INNOVATIONS AS AN IMPORTANT FACTOR INFLUENCING LABOUR PRODUCTIVITY IN THE MANUFACTURING INDUSTRY

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Abstract

Economic science has long recognized labour productivity as an important factor of economic growth. In the uncertain conditions of increasingly fierce and complex competition, it becomes one of the key prerequisites for an adequate response to global challenges. The development of labour productivity has to be observed as a multi-dimensional process including numerous interconnected quantitative and qualitative factors, in particular human factors and technological advancement realized through investments in research and development (innovations). The analysis of labour productivity in the manufacturing industry of the selected countries, Germany and China, is performed in the context of an important influential factor – innovations, and interdependently with the economic growth of the selected countries. The research results and the conducted regression analyses indicate a superiority of German labour productivity in the manufacturing industry, which is strongly affected by considerable investments in research and development. However, the technological convergence of China as the upcoming power is increasingly important, which shows that the gap in labour productivity is decreasing, making developed countries face new challenges posed by globalization. The analysis of the interdependence of economic growth (GDP) and labour productivity in the manufacturing industry points to a positive link and the conclusion that the elasticity of the GDP to changes in labour productivity is greater in China than in Germany.

Keywords: Labour productivity in the manufacturing industry, innovations, economic growth, Germany, China

1. Introduction

The uncertain global surroundings of an ever stronger and more complex competition puts the topic of development, the position of a country on the global market and social welfare into a new context which points out with increasing intensity the strategic imperative of labour productivity development. The main issue of economic survival becomes: *How to overcome the challenges brought about by the global market?* Factors important in overcoming global challenges are a dynamic economy, successful implementation of new technologies, efficient organization, managerial skills, institutional flexibility, human resources quality and, above all, investments in knowledge and innovations. Without successful labour productivity, a country will not have satisfactory growth on both the level of the whole economy and that of individual economic activities, like the manufacturing industry that is the topic of the present research. Historically, industrial production marked the economic development of

numerous countries, western and eastern, and its importance is unquestionable today, especially in the segment of modern complex industry based on high-tech, because it is a production greatly contributing to the creation of added value of the economy and encouraging enterprise in other service activities.

The research includes two seemingly incomparable countries, the Federal Republic of Germany and the People's Republic of China, which have a very different history, geography, development, economy and culture. The answer to the question: *Why these two countries?* has to be looked for in what they have in common, i.e., a drive for economic success and advancement that cannot be achieved without developing labour productivity. The selected countries show the development and trend of labour productivity in Europe and Asia, in traditionally highly productive economically developed countries and fast growing developing countries, while at the same time pointing to an ever more intense global competition. What is more, the existing research shows that in the last two decades, the European Union has been lagging behind in the area of labour productivity. An international comparison of labour productivity can lead to the conclusion that European Union countries, despite implemented initiatives, still realize around 30% lower labour productivity compared to the USA, which indicates a necessity for further research (OECD, 2014). On the other hand, the considerable economic development of China and a very high growth rate of Chinese labour productivity stimulate further research. According to data of the Asian Productivity Organization (APO), in the period 2005 – 2011, Chinese labour productivity grew at an annual growth rate of 10.2% (APO, 2014).

This research wants to answer questions like: *What is the difference in the level of labour productivity in the manufacturing industry between economically developed Germany and the fast growing developing country of China? What is the interdependence of investment in research and development (innovations) and the realized labour productivity?* What is the interdependence of trend dynamics of labour productivity and the economic growth of the selected countries?

The structure of the paper includes an introduction and a central part with the development of the paper topic and a conclusion in the end. The first part includes a review of literature and existing studies, describes the work hypotheses, the subject matter and methods of research. The second part focuses on an analysis of labour productivity in the manufacturing industry of the selected countries observed in the context of technological advancement and innovations as important factors for economic growth and level of labour productivity. The empirical results of the research are analysed with econometric models of the regression analysis to determine the interdependence between innovations (investment in research and development) and labour productivity, as well as that between labour productivity and the economic growth (GDP). The paper ends with the conclusion, i.e., an estimate of the validity of the formulated hypotheses.

2. Literature review

For years, labour productivity has been the topic of numerous studies researching, measuring and monitoring the development of productivity and its factors of influence through different periods of time and in various regions. The growth of productivity is determined by numerous factors such as improved work quality, increased employees' capital equipment and an increase of efficiency in combining production resources. The advancement of technology and a higher level of skills and education of the workforce have determined the growth of the total factor productivity at an average rate that was a bit under 1.5% annually during the 20th century (Samuelson, Nordhaus, 1992). In the long run, labour productivity as a dynamic economic indicator reflecting the basic principles of economy necessary for economic growth and social development proves to be the crucial factor of a country's development and reflects the trends of a series of other economic indicators. If we observe the US economy, as a global leader in the achieved level of labour productivity, long-term trends in the 20th century show an average annual growth of labour productivity (measured as output per hour of work) between 2% and 3% (McConnell, Brue, 1986). However, in the last three decades of the 20th century labour productivity growth slowed down and was considerably lower than the long-term and century rate. All the measurements have shown a significant slowdown of the productivity growth: the 70s saw an annual productivity growth rate of only 0.75%. The 80s saw a modest increase in the productivity growth, with the American productivity being from 1.2% to 1.5% annually, which is a consequence of the

disappearance of factors that burdened the productivity growth rate, such as problems of stagflation, a growth of investments in research and development, new technological innovations (computers, robotics), better quality and a more experienced workforce (McConnell, Brue, 1986).

Events in the economy and social changes marking the last two decades encourage further research into labour productivity in both the western economies and the Asian countries.

As far as the western economies are concerned, if we observe the economic indicators between the USA and the EU, we can see a problem in the competitiveness of the European Union, which has been lagging behind in the last two decades in the area of labour productivity. Studies show that since 1995 there have been growing differences between Europe and the USA. The biggest differences are concentrated in the high technology of the industrial sector, while the basic reason is to be found in the adverse development of economic resources and structural components of the measured productivity, manifested in insufficient investment in higher education and innovations (EC, European Economy, 2007). In the 90s, the average annual growth rate of the American labour productivity was 1.62%, while in the period from 1995 to 2012, the growth rate was 1.8% a year (OECD, 2014). The labour productivity of developed European economies (EA17) grew at an average rate of 0.8% in the period from 1995 to 2012, which indicates that it is lagging behind the labour productivity in the USA. Furthermore, in the period from 2007 to 2009, the growth rate of the European labour productivity, under the influence of the global economic crisis, was negative (-1.5%), after which it recovered with a growth rate of 1.2% (2009-2012). The long-term labour productivity growth rate of the German economy, the most important economy in Europe, is 1.5% annually (1970-2012). In the period from 1970 to 1995, the growth rates were ranging from 1.2% to 2.6% after which growth significantly decreased to an annual 0.8% (1995-2012), in particular in the period 2007-2009, when the growth rate was negative (-2.7%). In the period 2009-2012, there was a growth rate of 1.6% (OECD, 2014). Within EU27 in 2011, according to Eurostat information, the highest labour productivity (GDP per work hour) is registered in Luxembourg, Denmark and Ireland, while Germany is in 8th place. If we observe the GDP per employee, the European countries (EA17) have a weaker labour productivity than the USA, the global leader in productivity, by more than 30% (OECD, 2014). In Germany, the real GDP per work hour is 42.4 EUR and the average annual growth rate in the period from 1991-2012 is 1.5% (Eurostat, 2013).

On the other hand, the major economic boom of China in the last three decades has inspired a whole series of economic analyses aiming at determining the source of such a quick growth. The research done so far indicates that from the mid-70s the Chinese economy has been marked by a relocation of economic resources, especially from work in agriculture into other areas of activity, mainly industry, as well as by an increase in investments. According to research done by the World Bank, the average annual labour productivity growth in China, for the period from 1999 to 2008 was 7.3% (World Bank, 2016), which puts China among the countries with the highest average annual growth. Single economic analyses state that the main reason for the economic success of China is the significant increase of the total factor productivity (TFP) and labour productivity in the non-state and non-agricultural sector (Brandt, Zhu, 2010). In China's case, research shows that the increase of productivity can explain the growth of the economy by more than 42% (for the period 1997-2004) and that productivity has surpassed the investments and capital accumulation already in the beginning of the 90s, as the most important source of growth (Hu, Khan, 1996). Therefore, the Chinese economic development is not only the result of significant capital investment but also of higher productivity and the transfer of existing acknowledged technologies, knowledge and ideas. Such research indicates the need for further analyses in order to identify the main sources of economic growth. Chinese labour productivity has had a long-term growth at an extremely high average rate of an annual 8.2% (1970-2012) and 8.9% in the period 1995-2012. The highest growth rate was realized in the period 2001-2007, namely 10.6% (OECD, 2014). According to data from the Asian Productivity Organization (APO), the whole Chinese economy has registered an average annual growth in labour productivity of 9.1% in the last two decades (1990-2010). The most significant growth in labour productivity was realized in the period from 2005 to 2011 when it amounted to 10.2% and reached the sum of 13.500 USD (9.700 EUR) of the GDP per employee. Although progress is evident, Chinese labour productivity in 2011 still represents

only 14.5% of the level of labour productivity in the USA, that is 17.2% of the level in EU15 (APO, 2014). A high heterogeneity in the economic development of individual Chinese regions reflects in the trends of their labour productivity. The highest labour productivity is realized in the area of municipal cities (Beijing, Chongqing, Shanghai, Tijanjin). Labour productivity in eastern and central regions is lower by 65% to 70%, while the western part of China is the least developed, with up to 80% lower labour productivity (Su, Heshmati, 2011).

If we observe the level of labour productivity as real GDP per employed person, it is as follows:

- USA: 99,346 USD (2011), 100,556 USD (2012),
- EA 17: 68,166 USD (2011), 68,119 USD (2012): 67.8% compared to USA,
- Germany: 68,814 USD (2011), 68,529 USD (2012): 68.2% compared to USA,
- China: 13,093 USD (2011), 14,058 USD (2012): 14.0% of USA, 20.5% of German productivity (OECD, 2014).

From all of the above we can say that the USA economy is the leading economy in the world according to the level of labour productivity while Germany has a 30.8% lower labour productivity. The Chinese economy, despite its fast development and high growth rate, still accounts for only 14% of the American and 20.5% of the German level of labour productivity.

Research into labour productivity aiming solely at the manufacturing industry is fairly rare in literature, which was an incentive for the scientific analysis in this paper, where research is done for two countries in which the processing industry has had an important role in the development of their economy.

The German Federal Bureau of Statistics publishes, on a monthly basis, the official index of labour productivity of the manufacturing industry, which is a significant indicator of the short-term business cycle. This index is used to measure monthly results of the industrial sector and indicate the development of industrial production and the number of people employed. The index represents the relation between the index of industrial production in companies with more than 50 employees and the established work volume. The work volume component, contributing to the creation of the production result, can be expressed as a number of people employed or as the number of performed work hours. The highest increase in the labour productivity of the manufacturing industry was realized in 2011 when it was 13.6% (according to results per number of employed), that is 12.7% (according to the number of work hours) higher than in 2005. A decrease compared to the year 2005 happened in 2009 and was 6.1% or 0.4% in work hours (Destatis, 2014).

The labour productivity of the Chinese manufacturing industry grows at an average annual rate of 7% (2000-2009) and contributes to the total labour productivity growth rate with 2.9 p.p. which accounts for 31% of the total labour productivity growth (APO, 2014). According to the existing research, the labour productivity of the Chinese industrial production, measured with the ratio of the added value and the number of employees, is higher than the labour productivity of the entire economy. For example, in 2000 it was 6,160 EUR as opposed to 5,190 EUR (NBS China, 2014).

3. Work hypotheses and research methods

The subject matter of this paper is a comparative analysis of the dynamics of labour productivity trends in the manufacturing industry in the selected countries in the context of investment in research and development as important factors and the context of their interdependence with the economic growth indicators (GDP). The selected countries are:

- Federal Republic of Germany, representative of the West and the economic leader in the European Union,
- People's Republic of China, increasingly important upcoming economic power from the East.

Considering the subject matter of the research, the following work hypotheses have been formulated:

Fundamental work hypothesis:

Labour productivity performances are interdependent with economic growth and define the future economic perspective of the country. Success on the global market can only be achieved by dynamic economies with a clear initiative to increase labour productivity and make effective investments in knowledge and innovations.

The following *additional hypotheses* are used in the paper:

- The German economy is one of the most successful economies in the world, meaning there is a high level of investment in research and development (innovations) resulting in greater technological complexity of production and reflecting on higher labour productivity.
- Owing to an intense development of the manufacturing industry, in the last three decades China has had a fast economic growth that would not have been possible without an increase in labour productivity.

The following methods were used because of the logical conception of the paper, starting from the description of key terms and determinants in the paper presented with the *method of description and classification*. The comparative analysis, i.e., the conducted international comparison, implies the *method of analysis and synthesis*. Based on the individual and particular information collected, we arrive to general conclusions by way of the inductive method. The deductive method makes it possible to draw individual conclusions from the existing general positions. Considering the subject matter of the research, we use the *mathematical – statistical method (descriptive statistics method)* to calculate the level of labour productivity on the basis of data available from the national bureaus of statistics. The empirical results obtained with the research are analysed by way of the *quantitative econometric methods of regression analysis*, within which there is a specification of the econometric model of interdependence between the key factors. Based on the research results obtained through the *method of proving* or *disproving* we determine the accuracy of the formulated work hypotheses.

4. The scope and measures of the research

The research area of the paper is the manufacturing industry in the selected countries, structured according to national classifications of economic activities of the selected countries, based on the international classification of activities of the United Nations (ISIC), which on higher levels of data aggregation enables international comparisons[1].

The research of the interdependence between the aggregate labour productivity of the manufacturing industry and the economic growth (GDP) for the selected countries covers the period from 1998 to 2011, since there are available empirical data for both countries for the given period. The analysis is performed on the basis of official data from national bureaus of statistics in the selected countries[2], mostly data from structural business statistics (SBS) within which the value of production (output measure) is divided in single expenditure components, enabling a better quality analysis of labour productivity. The data of the structural business statistics are officially published with a delay of 18 months so that the data for the year 2011 (for Germany) were published in June 2013. Considering the availability of information, the years 2012 and 2013 were at times included in the analysis of German labour productivity, while similar data were not available for China.

Considering data availability, the research includes the following:

For Germany, the data are relative to, for the period:

- 1998-2003, all companies (WZ 1993),
- 2004-2007, all companies (WZ 2003→NACE Rev.1),
- 2008-2011, companies with 20 and more employees (WZ 2008→NACE Rev.2).

For China, the data are relative to companies with an annual income from basic activity above the determined boundary which, for the period:

- 1998-2010 amounts to 5 million yuans – 556,000.00 EUR,
- 2011, the boundary is 20 million yuans – 2.2 million EUR (GB/T4754-2002→ISIC Rev.4).

Considering the availability of information, this paper considers labour productivity as a ratio of the gross value of manufacturing industry production and the number of employees taking part in the production, which is expressed as follows:

$$P = \frac{Gross\ value\ of\ manufacturing\ industry\ production}{Number\ of\ employees} \quad (1)$$

The gross value of production represents the market value of all produced goods intended either for direct consumption or further production, as opposed to the value added which represents the difference between the gross value of production and the interphase production. Interphase production marks the value of products and services that are

transformed, used and consumed in the production process (the so-called intermediate goods). If we observe the interrelation between the gross value of production and the gross value added (GVA) of the manufacturing industry, we can conclude that the GVA accounts for only 27% of the gross value of production (Germany; 2011), i.e. 26.6% (China; 2007). In that context, we can also observe the obtained empirical data on the absolute level of the realized labour productivity. However, if relative values are observed, the conclusions on its trend dynamics are identical.

Furthermore, in order to make the international comparison possible, the used data needs to be harmonized since each country expresses the values in its own national currency and has its own national classification according to which it sorts out its statistical data. The conversion of the Chinese yuan into the euro was made according to the average annual exchange rate published by the ECB (*EUR-CNY*). The value information used in the paper is expressed in constant prices. Current values are deflated by the GDP implicit deflator[3].

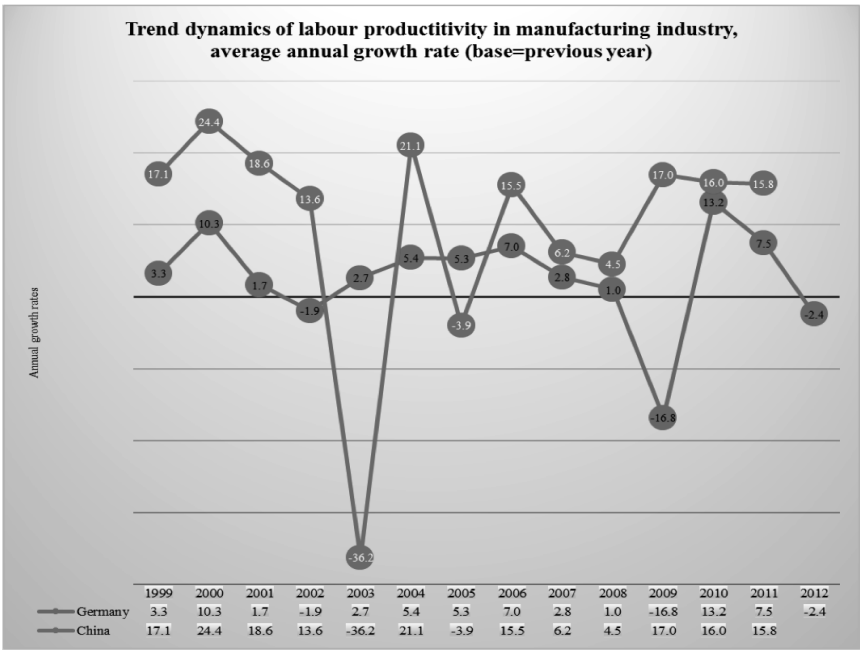
5. Empirical results of the research

5.1 Comparative analysis of labour productivity in the manufacturing industry

The comparison between Germany and China in terms of the realized absolute level of labour productivity in the aggregate manufacturing industry (1998-2011) and the average annual growth rate, as shown in Figures (1, 2 and 3), shows as follows:

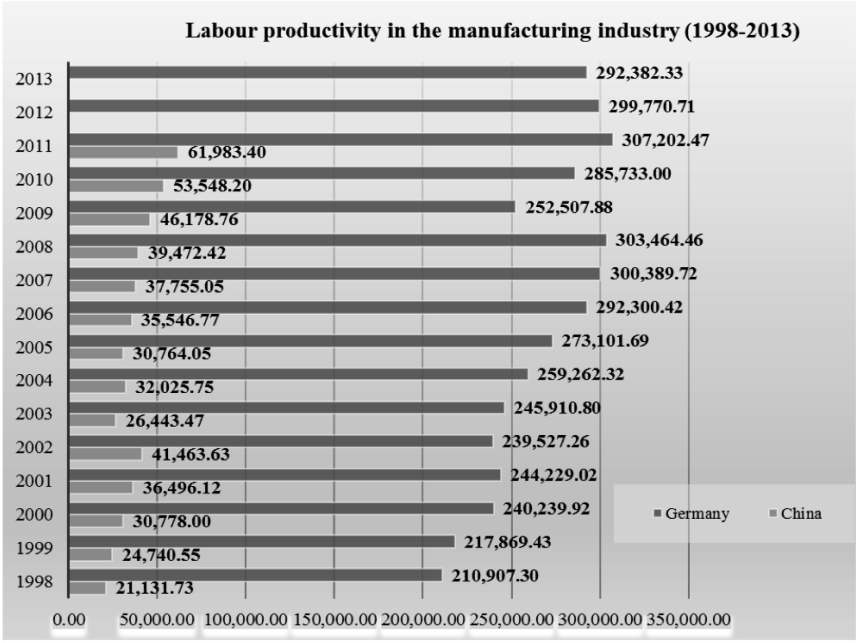
- an outstanding superiority and high level of the German labour productivity compared to the Chinese. For example, in 2011 Germany realized 307,202.47 EUR of production value per employed person, which is 79.8% more than in China,
- the considerable decrease of German labour productivity in 2009 and 2010, which indicates an influence of a slowdown in economic activities in 2009 due to the global economic crisis which decreased the production values and the number of the employed and consequently also the labour productivity which went down by 16.8%,
- a remarkable German recovery in 2010 (13.2% growth) indicating its capability for fast recovery, after which there was again a slight fall,
- the average German annual labour productivity in the manufacturing industry growth rate is 2.5%,
- the average Chinese annual labour productivity in the manufacturing industry growth rate is 5.9%,
- the Chinese manufacturing industry is marked by progress and an above average labour productivity growth which ranges from 4.5% to 17% in the period 2006-2011, representing an exceptional success and enabling the decrease of the gap. For example, in 1998 Chinese labour productivity was 10.0% of the German labour productivity while in 2011 it was 20.2% (Figure 2)
- the trend dynamics of Chinese labour productivity in 2003 shows a considerable decrease in labour productivity (-36.2%), which is a consequence of a felt increase of the number of workers employed in the manufacturing industry (from 29 to 48 million people; +68% growth), which reflects on a visible decrease in labour productivity in 2003. The increase of the number of workers in the Chinese manufacturing industry is a consequence of huge workforce migrations from rural to urban areas, with about 45% of migrant workers finding employment in the manufacturing industry (CLB, China Labour bulletin, 2012),
- despite China's huge progress and positive trends, the level of the realized labour productivity is still way under the German level. The research results indicate some positive movements in keeping with the Chinese economic growth and require a more exhaustive scientific research.

Figure 1 Trend dynamics of labour productivity in the manufacturing industry



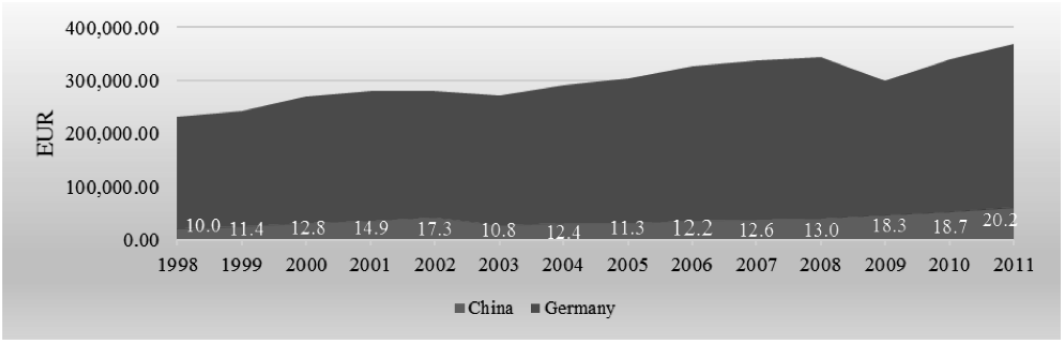
Source: Authors' research and calculation on the basis of data: Destatis, NBS China (2015)

Figure 2 Comparison of labour productivity in the manufacturing industry



Source: Authors' research and calculation on the basis of data: Destatis, NBS China (2015)

Figure 3 Interrelationship of labour productivity in the manufacturing industry of Germany and China (1998-2011)



Source: Authors' research and calculation on the basis of data Destatis, NBS China (2014)

5.2 Innovations: Important factor of influence on labour productivity in the manufacturing industry

The development of efficient technologies and the information and communication technology (*ICT*) enables a better technological equipping of the work process with better, more modern and more sophisticated work tools. The technological advancement is made possible by investments in long-term property (fixed capital), direct foreign investments (they were very important in the development of China: in 2011 they were 90.2 billion EUR; 1.59% of the Chinese GDP) and investment in research and innovation (Table 1). Inventions and innovations, discoveries and a continuous process of quality development are the basis of a dynamic development of labour productivity in economy and sustainable development. The achievement of economic growth in conditions of globalization is not possible without creating optimal conditions for scientific research and without increasing investments in research and development, which is one of the goals of the *Strategy "Europe 2020"* (Eurostat, 2014). In the last couple of years, the budget for research and development was increased in Germany from 2.54% of the GDP (2006) to 2.82% (2010) and 2.91% (2011), i.e. from 58.8 billion EUR to 75.5 billion EUR, closing up on the European goal of 3% of the GDP (Destatis 2014). Table 1 shows that the greatest portion of the expense is taken up by the business sector (68.1%) which in 2012 invested 53,8 billion EUR or 1.98% of the GDP. By observing the structure of the expense for research and development (2012) we can see that the German business sector invested no less than 86.1% (46.3 billion EUR) of the total expense in the manufacturing industry. This reflects in an increase of efficiency and labour productivity in the manufacturing industry, especially in areas of high-tech that are crucial for development, as defined by the European Commission, like nanotechnology, biotechnology, materials science and engineering, ICT, optical and production technologies. The average annual growth rate of investments in research and development of the German manufacturing industry is 2.8% (1998-2012), with most investments in production of high and mid-high level of technology: production of motor vehicles (36.8%), computer production, electronic and optical products (14.9%) and the production of machinery (11.4%). Considering the importance of innovations, which are especially important in the German economy, this paper wants to establish the impact of investments in research and development of the manufacturing industry on the labour productivity trends.

Table 1 Expense for research and development (Germany, China, 2011-2012)

Mil. EUR	Germany			China		
Expenses for research and development	2011	2012	2012	2011	2012	2012
TOTAL	75,500	78,954		96,565	127,059	
2012/2011		*(+4.6%)*	*100%*		*(+31.6%)*	*100%*
Expense sources:						
Business sector	51,077	53,790	*68.1%*	71,372	94,076	*74.0%*
State sector and non-profit organizations	10,974	11,341	*14.4%*	20,931	27,407	*21.6%*
Higher education and other	13,499	13,824	*17.5%*	4,262	5,576	*4.4%*
Share in the GDP	*2.91%*	*2.96%*		*1.84%*	*1.98%*	
Manufacturing industry	43,733	46,333		63,276		
Share	85.6%	86.1%		65.5%		

Source: Destatis (2014), NBS China (2014)

China has also increased investments in research and development over the last years so that it has become an important innovator with more patents on an annual basis than any other country in the world (2011: 1,633,347). Expenses for research and development (2011) make up for 1.84% of the Chinese GDP (96.6 billion EUR) closing up on the Chinese goal: 2.2% GDP. Their average annual growth rate is 21.2% (2007-2011). A considerable increase of investments (31.6%) is realized in 2012, meaning that China keeps converging toward the developed western countries in terms of innovations. In the expense structure, the most comes from business funds of companies (74%) and the 83% of the total finances are directed towards development research whose result is the creation of an original product prototype. Investment activities focused on new discoveries (products, technologies, processes) or the improvement of the existing lead to an increased capability in building Chinese innovations, resulting in a growth of labour productivity and the exports of high-tech products. Out of the total expense for research and development (1.2% of the GDP) 65.5% goes to the manufacturing industry.

5.3 Interdependence of investment in research and development and labour productivity in the manufacturing industry in Germany

Innovations can be qualified on the basis of the amount of the expense for research and development. Considering the German achievements regarding the realized labour productivity in the manufacturing industry and the considerable investments in research and development, this part of the paper aims at establishing the interdependence of labour productivity and expenses for research and development on the example of the German manufacturing industry.

The research covers the period between 1998 and 2012. The data on the amount of the expense were taken over from the statistical bulletins of the German Federal Bureau of Statistics for different years, while the data on the amount of the labour productivity are empirical (authors' calculation) and are described in the previous chapters. The variables in the regression analysis are shown in Table 2.

Table 2 Regression analysis variables

T=15 observations Time series: 1998-2012	Absolute amount	Relative amount (logarithm)
Labour productivity in the German manufacturing industry based on the gross value of production (constant prices)	*Dependent variable y*	*lny*
Expense of the business sector for research and development in the manufacturing industry (constant prices)	*Independent variable x*	*lnx*

Source: Authors' interpretation

The interdependence of the selected variables is established on the basis of a simple regression analysis using the method of least squares (OLS or LS method). A simple linear regression model expresses the stochastic linear connection between the dependent variable *y* and the independent variable *x*, which can formally be described as follows:

$$y = f(x) + \varepsilon \quad (2)$$

$$f(x) = \beta_0 + \beta_1 x \quad (3)$$

where *f(x)* is the linear function of the variable *x*, β_0 and β_1 are unknown parameters and ε is the casual variable giving the model its stochastic character.

Since the economic relationships are best explained by way of relative changes, for the needs of this research, the absolute values of labour productivity in the manufacturing industry and the expense for research and development are logarithmized on the basis of the natural logarithm. In that way we obtain the following specification of the econometric model:

$$lny = ln\beta_0 + \beta_1 lnx + \varepsilon \quad (4)$$

in which the parameter β_1 represents the partial coefficient of elasticity of the variable y in relation to the change of the variable *x*, that is:

$$\beta_1 = \frac{\partial lny}{\partial lnx} = \frac{\partial y}{\partial x} * \frac{x}{y} \quad (5)$$

The coefficient of elasticity shows the percentage by which variable y is going to change in case variable *x* increases by 1%.

The research resulted in the following econometric model:

$$lny = 3.97 + 0.79lnx \quad (6)$$
$$(1.961) \quad (4.199)$$

from which, at a level of statistical probability of 5%, we can conclude that there is a positive link between investment in research and development (innovations) and labour productivity in the manufacturing industry, and that labour productivity is relatively elastic to changes of investments in innovations.

The coefficient b_1 shows that an increase of investments in research and development by 1% leads to an increase of labour productivity in the manufacturing industry by 0.79%. Tests of credibility of the obtained results are shown in Table 3.

Table 3 Statistical tests

Level of reliability 95% **Level of importance 5%**		**p-value**
Coefficient b_1= 0.79	t-value: 4.199	0.001
Determination coefficient R^2	0.58	
AUTOCORRELATION TESTS		
LM	LMF: 0.723341	0.41
Durbin-Watson	DW: 1.591463	0.16
Ljung-Box Q‘	0.709496	0.40
Alternative statistic	TR^2 = 0.852772	0.36
RESIDUAL DISTRIBUTION NORMALITY	t-statistics: 2.32179	0.31
HETEROSKEDASTICITY White`s test	LM: 1.36009	0.24
ERROR SPECIFICATION (Ramsey`s RESET)	0.053587	0.95

Source: Authors' interpretation based on the application of Gretl software

5.4 Interdependence of labour productivity in the manufacturing industry and economic growth

The regression analysis is performed in an attempt to establish the interdependence of labour productivity in the manufacturing industry and the economic growth of the selected countries with the aim of testing the basic work hypothesis saying that the performances of labour productivity determine the future economic perspective of the country.

The variable used most often as a sign of the economic growth is the GDP. It is therefore also used in this research and represents the dependent variable. The data on the level of labour productivity in the manufacturing industry are established empirically in this research and represent the independent variable (Table 4).

Table 4 Regression analysis variables

Variable T=14 observations Time series: 1998-2011	Growth rates	Absolute amount	Relative amount (logarithm)
GDP, constant prices		*Dependent variable y*	
Germany	*1.06%*	*yg*	*lnyg*
China	*7.44%*	*yc*	*lnyc*
Labour productivity in the manufacturing industry based on the gross value of production, constant prices		*Independent variable x*	
Germany	*2.53%*	*xg*	*lnxg*
China	*5.95%*	*xc*	*lnxc*

Source: Authors' interpretation based on the application of Gretl software

The interdependence of the selected variables is established using the methodology described in the previous chapter, on the basis of a simple regression analysis using the least square method (OLS or LS method) and the specification of the logarithmic econometric model through which we determine the partial coefficient of elasticity of the variable y in relation to the change of variable x, that is:

$$\beta_1 = \frac{\partial lny}{\partial lnx} = \frac{\partial y}{\partial x} * \frac{x}{y} \qquad (7)$$

The coefficient of elasticity in this case shows to what percentage variable y is going to change (GDP of the selected country) if variable x (labour productivity in the manufacturing industry of the selected country) increases by 1%.

The interrelationship of the German GDP (*lnyg*) and the labour productivity in the manufacturing industry (*lnxg*), expressed in logarithmic form, shows the influence of the economic recession in 2009 and 2010 when there is a significant decrease of the GDP and labour productivity in the manufacturing industry, which needs to be included in the regression analysis in order to determine a regular econometric model.

The influence of recession on regression between the selected variables enables the introduction of the dummy variable of observance with a value of 1 in the years of recession and 0 in the years without recession. Since it can be assumed that the regression direction changes its inclination in the recession years (2008, 2009 and 2010), the dummy variable is multiplied by the independent variable (lnxg) and is represented as *D*.

On the basis of the exposed data we can determine the following econometric model:

$$lnyg = \underset{(9.8)}{3.26} + \underset{(13.6)}{0.36 lnxg} + \underset{(2.6)}{0.001 D} \quad (8)$$

from which, at a level of statistical importance of 5%, it can be concluded that there is a positive link between labour productivity in the manufacturing industry and the GDP. The coefficient of elasticity b_1 shows that in case the labour productivity of the German manufacturing industry increases by 1%, the GDP shall increase by 0.36%. On the basis of these data it can be concluded that the German GDP is not that elastic to the change of labour productivity in the manufacturing industry.

The interdependence of the Chinese GDP (*lnyc*) and the labour productivity in the manufacturing industry (*lnxc*), expressed in logarithmic form, shows that after an uneven relationship in the beginning of the 21st century (2000-2003), especially in years 2001 and 2002 (influence is shown through dummy variables with a value of 1 in years 2001 and 2002, and is represented as *D)*, from the year 2005 on there is a positive trend.

On the basis of the exposed data we can determine the following econometric model:

$$lnyc = \underset{(-4.5)}{-3.71} + \underset{(13.5)}{1.07 lnxc} - \underset{(-4,7)}{0.02 D} \quad (9)$$

from which, at a level of statistical importance of 5%, it can be concluded that there is a positive link between labour productivity in the manufacturing industry and the GDP and that the Chinese GDP is elastic to changes in labour productivity in the manufacturing industry. The coefficient of elasticity b_1 shows that in case the labour productivity of the manufacturing industry increases by 1%, the GDP will increase by 1.07%. From all of the above it can be concluded that in the Chinese economy there is a stronger link between labour productivity in the manufacturing industry and economic growth than in Germany. The credibility tests of the conducted analysis are shown in Table 5.

Table 5 Statistical tests

Level of reliability 95% **Level of importance 5%**	**Germany** b_1**=0.36**	**p-value**	**China** b_1***= 1.07***	**p-value**
	t-value:13.6	3.15e-08	t-value: 13.5	3.46e-08
Determination coefficient R^2	0.95		0.94	
Autocorrelation				
LM (Lagrange multiplier)	LMF: 0.449536	0.51	LMF: 0.338975	0.57
Durbin-Watson	DW:1.490805	0.07	DW:2.19565	0.47
Ljung-Box Q'	0.403005	0.52	0.474197	0.49
Alternative statistic	TR^2 = 0.6202276	0.44	TR^2 =0.459006	0.49
Residual distribution normality	Chi-square (2): 1.33	0.51	Chi-square (2): 3.6847	0.15
HETEROSKEDASTICITY White`s test	LM=5.506563	0.24	1.08915	0.29
ERROR SPECIFICATION (Ramsey`s RESET)	F = 0.583102	0.58	3.802383	F=0.06

Source: Authors' interpretation based on the application of Gretl software

6. Conclusions

Though mankind has, since the very first form of society, been striving for the better, globalization has created a whole new and more complex context for the same issue, pointing out the interdependence of innovations, labour productivity and economic growth. In the uncertain conditions of a growing and more complex competition, the advancement of labour productivity becomes a crucial issue and one of the key prerequisites of economic success on both the level of the entire economy and the level of single branches of economy like the manufacturing industry. The high-tech manufacturing industry is becoming increasingly important for economic growth, especially in the examples of the two selected countries.

In order to understand the development of labour productivity in a country, we need to observe numerous quantitative and qualitative interconnected factors among which a valuable role is played by the human factor (investment into knowledge) and the creation of optimal conditions for innovations (research and development), which is key for the functioning of any organization and society.

The stated positions were confirmed by the comparative analysis of labour productivity in the manufacturing industry of the selected countries in the period 1998-2011.

The German economy is marked by a high level of investment in research and development and the labour productivity of the German manufacturing industry is 79.8% stronger than the Chinese, growing at an annual rate of 2.53%. Investments in research and development (innovations) are an important factor of the trend dynamics of the German labour productivity, accounting for 2.96% of the GDP, which makes Germany one of the leading European countries. In the structure of investments in research and development of the business sector, the manufacturing industry accounts for 86.1%, enabling technological and organizational innovations and requiring a competent workforce, which reflects on an increase in labour productivity. Using a regression analysis of the interdependence of the total investment in research and development of the German manufacturing industry and its labour productivity, based on empirical data for the period 1998-2012, with the level of importance of 5%, we

estimated the coefficient of elasticity of labour productivity to changes in investment in research and development. The research results show that there is a positive interdependent link with a coefficient of elasticity of 0.79, meaning that in case the investments increase by 1%, labour productivity will increase by 0.79%.

Based on this research we can accept the additional hypothesis that the German economy is one of the most successful world economies and that it has a high level of investment in research and development (innovations) which results in higher labour productivity.

The research results show that the Chinese economic take-off is accompanied by an above average growth of labour productivity in the manufacturing industry, growing at an annual rate of 5.95% (Constant prices). Since 2005, there has been a strong increase of Chinese labour productivity (the average growth rate is 11.1%), which made it possible to decrease the gap with Germany from the level of 11.3% of the German labour productivity to 20.2%. The obtained results coincide with the existing research according to which the Chinese labour productivity is 20.5% of the German labour productivity and is growing at an average annual rate of 7% to 10.2%, depending on the year observed. The example of the Chinese economic development shows that connected and complementary technological, social, educational and institutional changes, along with an efficient adjustment of economic policies as well as a gradual liberalization and opening of the economy can lead to an increase of labour productivity in the manufacturing industry, to long-term economic growth and higher global competitiveness of the country.

With the regression analysis of the interdependence of labour productivity in the manufacturing industry and the GDP, and the calculation of the coefficient of elasticity, we tried to estimate the influence of labour productivity in the manufacturing industry on the economic growth of the selected countries. On a level of statistical importance of 5%, we can conclude that there is a positive link between labour productivity in the manufacturing industry and the GDP. The interdependence is more visible in the Chinese economy since the coefficient of elasticity is 1.07, meaning that a growth of labour productivity of 1% affects the growth of the GDP by 1.07%. On that basis, we can conclude that the Chinese GDP is elastic to changes in the labour productivity in the manufacturing industry and that a growth of productivity contributes to the Chinese economic development. In the German economy the mentioned coefficient of elasticity is lower and amounts to 0.36 meaning that a growth of labour productivity of 1% results in a GDP growth of 0.36%.

Developed countries have lower annual economic growth rates, meaning that there is need for substantial investment in innovations in order to keep the existing level of competitiveness. Developing countries have high annual economic growth rates, which means that a country grows more easily if it is relatively poor in the start and if it uses the existing established technologies. The technological convergence of the upcoming economic power of China, which invests more and more in research and development, is ever more important, leads us to conclude that the technological superiority of the West is decreasing. This confirms the basic work hypothesis that success on the global market can only be achieved by dynamic economies with a pronounced initiative for an increase of labour productivity and an efficient investment in knowledge and innovations.

This research indicates a positive interdependence between innovations and labour productivity in the manufacturing industry, meaning that the innovations are an important factor affecting labour productivity. Besides innovations, there are numerous other factors, like investment in knowledge and education (human resources), whose influence on productivity needs to be analysed further and might be an incentive for future research. Starting from the premise that industries with higher technological intensity also have a higher level of labour productivity, it is important to examine how the technological complexity of production affects the trend of movement of labour productivity. What is more, besides affecting economic growth, labour productivity also affects the competitiveness of single countries. Future research has to be directed towards the establishment of interdependence between labour productivity and competitiveness of economy. New research should encompass numerous countries and regions in order to find the answer to a question that is still open: *Why do some countries develop faster and others more slowly? Do countries that realize a higher level of labour productivity and invest more in research and development (innovations) develop faster than other countries?*

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(Endnotes)

1 **ISIC Rev. 4** - International Standard Classification of All Economic Activities, version 4., classification of economic activities published by the United Nation Statistic Division
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2 Federal bureau of statistics of the Federal Rep. of Germany, ***Destatis,*** *Statistisches Bundesamt:* data of the Structural Business Statistics (**SBS**) National Bureau of Statistics of the PR of China, ***NBS China****, National Bureau of Statistics of China*

3 Source: World Bank national accounts data, 2016

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INOVACIJE KAO BITAN ČIMBENIK UTJECAJA NA PROIZVODNOST RADA PRERAĐIVAČKE INDUSTRIJE

Sažetak

Ekonomska znanost već dugo prepoznaje proizvodnost rada kao značajnu odrednicu gospodarskoga rasta, koja u neizvjesnom okruženju sve jače i složenije konkurencije postaje jedan od ključnih preduvjeta za prevladavanje globalnih izazova. Razvoj proizvodnosti rada treba promatrati kao višedimenzionalni proces koji uključuje mnogobrojne međusobno povezane kvantitavne i kvalitativne čimbenike, s posebnim naglaskom na ljudske čimbenike i tehnološki napredak, koji se ostvaruje ulaganjem u istraživanje i razvoj (inovacije). Analiza proizvodnosti rada prerađivačke industrije odabranih zemalja: SR Njemačke i NR Kine, provodi se u kontekstu bitnoga utjecajnog čimbenika - inovacija, te u međuzavisnosti s gospodarskim rastom odabranih zemalja. Rezultati istraživanja i provedene regresijske analize ukazuju na nadmoć njemačke proizvodnosti rada prerađivačke industrije, na koju utječu znatna ulaganja u istraživanje i razvoj. Međutim, tehnološka konvergencija nadolazeće sile NR Kine je sve značajnija, što označava da se i jaz u proizvodnosti rada smanjuje, suočavajući razvijene zemlje s novim izazovima globalizacije. Analiza međuzavisnosti gospodarskoga rasta (BDP-a) i proizvodnosti rada prerađivačke industrije, ukazuje na pozitivnu poveznicu i zaključak da je u NR Kini veća elastičnost BDP-a na promjenu proizvodnosti rada nego u SR Njemačkoj.

Ključne riječi: proizvodnost rada prerađivačke industrije, inovacije, gospodarski rast, SR Njemačka, NR Kina