COMPARATIVE ANALYSIS OF SELECTED INNOVATIVENESS MEASURES OF ECONOMIES SHOWN ON THE EXAMPLE OF CHINA, GERMANY, USA AND UNITED KINGDOM

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Abstract

The article attempts to make a comparative analysis of the selective innovativeness measures in four countries. For this purpose China, Germany, USA and United Kingdom have been selected due to the thesis concerning the diversity of the level of innovativeness characteristic for their economies. Thus the main aim of the article is to identify basic similarities and differences between the selected measures of innovativeness in the four analysed countries. Such measures include the number of patents registered by the citizens of particular countries, expenditure on research and development, and the number of articles published by scientists in scientific magazines.

Owing to the complexity of the matter discussed, the article is divided into two parts. The first one, strictly theoretical, contains lapidary description of the most innovative enterprises in China, Germany, USA and United Kingdom. The second one, depending on statistical database of The World Bank, presents a comparative analysis of innovativeness determiners.

The research period began in 2011 whereas the last analysed year was 2015 due to limited amount of data accessible in the course of research. To accomplish the objective it was necessary to apply comparative analysis and the analysis of statistical data.

Key words: characteristics of enterprises, foreign economies, innovativeness

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Introduction

Nowadays innovations refer to every aspect of life. They reflect dynamic changes that occur in the world. It seems that every consecutive product or idea is connected with innovativeness which consequently depreciates the meaning of the term (Wolak-Tuzimek,

2016). The word „innovation" is often used by marketing agencies trying to outrival their competitors (Marakova et al., 2016).

According to what Christopher Freeman said a country's innovation system is a network of institutions in public and private sectors whose activities and interactions initiate, import, modify and promote new technologies. Such systems are significant as the success of innovation in a particular country is connected with its policy and innovation plans which should be efficient and synergistic (vide: Gorokhova, Šafránková, Sekerin, 2015).

Better understanding of the origin, development and functioning of the national innovation system may help decision makers to determine its most important advantages and drawbacks and define the necessary political changes that will raise the level of innovativeness in a given country. Due to numerous factors every national system of innovation is different, exceptional and must be discussed separately (more Lyasnikov, Dudin, et al., 2014). Hence in the present article the area of research has been limited to precisely specified part of a broad issue. The remaining problems are worth discussing in successive scientific papers dealing with innovativeness.

1 Innovation system in China, Germany, UK and USA – short brief

The first aspect of the analysis will be a short presentation of innovation systems functioning in China, Germany, United Kingdom and USA.

An important point in the Chinese economy was the accession to the World Trade Organization (WTO), thanks to which the economy accelerated at a tremendous pace. There was an increase in imports and exports, foreign investments have started on a large scale and the average annual GDP growth rate has amounted to over 15% since 2001. With the accession to the WTO, China has awakened its potential to become a real "Tiger" of the global economy.

The Beijing government has created a medium and long-term science and technology development plan for 2006-2020, which is known as the MLP, whose overarching goal is "the great renaissance of the Chinese people" (Lynch, 2015). By 2020, China is planning to become a powerhouse in modern technologies, and by 2050 a world leader (Pei, 2006).

Various kinds of research institutes have a significant impact on the innovation of the German economy, which in the 20th century in particular were subjected to political and economic pressure. One of the most important are: The Max Planck Society, The Fraunhofer Society, The Leibniz Association.

In order to create the right conditions enabling researchers, scientists, engineers and organizations to gain a leading position in technology markets, the federal government announced a High-Tech strategy in August 2006. For the first time a national strategy that covered all ministries in Germany was developed. Its content was shaped during consultations with representatives of industry and science. The government in Berlin assumes that the strategy will become an accelerator for efforts to transform Germany into a country that will provide the most favorable conditions in the world for research and innovation (The Federal Government, 2014).

The British innovation system is based on a document „Our plan for growth: science and innovation, created in 2014 by the Department for Business, Innovation and Skills". According to the plans of the British government, it is necessary to create a long-term concept that would allow to implement appropriate conditions for development in the field of business and science.

As part of tax regulations, whose task is to support new technologies, the government created the Patent Box, thanks to which it is possible to use a reduced, 10% CIT rate if the profits of the enterprise have increased thanks to implemented innovations that have been legally patented.

In the United States of America, the innovation system is based on two fundamental aspects: supporting mission-oriented research (e.g. defense and health), supporting federal laboratories and basic, interesting research through university funds. The United States finances between 80 and 100 government research laboratories (some administer the government and some are managed by private economic operators). The largest laboratories are supported by the defense, energy and health departments (Stepp, Pool et al., 2013).

The American government has created strong relations between academic centers, research institutes and the private sector. These entities often conduct joint research aimed at creating innovative technologies. Higher education in the United States is considered the best in the world, 17 American universities are in the top twenty of the world ranking (Times, 2018).

Analyzing technology transfer (from universities or government laboratories to the market), certainly institutions such as: MIT and Stanford University have an important role in cooperation with the industry and supporting new business ventures.

In the United States, most commercial activities are run by private for-profit companies. The United States generally does not support research and development directly in

companies unless R&D is associated with the achievement of a basic mission and in particular defense.

2 Analysis of selected innovation indicators

The next stage in the comparative analysis of selected measures of innovation will be the presentation of statistical data on such aspects as GDP, the number of patents submitted by citizens, advanced technology exports, expenditure on R & D and the average annual salary. Next, after analyzing the data, the Pearson correlation coefficient will be tested between individual measures.

The first step will be to present the analysis of statistical data changes in GDP in China, Germany, United Kingdom and United States of America in 2012 – 2015 (tab.1).

Tab. 1: Changes in GDP in China, Germany, United Kingdom and USA in 2012-2015 (in USD billion)

Country/Year	2012	2013	2014	2015
China	8 560.6	9 607.2	10 482.4	11 064.7
Germany	3 544.0	3 752.5	3 879.3	3 363.6
USA	16 155.3	16 691.5	17 393.1	18 036.6
UK	2 646.0	2 719.5	2 998.8	2 861.1

Source: The World Bank, https://data.worldbank.org, [access 20/04/2018]

Table 1 shows that in the analyzed period, the United States had the highest budget among four countries, an average of USD 16 155.3 billion. The second country was China, whose average GDP amounted to 11 064.7 billion USD. In this case, it should be noticed that the growth between 2012 and 2015 was extremely dynamic and amounted to + 29%. The country with the lowest GDP ratio was The United Kingdom, where the average was 2 998.8 billion. USD. Noteworthy is the great difference in GDP between the US and the UK, which goes over USD 13 000 billion.

The next analyzed indicator shows the number of patents submitted by citizens of four selected countries in 2012-2015 (Table 2).

Tab. 2: The number of patents submitted by citizens of China, Germany, United Kingdom and USA in 2012-2015

Country/Year	2012	2013	2014	2015

China	535 313	704 936	801 135	968 252
Germany	46 620	47 353	48 154	47 384
USA	268 782	287 831	285 096	288 335
UK	15 370	14 972	15 196	14 867

Source: The World Bank, https://data.worldbank.org, [access 20/04/2018]

According to the data in table 2, the country that reports the most number of patents is China. In 2012 their number amounted to 432 939 applications and by 2015 it increased to 968 252, which is another proof that China has rapidly changed from the copying model to the innovative model. The second in this study, the United States reported 288 335 in 2015, which is 679 917 applications less than China. Germany and UK reported on average 47 378 and 15 101 applications in the analyzed period (vide Firlej, 2013).

The next stage of the analysis is the presentation of incomes related to the export of advanced technology (Table 3).

Tab. 3: Export of advanced technology in China, Germany, United Kingdom and USA in 2012-2015 (in USD billion)

Country/Year	2012	2013	2014	2015
China	505.6	560.1	558.6	554.3
Germany	187.0	193.8	199.7	185.6
USA	148.3	148.5	155.6	154.3
UK	67.8	69.2	70.6	69.4

Source: The World Bank, https://data.worldbank.org, [access 20/04/2018]

Table 3 shows that the highest income related to the export of advanced technology was recorded in China, on average 544.7 billion USD in the analyzed period. The other countries have earned far less than Chinese enterprises and organizations. In the same period, Germany recorded an average of USD 191.5 billion, USA recorded 151.7 billion USD and United Kingdom recorded only USD 69.3 billion.

It is also worth paying attention to the expenditure of R & D, which is an important element in the creation of innovative products and services. The data is presented in Table 4.

Tab. 4: Expenditure on R & D in China, Germany, United Kingdom and USA in 2012-2015 (in % of GDP)

Country/Year	2012	2013	2014	2015
China	1.91	1.99	2.02	2.07
Germany	2.87	2.82	2.89	2.88

USA	2.70	2.74	2.75	2.79
UK	1.61	1.66	1.68	1.70

Source: The World Bank, https://data.worldbank.org, [access 20/04/2018]

According to Table 4, the average of the most expenditure on R & D in relation to GDP is borne by Germany, who spent 2.86% in the analyzed period. The second in this study is the United States, which on average spent 2.75%. China was in the third place, but it can be noted that each year they increase the percentage of GDP transferred to research and development. Once again, the United Kingdom was the last in the ranking, with an average of 1.66%.

The last analyzed indicator is the average annual salary received by employees in China, Germany, the United Kingdom and the USA (Table 5).

Tab. 5: Median salary in China, Germany, United Kingdom and USA in 2012-2015 (in USD)

Country	2012	2013	2014	2015
China	47 593	52 388	57 361	63 241
Germany	43 701	44 161	44 743	45 810
USA	57 653	57 369	58 219	59 691
UK	42 330	42 058	41 878	42 304

Source: https://data.oecd.org, [access 20/04/2018]

In 2015, the highest average annual salary were recorded in China - 63 241 USD, with The United States on the second place, where the average annual salary was 59 691 USD. Next we had Germany - 45 810 USD and the United Kingdom with a slightly lower average annual salary of 42 304 USD.

Although the Chinese show the highest average annual salary among selected countries, it should be noticed that in this country, unlike the others, there is a very large social stratification, in which there is a big difference in earnings between citizens of large metropolises and citizens of the village.

The next step in the comparative analysis of selected innovation indicators will be to examine Pearson's correlation coefficient between them. The table below presents the results of dependencies.

Tab. 6: Correlation indicators between selected measures of innovation

Correlation Coefficient	China	Germany	USA	UK
GDP and number of patents submitted by citizens	0.99	0.59	0.75	-0.25
GDP and export of advanced technology	0.78	0.96	0.86	0.94
GDP and expenditure on R & D	0.99	-0.11	0.98	0.78
Number of patents submitted by citizens and export of advanced technology	0.74	0.79	0.52	-0.37
Number of patents submitted by citizens and expenditure on R & D	0.99	0.35	0.84	-0.80
Export of advanced technology and expenditure on R & D	0.84	0.05	0.75	0.79
Average annual salary and number of patents submitted by citizens	0.99	0.47	0.41	-0.01
Average annual salary and export of advanced technology	0.69	-0.16	0.71	-0.81
Average annual salary and expenditure on R & D	0.97	0.44	0.83	-0.32
Arithmetic average	0.89	0.38	0.74	-0.01
Standard deviation	0.12	0.39	0.18	0.68

Source: Own calculations based on statistics, (vide Borroni, 2009; Nelsen, 1998)

Studies show that the correlation between GDP and patents applicated by citizens in three cases is plus / positive (China r = 0.99, very strong relationship, Germany r = 0.59, moderate relationship, USA r = 0.75, quite strong relationship), and in one negative negative (United Kingdom r = -0.25, weak relationship).

When it comes to dependence between GDP and advanced technology exports, it can be noted that in each case the correlation is positive, therefore, with the increase of one indicator, the other increases. With regard to two countries: Germany and the UK, the relationship was very strong, while in China and the United States, the relationship was quite strong.

Analyzing the correlation between GDP and expenditure on R & D, three plus / positive relationships were obtained: China r = 0.99, very strong relationship; USA r = 0.98, very strong relationship; United Kingdom r = 0.78, the relationship is quite strong. In Germany, the correlation was minus / negative and r = -0.11, therefore there is no relationship.

The correlation between patents submitted by citizens and the export of advanced technology was plus / positive in three cases: China r = 0.74, quite strong relationship; Germany r = 0.79, quite strong relationship; USA r = 0.52, moderate relationship. In the United Kingdom, there was a minus / negative correlation r = -0.37, the relationship is weak. In the last case, along with the increase in the number of patents submitted by citizens, the number of exported advanced technology is decreasing and vice versa.

Looking at the results of the correlation between citizens' patents and R & D expenditure, it can be noted that in three cases the correlation was plus / positive: China r = 0.99, very strong relationship, Germany r = 0.35, weak relationship; USA r = 0.84, quite strong relationship. In United Kingdom, the correlation between the surveyed indicators was minus / negative and amounted to r = -0.80, the relationship is quite strong here.

The relationship between advanced technology exports and R & D spending in all countries was plus / positive. In three cases, the relationship was quite strong (China, USA, United Kingdom), and there was no relationship in Germany (Germany).

The correlation between the average salary and citizens' patents was plus / positive in China, Germany and the USA. In the first case the relationship was very strong and in the other two moderate. In the UK, minus / negative was reported and there was no relationship.
Analyzing the relationship between the average salary and the export of advanced technology in two cases was plus / positive: China r = 0.69, moderate relationship; USA r = 0.71, quite strong relationship. In Germany and the United Kingdom, the correlation was minus / negative and amounted to r = -0.16, no relationship and r = -0.81, quite strong relationship.

In the last statement, the average salary and expenses on R & D in China, Germany and the USA have a plus / positive correlation, respectively r = 0.97, a very strong relationship; r = 0.44 moderate relationship; r = 0.83, quite strong relationship. In the case of United Kingdom, the correlation was minus / negative and r = -0.32, weak relationship.
The arithmetic average for correlation indicators between selected measures of innovation was: 0.89 (China), 0.38 (Germany) 0.74 (USA) and -0.01 (United Kingdom). The standard deviation for China was 0.12; Germany 0.39; USA 0.18; United Kingdom 0.68.

Conclusion

Innovation is an important element of the development of the economy of every country in the world. Therefore, it is important that the governments of individual countries create appropriate systems supporting research and development.

In recent years, China deserves particular distinction because as mentioned, in just a decade, this country has developed from the model of copying products and services into an innovative model. According to the studies carried out comparison of innovation coefficients with macroeconomic factors shows that in each case the increase of one factor causes the increase of the other and in as many as five cases the relationship was very strong. Thanks to this, it can be stated that the innovation system implemented by China is extremely effective.

The same applies to the United States, where the system is based on the cooperation of government and enterprises with academic centers. This solution is used by all, the government and businesses receive adequate scientific knowledge, and academic centers provide adequate financial support for the education of scientists who can test their knowledge in a dynamically changing market. Looking at the United States, in seven cases the relationship was quite strong and very strong, and all correlations were plus / positive. Thus, just like in China.

Germany, considered as one of the most innovative countries in the world, bases its innovation system on the cooperation of the government with research institutes such as the Max Planck Society, the Fraunfoher Society, and the Leibniz Association. In addition, it should be noticed that products from this country are of high quality. The conducted research suggests that in case of Germany there are no such unambiguous results as in the countries mentioned above. Only one correlation was obtained with a quite strong relationship and one of very strong. In three cases, there was no relationship between the indicators, where two correlations were negative and one positive.

Analyzing the innovation system in United Kingdom, it is worth noting that over a period of more than 100 years, this country has lost its status as the richest country in the world and the most innovative one. At present, it can be stated that the British economy can not withstand competition with China, Germany and the United States. The studies carried out show that in five cases the correlation between innovation and macroeconomic indicators was minus / negative. Thus, the increase of one of the indicators did not guarantee, or even decrease, the level of the second indicator.

References

BORRONI, C. G. (2009). *Understanding Karl Pearson's Influence on Italian Statistics in the Early 20th Century.* International Statistical Review Vol. 77 Issue 1, Netherlands: Publisher INT Statistical INST, 2009, 81-95 pp.

FIRLEJ, K.A. (2013). *Innovation in the European Union in the Light of Lisbon Strategy and Europe 2020 Strategy.* In Jedlička P. (Eds.), Hradec Economy Days 2013, vol. 3(1), 57-58 pp. Retrieved from http:// uni.uhk.cz/.

GORAKHOVA, A.E., ŠAFRÁNKOVÁ, J.M., SEKERIN, V.D. (2015). *Potential of New Management Technologies for Growth of the Industrial Companies' Efficiency*. In Loster, T., Pavelka, T. (Eds.), The 9th International Days of Statistics and Economics, 477-486 pp. Retrieved from http://msed.vse.cz/.

LYASNIKOV, N. V., DUDIN, M. N., SEKERIN, V. D., VESELOVSKY, M. Y., & ALEKSAKHINA, V. G. (2014). *The national innovation system: The conditions of its making and factors in its development*. Life Science Journal, 11(6), 535-538 pp.

LYNCH, D.C. (2015). *China's Futures: PRC Elites Debate Economics, Politics and Foreign Policy*. Stanford, Stanford University Press, 101 p.

MARAKOVA, V., DYR, T., WOLAK-TUZIMEK, A. (2016) *Factors of Tourism's Competitiveness in the European Union Countries*, In: Ekonomika a management, 2016 XIX, 3. 92-94 pp.

NELSEN, R. B. (1998). *Correlation, regression lines, and moments of inertia*. American Statistician Vol. 52 Issue 4, USA: Publisher Amer Statistical ASSOC, 1998, 343-345 pp.

PEI, M. (2006). *The Dark Side of China's Rise.* Received form http://www.carnegieendowment.org, [access 23/04/2018].

STEPP, M., POOL, S., SPENCER, J., LORIS, N. (2013). *Turning the Page: Reimagining the Nationals Labs in the 21st*. Received from http://www2.itif.org, [access 24/04/2018].

THE FEDERAL GOVERNMENT. (2014). *The new High-Tech Strategy Innovations for Germany*. Berlin 2014, 11-13 pp.

THE WORLD BANK. Retrieved from https://data.worldbank.org, [access 20/04/2018].

TIMES HIGHER EDUCATION. (2018). *World University Ranking 2018*, Received form https://www.timeshighereducation.com, [access 20/04/2018].

WOLAK-TUZIMEK, *Innovative Activities of Small and Medium Sized Enterprises in Poland.* In Loster, T., Pavelka, T. (Eds.), The 10th International Days of Statistics and Economics, 2056-2058 pp. Retrieved from http://msed.vse.cz/.

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