econometric model used among others by M. Clemens and J. Williamson (2002), implemented also by M. Mata and J. Love (2008), as well as by the author previously in his own work, which, among others, used the data on the length of railway lines as physical capital.

Following the appropriate selection of variables, a model for GDP per capita has been created (for the period 1940–1913 the author has built two models: the level and the dynamics of GDP) (Myszczyszyn, 2013).

In the proposed model, GDP per capita is the endogenous (response) variable, while other variables used are the explanatory ones.

All variables are expressed in constant prices (as of the year 1913). From more than 140 statistical variables describing German economy for the time series 1879–1913, the variables have been assigned to several groups of factors, of which the author has left a few. At the preliminary stage, when choosing explanatory variables for the endogenous variable, the author used his knowledge of economy and previous studies, including determination of the role of the railway sector in generating GDP per capita.

Justification for the particular variables chosen:

- length of railway lines (in km) – the variable is regarded as material (physical) capital that may be assumed to express the innovation and to be an example of progress, under the conditions of the 19th century (Mata and Love, 2008);
- investment rate – the level of investments influence (ceteris paribus) upon interest rate. According to economic assumptions, investments have a significant impact on growth and development, as well as on physical capital maintenance. The model takes into account the level of investments in relation to GDP achieved;
- emigration – it has been considered that this factor may have contributed to the slowdown of economic growth. It may be assumed that migrants moved all human capital outside but as a rule, however, they left physical capital, which was not beneficial for the country abandoned by emigrants. The factor has been calculated as a percentage in relation to the number of employees in the national economy;
- the percentage of pupils and students in relation to the number of employees – it reflects the development of human capital. According to the theory of economics, economic growth is supported by investing in both physical and human capital (Weisbrod, 1962);
- agricultural development manifested by the increase in labor productivity, introduction of machinery, fertilizers, modern crop rotation, etc. resulting in a "draining" of part of the workforce to other sectors of national economy (industry, services), thus the variable includes the percentage of people employed in agriculture in relation to the total number of employees in the national economy;
- levels of imports and exports (as % of GDP), expressing the economy's openness;
- the level of industrial production (mln M), as a manifestation of changes in the structure of the economy.

To construct the functional form of econometric model, the author used the Cobb-Douglas production function. The function took the following general form:

$$\ln Y_{GDP} = \ln \beta_0 + \beta_1 \ln x_{t1} + \beta_2 \ln x_{t2} + \beta_3 \ln x_{t3} + \beta_4 \ln x_{t4} + \beta_5 \ln x_{t5} + \beta_n \ln x_{tn} + \varepsilon, \quad (1)$$

where Y_{GDP} – German *GDP per capita* (1879–1913); x_{t1}–x_{tn} – the selected explanatory variables, characterizing German economy; β_0–β_n – structural parameters; In – natural logarithm; ε – random component.

In that approach, the structural parameters β_0–β_n determine the elasticity of GDP per capita in relation to explanatory variables. They describe the relative change in GDP per capita (in %) due to the relative change by 1% in only one of the indicated factors, at a fixed level of other factors (*ceteris paribus*).

For the selected variables, the model uses time delays ($t - n$), the aim of which is to eliminate the endogeneity of those variables.

Following the model specification and the collection of statistical information for the adopted time series, including the selection of explanatory variables, the variables have been analysed by means of general statistics, using, among others, the descriptive statistics of candidate variables.

For the selected statistical data there has been determined the variability by estimating the coefficient of variation, by the formula:

$$V_j = \frac{S_j}{\overline{X}_j}, \tag{2}$$

where V_j – the coefficient of variation; $\overline{X}_j = \frac{1}{N}\sum_{n=1}^{N} x_{jn}$ – the arithmetic mean of the *j*th explanatory variable; $S_j = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(x_{jn} - \bar{x}_j)^2}$ – the standard deviation of the *j*th explanatory variable.

The assumption has been made to delete the variables for which $V_j < 0.1$ from the original set of explanatory variables.

The lowest variability (0.87%) has been obtained for the statistics (% of the number of pupils and students) and industrial output (5.49%), therefore those candidate variables have been eliminated.

The next step included the determination of Pearson's coefficients of correlation (*r*) between the explanatory variables under consideration and the dependent variable. Simultaneously, the critical value of correlation has been assumed to be calculated by the formula:

$$r^* = \sqrt{\frac{t^2_{\alpha,N-2}}{N-2+t^2_{\alpha,N-2}}} \approx 0{,}339, \tag{3}$$

where $t^2_{\alpha,N-2}$ – the value of statistics read from the Student's t distribution tables for the level of significance 0.05 and $(N-2)$ degrees of freedom.

Therefore, the variables not significantly correlated with the endogenous variable, according to the formula:

$$|r_j| \le r^* \tag{4}$$

have been deleted.

Apart from the variable "level of investment", all other exogenous variables have turned out to be significantly correlated with the dependent variable (Table 1).

In the next step, the Pearson's coefficients of correlation (r) between all the variables have been determined. The results are shown in Table 1.

The variable "Level of investments as % of GDP" has been deleted from the set of explanatory variables.

The results. To estimate the structural parameters of the above model, the least squares method (LSM) has been used. The estimated structural values, taking into account the binary variable U_ (value = 1 for the years 1891, 1901, 1902; for other years the value is 0) have allowed the function $\ln Y_{GDP}$ to be expressed as:

$$\ln Y_{GDP} = -0.65 + 0.7270 \ln RL_{t-1} - 0.1446 \ln EM_{t-1} + 0.2367 \ln IMP - 0.1065 U\_,$$
$$|t| \quad (0.83) \quad (4.49) \quad (3.06) \quad (2.39) \quad (5.39) \qquad (5)$$
$$R^2 = 0.9927 \quad Adj.R^2 = 0.9911 \quad DW = 1.52 \quad S_{EE} = 0.02$$

where $\ln Y_{GDP}$ – German *GDP per capita* in 1879–1913 (M); RL_{t-1} – length of railway lines (km) ($t - 1$); EM_{t-1} – level of emigration ($t - 1$); IMP – level of net import (% of GDP); $U\_$ – binary variable.

Table 1. **Pearson's coefficients of correlation (*r*) between the explanatory variables and the endogenous variable,** *author's*

Variable	GDP per capita, M	Length of the railway lines, km (t – 1)	Level of investments, % of GDP (t – 1)	Level of emigration (t – 1)	Level of net imports, % of GDP	Level of exports, % of GDP	Level of employment in agriculture
GDP per capita, M	1.000	0.985	0.067	-0.948	0.974	0.946	-0.978
Length of the railway lines, km (t – 1)	0.985	1.000	-0.002	-0.918	0.981	0.970	-0.992
Level of investments, % of GDP (t – 1)	0.067	-0.002	1.000	-0.081	0.014	-0.043	-0.021
Level of emigration (t – 1)	-0.948	-0.918	-0.081	1.000	-0.921	-0.879	0.902
Level of net imports, % of GDP	0.974	0.981	0.014	-0.921	1.000	0.960	-0.987
Level of exports, % of GDP	0.946	0.970	-0.043	-0.879	0.960	1.000	-0.958
Level of employment in agriculture	-0.978	-0.992	-0.021	0.902	-0.987	-0.958	1.000

For that stage of modelling, the coefficient of determination R^2 has been estimated to be 99.27% and its adjusted value to be 99.11%, the convergence coefficient φ^2 has been determined at -0.73%, and its adjusted value – at -0.89%.

Significance test has been based upon the distribution of t-Student statistics. For the 4 parameters, the following inequality is true: $/t/ > t_\alpha$ ($/t/ > 2.048$).

The figure below shows the actual and the estimated GDP, taking into account the residuals (Figure 1).

The variables: the level of industrial production ($/t/ = 0.70$); the level of employment in agriculture ($/t/ = 1.82$), have occurred to be insignificant.

Evaluation of structural parameters (under the ceteris paribus assumption) has allowed conclude the following:

a) the increase by 1% in the length of railway lines expressed in km caused the growth of German GDP per capita of approx 0.72%;

b) the increase by 1% in emigration expressed as a percentage in relation to the total number of people employed caused a decrease in GDP per capita by nearly 0.145%;

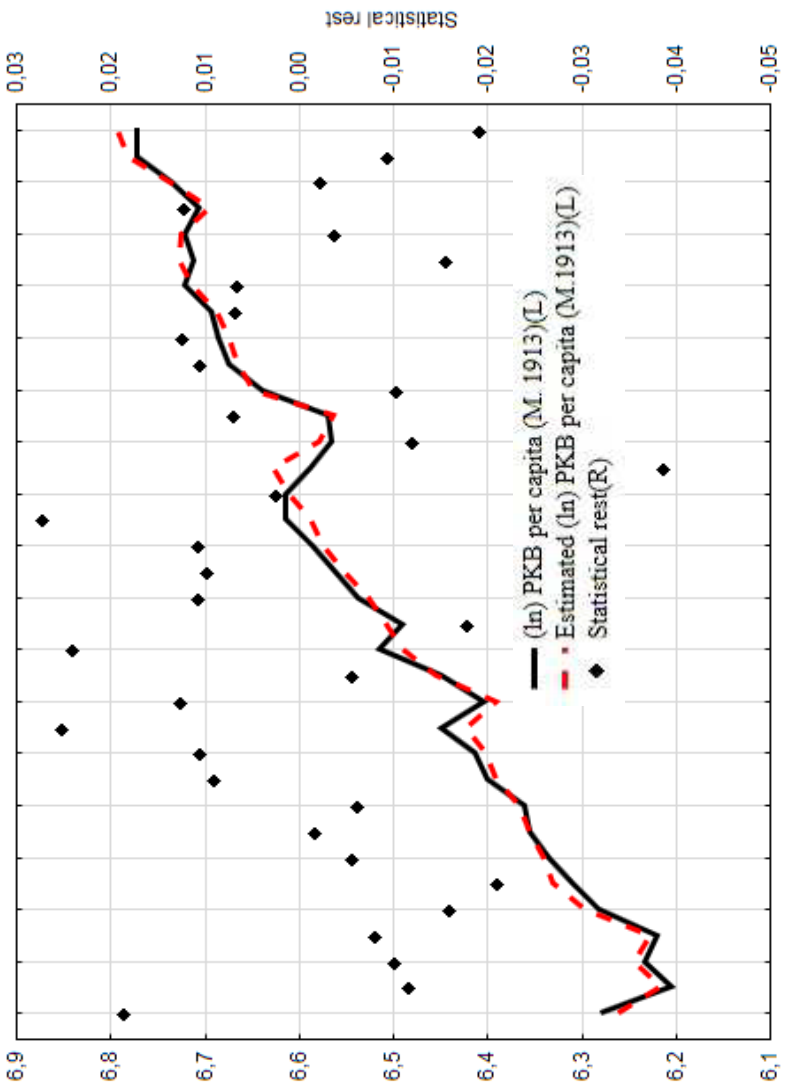

Figure 1. **Actual and estimated changes (ln) of GDP per capita, taking into account the binary variable and residuals,** *author's calculations*

c) the increase by 1% in imports caused the growth of GDP per capita of nearly 0.264%.

Among the three significant explanatory variables, the increase in the two of them (the length of railway lines and the level of net imports) has occurred to have a positive effect upon the growth of GDP per capita. The variable "level of emigration" has turned out to have an inversely proportional effect on GDP growth.

Analysis of the results. Having analysed the above calculations, we should note that the essential factors affecting the explanation of the endogenous variable GDP per capita in 1879–1913 include:

1. The length of railway lines, in km. The variable reflected the physical capital as well as technological progress in the transport sector. In the light of the data obtained, the increase by 1% in the length of railway lines caused approximately 0.72% growth of GDP per capita.

Analysis of the length of railway lines in Germany in 1879–1913 shows that the average annual rate of growth for railway lines was approximately 1.92%, while the increase rate of GDP per capita was approximately 1.69% per annum.

In 1879–1913, the length of railway lines increased from 33.2 ths km to 61.2 ths km, and the train runs increased: a) for goods – from 11.9 bln to 67.7 bln tonne-kilometers (almost sixfold increase); b) for passengers – from 6.1 bln to 41.2 bln passenger-kilometers (almost sevenfold increase). The output index calculated by the author (assuming that 1913 = 100) for the railway sector took the value of only 16.74% for 1879, as much as 49.75% for 1899 and 84.08% for 1910. That illustrates rather high rate of increase in the length of railway lines but primarily the increase in the freight transport volumes (Myszczyszyn, 2013).

Undoubtedly, railways (according to the studies by R. Fremdling) constituted an important growing sector, affecting other sectors through the economic effects: "forward" and "backward" (in German: Vorwartskopplungseffekte, Ruckwartskopplungseffekte). Railways influenced positively the economic growth of the country but their impact, however, was much greater than in the period 1850–1913 analyzed by the author (Myszczyszyn, 2013). To compare, inland waterway transport increased from 2.6 bln tonne-kilometers (1879) to 17.9 bln tonne-kilometers (1913) and still remained competitive with rail transport.

2. The impact of international trade – increase in imports had positive effect on German GDP. The claim seems to be quite debatable, however the structure of international exchange remains important. In 1880–1913, the trade volume of the Reich was tripled, and its share in the world trade increased from 9 to 12%. Despite the negative foreign trade balance, German economy, including the industry, needed resources (value of imports amounted to approximately 5 bln M) (1913), and growing population being relatively more and more affluent determined the increase of food supply (the value of imports – approximately 3 bln M) (1913); to compare – the exports of finished products at that time amounted to nearly 7.5 mln M (Myszczyszyn, 2013).

3. Demographic factors, including the level of emigration were also analyzed by the author. The increasing emigration had a negative effect on GDP per capita. As shown in the work, emigration in Germany temporarily tended to increase, particularly in 1881, 1890 and in other years when the economy plunged into crises. The

average increase in emigration by 1% caused a decline of 0.145% in GDP per capita.

4. The importance of human capital development, as a percentage of the number of pupils and students in relation to the total number of employees, has turned out to be insignificant, which may be quite surprising, since for the period 1850–1913, however, a positive effect of this factor has been determined by the author.

5. A decline in the number of people employed in agriculture also has proved to be insignificant, as compared to previous studies (for the years 1850–1913). That may be justified e.g. by restrictive trade policy pursued by the Reich from 1879. There was still a significant percentage of people employed in agriculture in relation to the total number of employees in the national economy; for instance, in 1913 it was still nearly 35% of the total number of the employed. That was caused by many reasons, including the nature of the Eastern provinces of the Reich, which meant to serve as a resource base. Another factor could be changes in trade policy, among others the alliance between the Junkers and industrialists, which made cereal production still profitable, and because of which labor outflows from agriculture to industry were relatively small.

Conclusions. Rapid changes in the structure of German economy (the take-off stage) took place from the fifties of the 1850s. That was reflected in rapid growth of GDP and GDP per capita, changes in the standards of living and establishment of a modern capitalist economy. In the face of industrial development and modern farming, that was also the period of growing importance of transport, including dynamic expansion of the railway network.

Generally, expansion of railways influenced the increase in total productivity by reducing costs, including transport time. A dense network of railways stimulated integration of markets and workforce mobility, was conducive to creation of the economies of scale and development of large agglomerations, facilitating the exploitation of natural resources and stimulating increased investments but at the same time, however, it was often not very competitive with waterway transport. As the leading sector, it induced economic backward and forward effects (Hirschman, 1967).

Econometric modelling used by the author here to search for significant determinants of economic development in Germany has once again confirmed that railways, as the expression of physical capital, had a positive effect on German GDP per capita in 1879–1913. At the same time, the results have indicated other key factors for economic development, including: the role of international trade (imports), as well as the negative impact of emigration processes.

The presented econometric model is very simplified and is a single-equation model. For more detailed explanations, in further steps the author will use multi-equation interdependent models.

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