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SYNCHRONIZATION OF INNOVATIVE ACTIVITY IN THE EU UNDER THE FORMATION OF THE EUROPEAN INNOVATION SYSTEM

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Abstract

The present paper is empirical analysis of innovation synchronization dynamics in the European Union (EU). Three levels of innovation are under analysis: scientific research, research findings and their implementation in innovative products. Assessment of correlation indices of innovation activity in the EU countries with the corresponding aggregate indicators across the EU has been conducted. In addition, dynamics of the synchronization indexes of innovative activity has been studied at all three levels. Lack of synchronization level of innovative activity in the EU over 1988-2000 and 2001-2013 has been substantiated. Based on this a conclusion on the lack of establishment of the European innovation system as a systemic formation with a new level of integration of national innovation systems has been drawn.

Keywords. Innovative activity synchronization, European innovation system, synchronization index, synchronization of national innovative systems

INTRODUCTION

The EU has achieved a lot in terms of integration of individual countries' economies into a single economic and financial space (Giannetti et al., 2002). Despite some ongoing discussions on strengthening or weakening of integration activity in Europe in the 21st century (Ilzkovitz etc. all 2007), one can take for a fact that growing integration of financial markets, manufacturing, logistics systems, individual national markets of raw materials and products into single European Economic is fairly simple. However, in the late 20th century P.-B. Maurseth, and B.

Verspagen brought up a question that remains relevant today: is the degree of integration in the field of innovation in Europe as high as in trade, manufacturing, finance, etc.? (Maurseth and Verspagen, 1999).

The relevance of this issue is stipulated by the fact that the global economy of the 21st century is characterized by increasing global competition for innovative leadership within the "triad" and beyond. An important factor that can guarantee the innovative leadership of the EU is the formation of a common innovation space. This view is reflected in the development strategy of the EU, when the European Commission declared creation of the Innovation Union top strategic priority (EUROPE 2020 STRATEGY). This priority is focused on facilitating access to research and innovation financing in different EU countries and the formation of a single European Innovation Area or the European innovation system.

The concept of the European innovation system implies that a supranational innovative system must be formed in Europe, which is not simply the sum of individual national innovation systems, but will have a new level of integration and meet the requirements and challenges of the global innovative competition of the 21st century. However, this new level of integration of national innovation systems must feature high synchronization levels and innovative activity. Therefore, the study of changes in the synchronization of innovative activity in the EU helps evaluate the extent of the efforts, which the EU has undertaken for more than two decades, leading to the formation of the European innovation system.

The problem of the formation of the EU innovation system (as well as international innovation systems) is a relatively new trend in economics, as evidenced by a relatively small number of research papers on the subject. Presently, issues of forming supranational innovation systems and international cooperation in the area of innovations in the field have become especially relevant (Schüller and Frietsch / eds. 2010; Fischer 2001). Thus, S. Borras raises the question of the existence of the EU innovation system and justifies the need for its analysis (Borras 2004). The researcher argues that the formation of innovation system concerns all aspects of economic integration within the EU. However, in our view, equally (unless more) important role plays the EU innovation system in ensuring the innovative global leadership of the EU. Issues in this area are indicated by the dynamics of aggregate EU share in world exports of high technology products, which went down from 35.6% in 1999 to 32% in 2012 (calculated against High-technology exports (current US $) - data. WorldBank).

It should be emphasized that the formation of a single innovation system in Europe is also due to the region's specifics, which historically was noted for strong ties, especially in the scientific community. J. Stein argues that the European system of knowledge existed as a prototype of the innovation system, encompassing not only the EU but other countries in the

region (Stein 2004). In addition, the European continent has long played a major role not only in the research sector, but also in the technological development of the world economy (Mataradzija, Rovcanin and Mataradzija 2013). However, J. Stein, in confirmation to the existence of the European system of knowledge, produces two arguments: in his view, the European system of knowledge is integral to internal relations and operates as a unit as to the environment (Stein 2004). However, this author overlooks the problem of synchronization within the European system of knowledge, although it is its integrity that should predetermine its internal synchronization processes.

J. Stein includes the following to the European system: international research cooperation; international cooperation in technology development; international policies in the field of research and technology (Stein 2004). However, provided that the European system of knowledge (it can be viewed as a basis for the entire innovation system) is integral, all activities across all components should be synchronized. Yet, the interrelationship of all system's components is its key feature (Edquist 1997).

It should also be noted that studies have been done on supranational innovation systems within the EU (e.g., innovation systems of "core", "south", and "north" EU states, which are distinguished by (Antonelli and Gehringer 2013) and presence/absence of their convergence processes into a single innovation system (Maurseth and Verspagen 1999).

Thus, certain theoretical substantiations of the formation of the European national system exist, which, however, are not backed up by empirical results.

Therefore, the aim of the present paper is empirical analysis of the existence or successful formation of the European innovation system in the 21st century. In this case, we take into account the fact that along with the development of the EU as a truly unified innovation system an increase in the innovation activity synchronization must take place in the latter stages comparing to the preceding ones.

METHODOLOGY

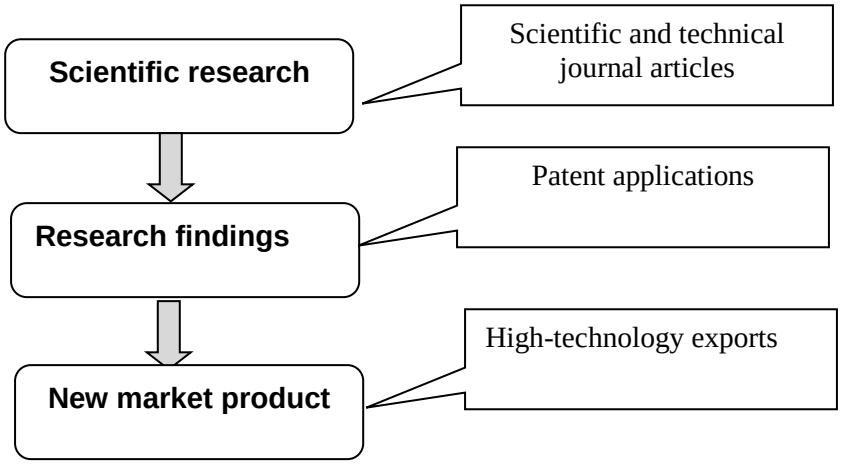
We used the World Bank database as a source of statistic information. Three indexes were selected as indicator for the study of innovation activity synchronization: High-technology exports (current US$) - http://data.worldbank.org/indicator/TX.VAL.TECH.CD; Patent application - http://data.worldbank.org/indicator/IP.PAT.RESD; Scientific and technical journal articles- http://data.worldbank.org/indicator/IP.JRN.ARTC.SC

The selection of the above indexes was based on the availability and accessibility of numerical data for a time frame as long as possible. Values of indexes are shown in the World Bank database. Time frames with the available data across the selected indexes are as follows:

High-technology exports (current US$) – 1988-2013; Patent applications, residents – 1963-2013; Scientific and technical journal articles – 1985-2011.

The three selected indexes, in our view, can adequately show different levels of innovation activity and account for its three main levels.

Figure 1. Relationship of chosen indices with the main levels of the innovation activity



Source: Compiled by Author

In reality, links across levels in innovation activity are much more complex than what is illustrated in Figure 1 and by no means unambiguous (Rosenberg 2004). Therefore, Figure 1 is not a pattern of an innovation system. Rather, it displays the connection between main levels of innovation activity with indicators which allow monitoring the dynamics of innovation activity at a certain level. In addition, data shown in Figure 1 is the basis of any innovation system, thus synchronization must be studied at least on three levels of innovation activity.

We used the abovementioned aggregate indices as basic for the comparison of synchronization level assessment. Separately, indices of individual countries were compared, which were defined as “synchronization” core by a certain index.

In a data set was missing, it was filled in as a mean average of two adjacent data. If there are two data gaps for two or more consecutive intervals, data interval with long missing data was excluded from the analysis.

By introducing the concept of “synchronization core” of a process, we believe that the dynamics of a particular aggregate index can be determined, above all, through the dynamics of the process in a small number of countries that make the largest contribution to the formation of aggregate index if their share differs significantly (e.g. one level up) from those in other countries. To identify the group of countries referred to as the “core”, the proportion of countries

with the largest share for each index in the EU was used. In this study, we used the cumulative proportion of countries with the largest share in the total figure for the 70% core identification.

In the study, we distinguish the Eurozone countries (included were countries that joined the EU after 2004) and the "old EU states". The distinction between the two groups is due to the fact that the "old EU states" form the innovative basis of the EU, since the synchronization of innovation activity within this very group is important in terms of establishing a pan-European innovation system. A logical conclusion can be easily reached that the synchronization of the national systems of the new EU members will increase after their EU inclusion. However, this increase will be due not so much to the formation of a Pan-national innovative system as to their closer integration to the all-European, including innovation and research units.

The following correlation indices were assessed as synchronization markers:

$$R_i^{ex} = corr\left(c_i^{ex}, c_{UE}^{ex}\right), \quad i = 1,...28 \tag{1}$$

$$R_i^{pat} = corr\left(c_i^{pat}, c_{UE}^{pat}\right), \; i = 1,...28 \tag{2}$$

$$R_i^{article} = corr\left(c_i^{article}, c_{UE}^{article}\right), \; i = 1,...28 \tag{3}$$

where c_i^{ex}, c_i^{pat}, $c_i^{article}$ stand for time intervals of high tech exports, number of patents applied and research papers published by each country i, c_{UE}^{ex}, c_{UE}^{pat}, $c_{UE}^{article}$ are the relevant time intervals for the EU.

De-trending and finding cyclical component were performed in accordance with the general methodology of economic activity synchronization (Afonso and Sequeira, 2010) using HP-filter with the smoothing parameter $\lambda = 100$.

To investigate the dynamics of the general synchronization level, the mean correlation ratio for groups of countries over 1988-2000 and 2001-2013 (regarding Scientific and technical journal articles indicator – the latest available data was for 2001-2011) was employed.

Given the fair criticism as to the correct implementation of HP-filter de-trending in the synchronization of certain processes (Canova) Business Cycle Synchronization Index (BSCI) was used, which can be illustrated as follows (Kalemli-Ozcan Papaioannou and Perri 2010):

$$S_{i,EU,t} = -\left|\left(\ln\left(Y_{i,t}\right) - \ln\left(Y_{i,t-1}\right)\right) - \left(\ln\left(Y_{EU,t}\right) - \ln\left(Y_{EU,t-1}\right)\right)\right| \tag{4}$$

where $S_{i,\mathrm{EU},t}$ is synchronization index of certain indicators-indexes across countries and the cumulative index across the EU over the time sequence t;

$Y_{i,t}$, $Y_{i,t-1}$, $\ln Y_{EU,t}$, $Y_{EU,t-1}$ are values of macro indexes of a country i and a cumulative index across the EU over the time sequences t and $t-1$, respectively.

BSCI is easy to understand (Giannone, Lenza, and Reichlin 2010). The closer its value to zero, the higher the synchronization level. The higher the modular $S_{i,\mathrm{EU},t}$ value, the lower the synchronization dynamics of the processes that are determined against Y indicators between countries i and j. Indicator (4) is also insensitive to various smoothing techniques (Canova 1998; Canova 1999). BSCI was calculated for all countries. Further, its mean value $\overline{S_t}$ was determined:

$$\overline{S_t} = \sum_i \frac{S_{i,EU,t}}{n} \quad (5)$$

where n is number of countries for which the mean value is calculated.

Synchronization dynamics for all three indicators over 1988-2013 was determined according to $\overline{S_t}$ calculations (Scientific and technical journal articles 2001-2011).

ANALYSIS AND RESULTS

Before actually doing the analysis on innovation activity synchronization, first, let us distinguish groups of countries that constitute the "synchronization core" for each of the three indicators.

Table 1. "Synchronization core" countries for innovation indicators

	1988-2000		2001-2013	
№	Countries	Share in EU, %	Countries	Share in EU, %
High-tech exports				
1	GERMANY	22.64	GERMANY	27.15
2	FRANCE	15.50	FRANCE	15.15
3	UNITED_KINGDOM	19.04	UNITED_KINGDOM	12.7
4	NETHERLANDS	9.14	NETHERLANDS	10.82
5	ITALY	5.99	SWITZERLAND	6.46
	Total TOP-5 country	72.32	Total TOP-5 country	72.27
Patent application				
1	GERMANY	39.14	GERMANY	44.76
2	UNITED_KINGDOM	19.81	UNITED_KINGDOM	16.41
3	FRANCE	13.11	FRANCE	13.33
	Total TOP-3 country	72.07	Total TOP-3 country	74.51
Scientific and technical journal articles				
1	UNITED_KINGDOM	23.24	UNITED_KINGDOM	19.18
2	GERMANY	19.73	GERMANY	18.43
3	FRANCE	14.54	FRANCE	12.94
4	ITALY	8.81	ITALY	10.49
5	SPAIN	5.41	SPAIN	7.98
	Total TOP-5 country	71.73	Total TOP-5 country	69.02

Source: Compiled by the author according to (High-technology exports (current US$); Patent application; Scientific and technical journal articles - worldbank database)

As evidenced from Table 1, Germany, Britain and France constitute the synchronization core across all three indicators under study. As far as the “Patent application” indicator is concerned, the composition of the synchronization core is limited to the above countries. However, in the case of high tech exports and the number of scientific articles, these 3 countries account for cumulative share of under 70%. Therefore, the “Patent application” indicator had to include Netherlands and Italy in the “synchronization core” in 1988-2000 as well as Netherlands and Switzerland in 2001-2013, respectively, in order that the share of the “synchronization core” exceeded 70% of the cumulative value of the given indicator. Similarly, Italy and Spain were placed in the core within the “Scientific and technical journal articles” indicator for the same reason.

At the first stage, the correlation between the cyclical component of high-tech exports of individual EU states and the given indicator across the EU in 1988-2000, 2001-2013 and 1988-2013 will be explored (Table 2).

Table 2. Correlation ratio of high-technology exports of EU countries with EU

	Correlation with EU		
Countries	1988-2013	1988-2000	2001-2013
AUSTRIA	0,390	0,206	0,480**
BELGIUM	n/a	0,239	0,320*
BULGARIA	n/a	-0,041	0,274
CZECH_REPUBLIC	n/a	-0,154	0,577**
DENMARK	0,291	0,441	0,276
ESTONIA	0,473	0,291*	0,574**
FINLAND	0,536	0,400*	0,623**
FRANCE	0,547	0,413*	0,672***
GERMANY	0,749	0,529**	0,892***
GREECE	0,420	0,423*	0,449*
HUNGARY	0,355	0,255	0,419*
IRELAND	0,383	0,439*	0,336
ITALY	0,508	0,220	0,665***
LATVIA	-0,006	-0,213	0,038
LITHUANIA	0,138	-0,281	0,221
LUXEMBOURG	0,369	0,254	0,466
NETHERLANDS	0,603	0,314	0,753***
POLAND	-0,334	-0,621*	-0,357
PORTUGAL	0,426	0,296	0,508**
ROMANIA	0,053	0,480**	0,039
SLOVAK_REPUBLIC	0,161	-0,257	0,253
SLOVENIA	0,031	-0,275	0,198
SPAIN	0,259	0,070	0,337
SWEDEN	0,633	0,415*	0,803***

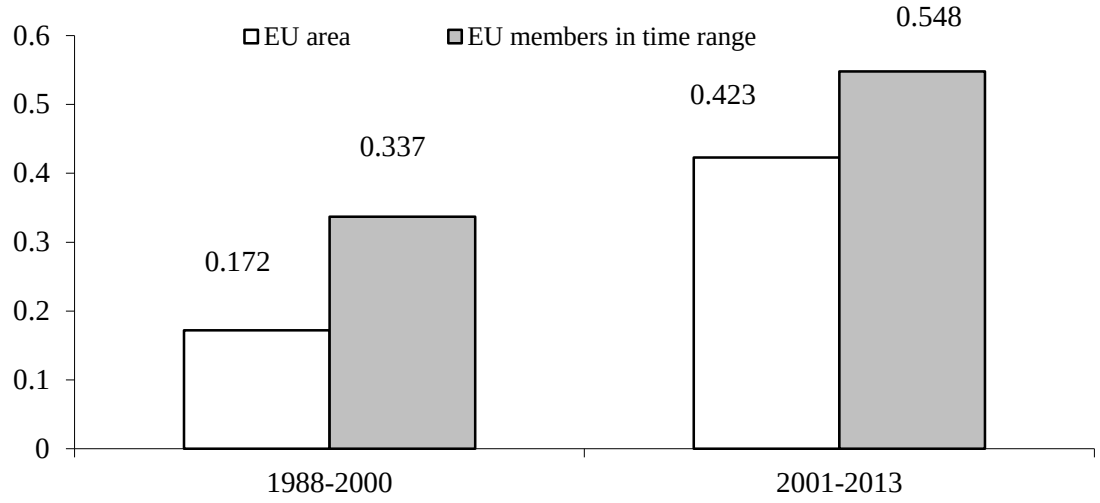
Table 2...

SWITZERLAND	0,289	0,138	0,367
UNITED_KINGDOM	0,681	0,500**	0,824***
Average (only EU ares countries)	0,346	0,172	0,423
Average (only EU -members)	0,472	0,337	0,548

Note: *** - significance at 0,001; ** - significance at 0,05; * - significance at 0,1.

The results indicate a difference in the mean value of the correlation index in the early period (1988-2000) the later one (2001-2013).

Figure 2. Mean value of the correlation between the cyclical component of high-tech exports of individual EU states and the given indicator across the EU in 1988-2000 and 2001-2013.



Source: Table 2

The identification of the two groups is due to the fact that a number of Eastern European countries were not part of the EU prior to 2002 (these countries are highlighted in the gray background in Table 2).

Looking at countries located in the EU (including prospective member states starting from 2002) at Fig. 2, it can be evidenced that the synchronization of innovative activity against mean correlation index of high tech exports with the respective indicator in the EU has generally increased. Preliminary testing showed that the distribution of correlation indexes for both series corresponds to a normal distribution at the level of significance at 0.05%. According to ANOVA-analysis (Table 3), differences between correlation values are significant at the 0.01 level of significance.

Table 3. Test for Equality of Means Between Series «high-technology exports»

Method	df	Value	Probability
EU ares			
t-test	50	-3.101091	0.0032
Satterthwaite-Welch t-test*	49.65402	-3.101091	0.0032
Anova F-test	(1, 50)	9.616763	0.0032
Welch F-test*	(1, 49.654)	9.616763	0.0032
“Old EU members”			
t-test	29	-3.395794	0.0020
Satterthwaite-Welch t-test*	26.44449	-3.438341	0.0020
Anova F-test	(1, 29)	11.53142	0.0020
Welch F-test*	(1, 26.4445)	11.82219	0.0020

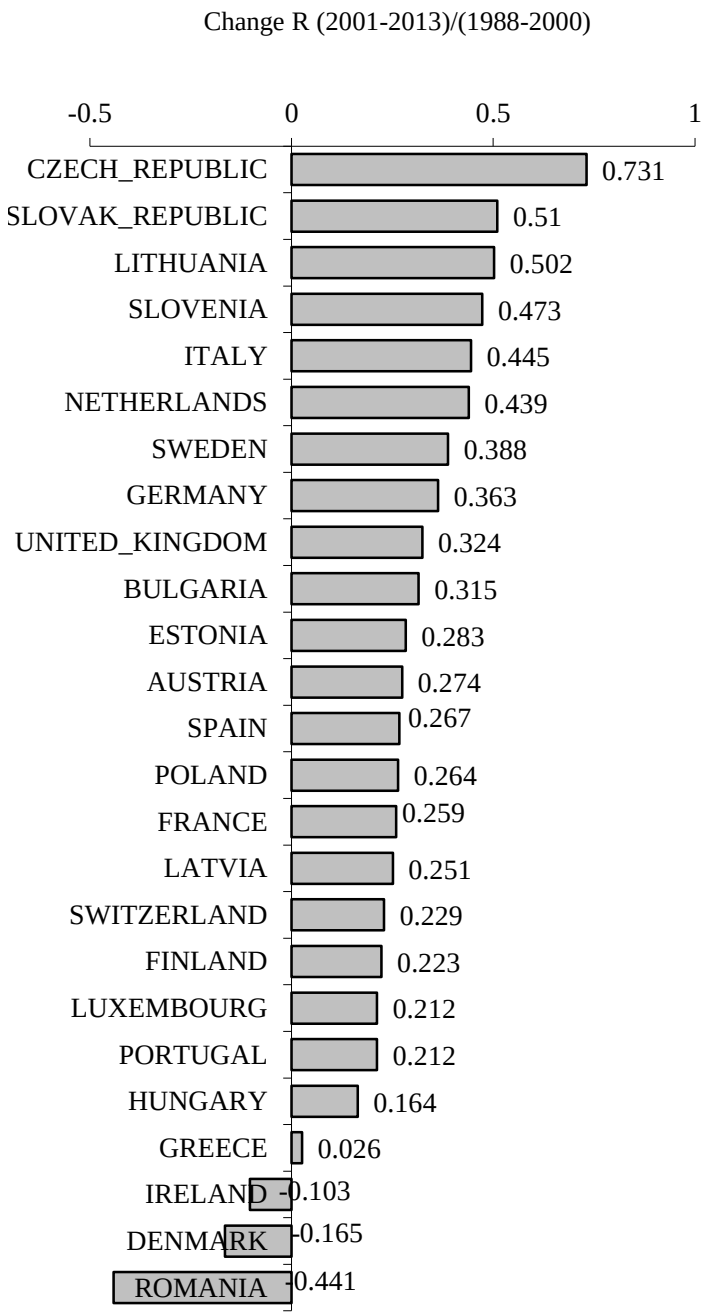
Thus, we can conclude that there was an increase in innovation cycles synchronization in the EU in 2001-2013 against high tech exports indicator.

The above result is somewhat expected given that EU enlargement in 2002 and the convergence of innovative systems of Eastern Europe "Western" model were supposed to boost the synchronization of innovative activity in the EU, at least toward “East-West” direction.

Indeed, if changes in the correlation ratio in terms of the EU and the two periods under study (1988-2000 and 2001-2013) are considered, the attention is drawn to the fact that the highest growth in synchronization dynamics of high tech goods is expectedly observed in a number of “new” EU member states, including the Czech Republic, Slovakia, Lithuania and Slovenia.

However, it should be noted that the increase in the correlation ratio of high-tech exports with the respective indicator in the EU is also observed for a number of “old” EU member states, including Italy, the Netherlands, Sweden, Germany, and the UK. The other countries of this group also saw an increase in high tech exports synchronization, which can be referred to as “moderate”. On the other hand, a group of countries exists where synchronization of innovative activity with the EU (high-tech exports) remained unchanged in the 20th century compared to the 1990s (Greece) or even went down (Ireland, Denmark).

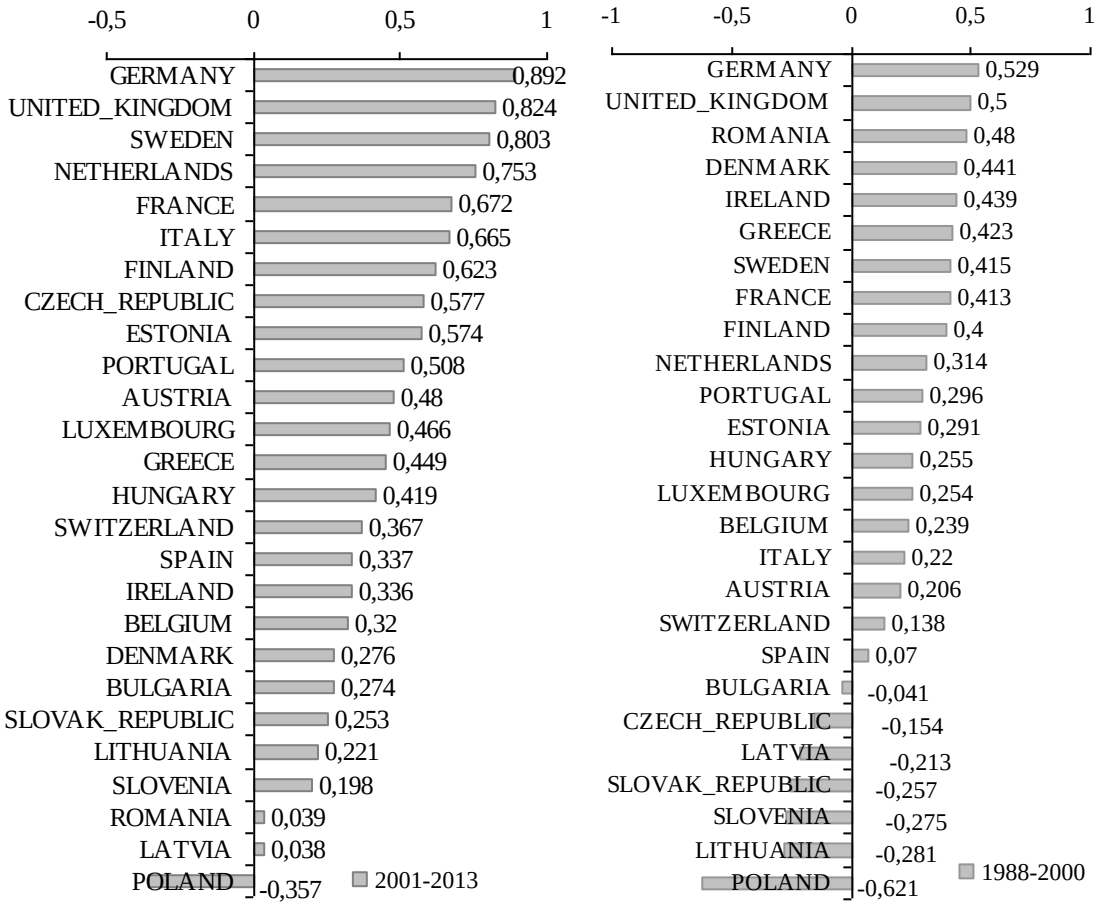
Figure 3. List of EU countries by growth of correlation ratio of high tech exports with the respective indicator in the EU in 2001-2013 and 1988-2000.



Source: Developed according to Table 2

In 2001-2013, most synchronized with the European high-tech products were the innovative systems in Germany, the UK, Sweden, the Netherlands, France and Italy (Fig. 4). The first three countries on the above list were leaders in high tech exports in 1988-2000, followed by France and the Netherlands.

Figure 4. Correlation ratio of EU countries for “High-tech exports” index



Let us analyze transformations within the “synchronization core”. The correlation matrix for two periods is shown in Table 4. Correlation matrixes in the table are shown for four of the five countries in order to compare changes in reciprocal correlations indexes by countries.

The results shown in Table 4 indicate dual trends in reciprocal correlation of the core countries according to “High-tech exports” innovation indicator. Germany is a country with the most significant changes. In 1988-2000, it somewhat “dropped out” of the core, as the dynamics of high tech exports of the country as well as the correlation of the national innovation system with other national systems of innovation “synchronization core” was missing for “High-tech exports” indicator. However, the period 2001-2013 is marked by the correlation of the country’s national innovation system with other “synchronization core” countries at the level of significance of 0.05.

Table 4. Correlation matrixes for “synchronization core” countries according to “High-tech exports” index

1988-2000				
	FRANCE	GERMANY	UNITED_KINGDOM	NETHERLANDS
FRANCE	1.000			
GERMANY	0.162	1.000		
UNITED_KINGDOM	0.624*	0.214	1.000	
NETHERLANDS	0.531**	0.020	0.876*	1.000
2001-2013				
	FRANCE	GERMANY	UNITED_KINGDOM	NETHERLANDS
FRANCE	1.000			
GERMANY	0.603*	1.000		
UNITED_KINGDOM	0.483**	0.562*	1.000	
NETHERLANDS	0.454	0.900*	0.399	1.000

* - significance at 0,05; ** - significance at 0,1.

The opposite trend is observed in the Netherlands. In 1988-2000, this country’s innovation system correlated with the national innovations systems of the UK (0.05 level of significance) and France (0.1 level of significance) according to “High-tech exports” indicator. The results for the 2001-2013 period are not sufficient to identify correlation with those countries. Instead, the national innovation system of the Netherlands demonstrates correlation with Germany within this period.

However, Germany’s share in total exports of high technology products in the EU (as in the “synchronization core” formation) significantly exceeds the Netherlands’ share. Thus, we can conclude that synchronization enhancement of national innovation systems in terms of “high-tech exports” indicator within the “core” is primarily due to Germany’s synchronization with Britain, France and the Netherlands.

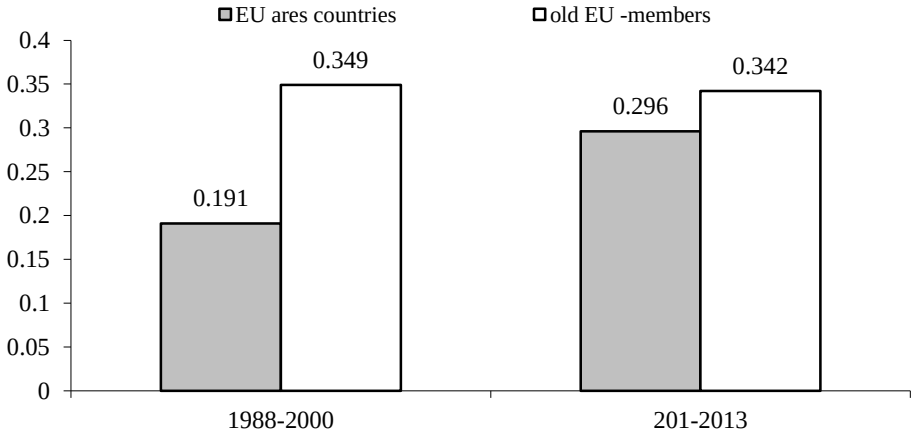
In general, synchronization enhancement of innovative activity outside the innovation “core” as well as synchronization enhancement within the “core” according to “High-technology exports” indicator should be emphasized.

Let us now study the correlation of the “Patent applications” indicator with the common indicator across the EU (Table 5). As with the “High-technology exports”, an increase in the average correlation with the corresponding index across the EU is seen.

Table 5. Correlation ratio of patent applications of EU countries with EU

	Correlation with EU		
Countries	1988-2000	2001-2013	Correlation ratio change (2001-2013)–(1988-2000)
AUSTRIA	0,366	-0,094	-0,459871
BELGIUM	-0,186	0,178	0,364286
BULGARIA	-0,590	-0,240	0,350139
CZECH_REPUBLIC	0,111	0,353	0,242482
DENMARK	0,660	0,214	-0,445731
ESTONIA	-0,392	0,517	0,908782
FINLAND	0,628	0,587	-0,040992
FRANCE	0,621	-0,010	-0,630581
GERMANY	0,809	0,409	-0,400151
GREECE	-0,394	0,527	0,920271
HUNGARY	0,098	-0,038	-0,136175
IRELAND	0,265	0,599	0,333349
ITALY	0,724	0,876	0,152626
LATVIA	-0,228	0,567	0,795239
LITHUANIA	0,029	0,247	0,217331
LUXEMBOURG	0,414	0,211	-0,203768
NETHERLANDS	0,382	0,301	-0,081483
POLAND	0,473	-0,017	-0,489534
PORTUGAL	-0,578	0,536	1,114404
ROMANIA	0,266	0,188	-0,078626
SLOVAK_REPUBLIC	0,083	0,394	0,311194
SLOVENIA	0,065	0,267	0,202304
SPAIN	0,088	0,465	0,37702
SWEDEN	0,705	0,515	-0,190048
SWITZERLAND	-0,171	0,155	0,326253
UNITED_KINGDOM	0,717	0,002	-0,714356
Means	0,191	0,296	-0,459871

Figure 5. Mean correlation ratio of the cyclical component of the “Patent applications” indicator of EU countries with the corresponding indicator across the EU in 1988-2000 and 2001-2013



However, a small increase in the average correlation ratio is observed only for the EU countries. For the "Old EU countries" group there is even a slight reduction in the average correlation ratio with the aggregate indicator across the EU in 2001-2013 and 1988-2000. Yet, changes in the average value of the correlation ratio, given the results of statistical parity tests in average periods of 1988-2000 and 2001-2013 (Table 6), cannot be considered statistically significant at the level of significance $\alpha = 0,05$ (likelihood that mean values of correlation ratios are not different in these periods is 28% for EU area countries and above 95% for Old EU countries).

Table 6. Testing results for Equality of Means Between Series "patent applications" for "1988-2000" and "2001-2013" times frames

EU area	Df	Value	Probability
t-test	50	-1.084255	0.2835
Satterthwaite-Welch t-test*	42.03781	-1.084255	0.2844
Anova F-test	(1, 50)	1.175609	0.2835
Welch F-test*	(1, 42.0378)	1.175609	0.2844
"Old" EU country			
t-test	29	0.055591	0.9560
Satterthwaite-Welch t-test*	22.95988	0.054757	0.9568
Anova F-test	(1, 29)	0.003090	0.9560
Welch F-test*	(1, 22.9599)	0.002998	0.9568

Thus, no changes occurred in terms of the synchronization of innovation activity in the EU countries in the 1988-2013 period under study.

Let us analyze changes in correlation and share of EU countries for the "Patent applications" indicator across aggregate index in the EU.

Table 7. Changes in the correlation ratio in two periods under study and in aggregate "Patent applications" index in the EU.

Countries	Correlation ratio change (2001-2013)–(1988-2000)	Share in EU patent applications, % (2013)
GERMANY	**-0,400**	**43,630**
UNITED_KINGDOM	**-0,714**	**13,795**
FRANCE	**-0,631**	**13,535**
ITALY	0,153	7,654
POLAND	-0,490	3,904
SPAIN	0,377	2,788
SWEDEN	-0,190	2,149
NETHERLANDS	-0,081	2,133
AUSTRIA	-0,460	1,992

Table 7…

FINLAND	-0,041	1,471
SWITZERLAND	0,326	1,405
DENMARK	-0,446	1,236
ROMANIA	-0,079	0,915
CZECH_REPUBLIC	0,242	0,907
BELGIUM	0,364	0,659
GREECE	0,920	0,643
PORTUGAL	1,114	0,596
HUNGARY	-0,136	0,592
IRELAND	0,333	0,307
BULGARIA	0,350	0,260
LATVIA	0,795	0,207
SLOVAK_REPUBLIC	0,311	0,170
LITHUANIA	0,217	0,108
LUXEMBOURG	-0,204	0,104
ESTONIA	0,909	0,023
SLOVENIA	0,202	n/a

Three countries from the synchronization core (Germany, France and Britain) had a significant decrease in the value of correlation with the corresponding aggregate figure for the EU in 2013-2001 as compared to 1988-2000. The exception is Italy, for which the trend is reverse. Analyzing the data in Table 7, one fact cannot be ignored that a significant increase in the correlation ratio for this indicator is observed for countries whose aggregate share in the pan-European index is very small. In particular, the highest correlation growth is experienced in Portugal (+1.12) - the proportion of patents application in the EU -0.60%, Greece (+0.92) - 0.64%, Estonia (+0.91) - 0.02%, Latvia (+0.80) with the proportion of 0.20%. Therefore, in case of patents application in the decline in synchronization is observed in Eurozone in the 20th century, especially in the countries forming synchronization core (Germany, UK, and France).

Table 8. Correlation matrix of “synchronization core” countries in the Eurozone according to patent applications in the two periods under study

1988-2000	FRANCE	GERMANY	UNITED KINGDOM
FRANCE	1,000		
GERMANY	0,938*	1,000	
UNITED KINGDOM	0,557*	0,403	1,000
2001-2013	FRANCE	GERMANY	UNITED KINGDOM
FRANCE	1,000		
GERMANY	-0,395	1,000	
UNITED KINGDOM	-0,870*	0,591*	1,000

* - significance at 0,05; ** - significance at 0,1

The data shown Table 8 indicate the presence of a substantial imbalance in patent applications dynamics in France against the main “synchronization core” country - Germany in 2001-2013 as opposed to 1988-2000. Instead, dynamics correlation of patent applications between Germany and Britain increased.

In general, conclusion can be made that the overall level of synchronization within the Äcore” remained unchanged against “Patent applications” indicator in 2001-2013 compared with 1988-2013. The two opposing trends - France-Germany synchronization imbalances are offset by synchronization growth in Germany-UK.

Generally, unlike high-tech exports, a substantiated conclusion cannot be made as to the growth of innovation synchronization within the EU against “Patent applications” indicator.

The growth of the mean ratio of correlation dynamics of patent applications across the EU with the corresponding index generally occurs due to the synchronization growth of a number of countries, whose share in the aggregate number of patents applied is insignificant. These include both the “old” EU member states - Portugal, Greece, Spain, Ireland, Belgium, Switzerland, and the “new” ones - Estonia, Latvia, Bulgaria, and the Czech Republic. However, growth in the average correlation ratio of patent applications in countries with the aggregate index for the EU in 2001-2013 is not statistically significant as to the 1988-2000 period.

Let us explore the third chosen index for the synchronization of innovation activity in the Eurozone - scientific and technical journal articles. Values of the correlation ratio for individual countries and the EU as a whole are shown in Table 9.

Table 9. Correlation ratio of “Scientific and technical journal articles” indicator of EU countries with EU

	Correlation with EU		
Countries	1988-2000	2001-2013	Correlation ratio change (2001-2013)–(1988-2000)
AUSTRIA	0.470	-0.517	-0.986
BELGIUM	0.563	0.416	-0.146
BULGARIA	-0.252	0.573	0.825
CZECH_REPUBLIC	-0.461	0.679	1.140
DENMARK	0.730	-0.153	-0.882
ESTONIA	0.210	0.637	0.427
FINLAND	0.763	0.301	-0.463
FRANCE	0.937	0.546	-0.391
GERMANY	0.736	0.596	-0.140
GREECE	-0.150	0.723	0.872
HUNGARY	-0.010	0.340	0.350
IRELAND	0.436	0.650	0.214
ITALY	0.597	0.561	-0.037

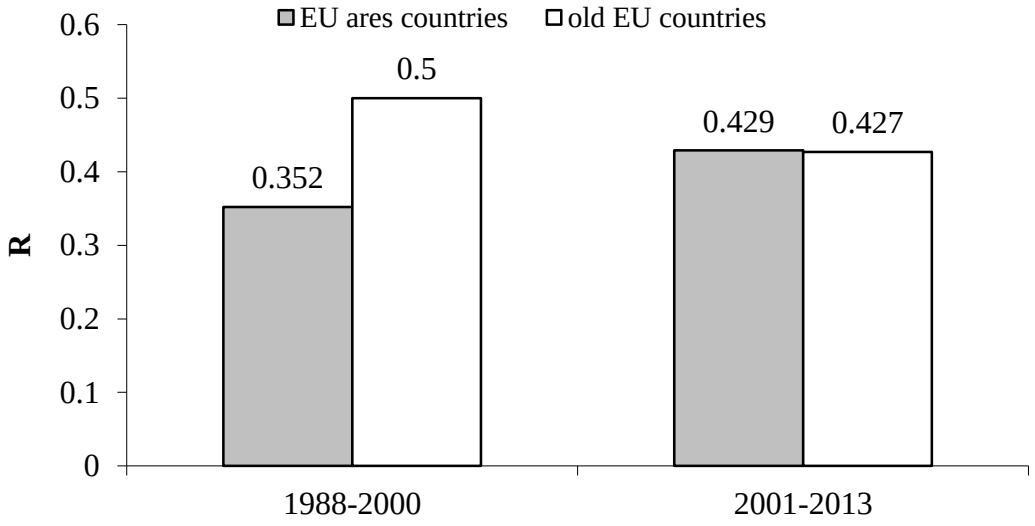
Table 9…

LATVIA	0.133	-0.087	-0.220
LITHUANIA	0.079	0.713	0.635
LUXEMBOURG	0.239	-0.220	-0.459
NETHERLANDS	0.533	0.494	-0.039
POLAND	-0.095	0.248	0.343
PORTUGAL	-0.567	0.437	1.004
ROMANIA	0.802	0.183	-0.619
SLOVAK_REPUBLIC	0.585	0.405	-0.180
SLOVENIA	0.099	0.621	0.522
SPAIN	0.652	0.883	0.231
SWEDEN	0.673	0.514	-0.159
SWITZERLAND	0.682	0.732	0.050
UNITED_KINGDOM	0.776	0.875	0.099
Average (only EU area countries)	0.352	0.429	0.077
Average (only EU -members)	0.500	0.427	-0.073

Note: *** - significance at 0,001; ** - significance at 0,05; * - significance at 0,1

According to the estimations, average correlation ratio changes have not been recorded in the EU.

Figure 6. Mean correlation ratio of the cyclical component of the “Scientific and technical journal articles” indicator of EU countries with the corresponding indicator across the EU in 1988-2000 and 2001-2013.



Source: Elaborated by the author according to Table 9

As evidenced from Fig. 6, the average correlation ratio for “EU area” countries has somewhat increased. Meanwhile, it plunged in the “Old EU countries”.

The results of parity tests in the two periods (Table 10) indicate no difference in average values of correlation dynamics of the index under study in the European countries with the aggregate EU index. Similar results were obtained for the “Old EU countries” group.

Table 10. Testing results for Equality of Means Between Series «Scientific and technical journal articles» for “1988-2000” and “2001-2013” times frames

EU area	df	Value	Probability
t-test	50	-0.68014	0.4992
Satterthwaite-Welch t-test*	48.54946	-0.68014	0.4993
Anova F-test	(1, 50)	0.462595	0.4992
Welch F-test*	(1, 48.5495)	0.462595	0.4993
"Old" EU country			
t-test	29	0.514	0.611
Satterthwaite-Welch t-test*	28.83667	0.514	0.611
Anova F-test	(1, 29)	0.264	0.611
Welch F-test*	(1, 28.8367)	0.264	0.611

Given the analysis of change in the correlation ratio of individual countries (Table 10), a significant drop should be emphasized in some countries - the old Member States: Austria (-0.986), Denmark (-0.882), Finland (-0.463), and France (-0.391). Meanwhile, a significant decrease in correlation is observed for the aggregate indicator in the EU, as well as for the new member states, including Romania (-0.619), Latvia (-0.220), and Slovakia (-0.180). However, the correlation ratio demonstrated a substantial growth in the Czech Republic, Hungary and Poland in 2001-2011 compared to the previous period. Such multi-vector dynamics of the correlation ratio indicates that the synchronization of the innovative activity in Europe saw no substantial growth in terms of scientific research. At present, the European research area is a set of individual national academic environments with relations between them weak to produce the synchronization of their dynamics.

To study the synchronization within the core according to this index let us analyze the corresponding correlation matrix (Table 11). The results in Table 11 indicate a synchronization reduction between “core” countries. In 1988-2000, the Germany-France pair was characterized by significant (p-value 0.05) stochastic bond, which was not observed in 2001-2011. A similar trend is observed for the France-UK pair. For this purpose, low statistical significance of correlational bonds in Germany-UK, Spain-France and France-Spain pairs needs to be determined. The dynamics of the Italian index under study is not synchronized with any corresponding index of the “core” countries.

Table 11. Correlation matrix of “synchronization core” countries in the Eurozone according to “Scientific and technical journal articles” indicator in the two periods under study.

	UNITED_KINGDOM	ITALY	SPAIN	FRANCE	GERMANY
1988-2000					
UNITED_KINGDOM	1.000				
ITALY	0.439	1.000			
SPAIN	0.428	0.454	1.000		
FRANCE	0.739*	0.420	0.740*	1.000	
GERMANY	0.359	0.222	0.296	0.700*	1.000
2001-2011					
UNITED_KINGDOM	1.000				
ITALY	0.386	1.000			
SPAIN	0.746*	0.420	1.000		
FRANCE	0.380	-0.066	0.531**	1.000	
GERMANY	0.569**	-0.229	0.528**	0.516	1.000

*- significance at 0,05; ** - significance at 0,1

Let us summarize the research on synchronization dynamics of innovative activity in Europe through three indexes correlation: hi-tech exports, patent applications and scientific and technical journal articles.

1. Synchronization growth of innovation activity in the EU was observed for only one indicator, i.e. “high tech exports”. “Patent applications” and “Scientific and technical journal articles” indicate no such synchronization.

2. The above conclusion is valid not only for the EU area countries, but for the “Old UE members”.

3. The positive dynamics in “High tech exports” synchronization is caused by synchronization growth of innovative activity within the “synchronization core” and outside countries. Dynamics imbalance of two other indicators is caused by zero correlation between individual synchronization core countries, since its presence is only formal in the case of “Patent applications” and “Scientific and technical journal articles” indicators.

Let us supplement the above analysis with the study of BSCI synchronization (calculated in accordance with (4)). The results are presented in the Tables 12-14.

Table 12. Synchronization index value for “high technology exports”

OBS	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AUSTRIA	-0.62	-0.20	-0.01	-0.49	-0.02	-0.09	-0.13	-0.05	-0.09	-0.01	-0.03	-0.04
BELGIUM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.05
BULGARIA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.10	-0.44	-0.27	-0.05
CZECH	n/a	n/a	n/a	n/a	n/a	-0.05	-0.50	-0.20	-0.02	-0.21	-0.13	-0.05
DENMARK	-0.45	-0.13	-0.09	-0.55	-0.06	-0.06	-0.10	-0.01	-0.05	-0.10	-0.03	-0.07
ESTONIA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.46	-0.24	-0.29	-0.04	-1.00
EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	-0.21	-0.08	-0.27	-0.71	-0.22	-0.24	-0.20	-0.05	-0.07	-0.12	-0.06	-0.11
FRANCE	-0.47	-0.08	-0.07	-0.51	-0.05	-0.04	-0.01	-0.07	-0.02	-0.04	-0.09	-0.05
GERMANY	-0.43	-0.04	-0.02	-0.47	-0.08	0.00	-0.04	-0.05	-0.05	-0.02	-0.03	0.00
GREECE	-0.44	-0.10	-0.11	-0.35	-0.40	-0.11	-0.39	-0.03	-0.13	-0.30	-0.04	-0.15
HUNGARY	n/a	n/a	n/a	n/a	-0.17	-0.06	-0.29	-0.20	-1.54	-0.29	-0.12	-0.18
IRELAND	-0.38	-0.06	-0.11	-0.52	-0.13	-0.08	-0.13	-0.13	-0.05	-0.08	-0.07	-0.01
ITALY	-0.43	-0.08	-0.01	-0.53	-0.01	-0.05	-0.07	0.00	-0.19	-0.01	-0.12	-0.04
LATVIA	-0.47	-0.14	-0.03	-0.50	-0.12	-0.03	-0.09	-0.15	-0.07	-0.19	-0.01	-0.10
LITHUANIA	n/a	n/a	n/a	n/a	n/a	n/a	-0.14	-0.09	-0.19	-0.47	-0.16	-0.06
LUXEMBOURG	n/a	n/a	n/a	n/a	n/a	n/a	-0.25	-0.18	-0.10	-0.26	-0.25	-0.35
NETHERLANDS	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.01
POLAND	-0.42	-0.08	-0.01	-0.58	-0.16	-0.07	-0.07	-0.05	-0.08	-0.10	-0.01	-0.01
PORTUGAL	n/a	n/a	n/a	n/a	0.00	-0.05	-0.14	-0.17	-0.17	-0.18	-0.24	-0.30
ROMANIA	-0.27	-0.02	-0.17	-0.53	-0.43	-0.31	-0.37	-0.26	-0.09	-0.08	-0.10	-0.13
SLOVAK REP.	n/a	-0.58	-1.13	-0.38	-0.12	-0.48	-0.18	-0.09	-0.06	-0.32	-0.57	-0.58
SLOVENIA	n/a	n/a	n/a	n/a	n/a	n/a	-0.28	-0.18	-0.33	-0.03	0.00	-0.12
SPAIN	n/a	n/a	n/a	n/a	-0.03	n/a	n/a	-0.17	-0.14	-0.04	-0.25	-0.08
SWEDEN	-0.42	-0.06	-0.16	-0.48	-0.09	-0.05	-0.17	-0.11	-0.16	-0.05	-0.05	-0.08
SWITZERLAND	-0.49	-0.03	-0.07	-0.46	-0.10	-0.05	-0.16	-0.12	-0.05	0.00	-0.10	-0.05
UK	-0.53	-0.04	-0.11	-0.53	-0.02	-0.04	-0.01	-0.04	-0.14	-0.01	-0.03	-0.13

OBS	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AUSTRIA	-0.06	-0.21	-0.09	-0.08	-0.21	-0.04	-0.14	0.00	-0.08	-0.02	-0.01	-0.05	-0.21
BELGIUM	-0.05	-0.06	-0.08	-0.03	-0.02	-0.12	-0.18	-0.07	-0.19	-0.05	-0.04	-0.07	n/a
BULGARIA	-0.15	-0.49	-0.32	-0.04	-0.19	-0.26	-0.35	-0.15	-0.08	-0.01	-0.11	-0.01	-0.22
CZECH_REPUBLIC	-0.34	-0.65	-0.05	-0.11	-0.04	-0.17	-0.31	-0.12	-0.05	-0.07	-0.17	-0.04	-0.03
DENMARK	-0.04	-0.19	-0.05	-0.03	-0.07	-0.10	-0.19	-0.03	-0.05	-0.38	-0.01	-0.03	-0.12
ESTONIA	-0.35	-0.44	-0.26	-0.06	-0.14	-0.18	-0.47	-0.05	-0.13	-0.56	-0.61	-0.19	-0.13
EUROPEAN_UNION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	-0.12	-0.01	-0.05	-0.16	-0.17	-0.12	-0.06	-0.02	-0.55	-0.27	-0.21	-0.16	-0.09
FRANCE	-0.04	-0.04	-0.02	-0.02	-0.03	-0.01	-0.09	-0.10	-0.04	-0.06	-0.07	-0.05	-0.13
GERMANY	-0.07	-0.04	-0.04	-0.07	-0.01	-0.02	-0.07	-0.02	-0.01	-0.01	-0.02	-0.02	-0.14
GREECE	-0.29	-0.22	-0.28	-0.10	-0.13	0.00	-0.12	-0.28	-0.05	-0.20	-0.05	-0.09	-0.11
HUNGARY	-0.01	-0.16	-0.18	-0.22	-0.13	-0.04	-0.33	-0.05	-0.03	-0.03	-0.03	-0.30	-0.06
IRELAND	-0.11	-0.09	-0.22	-0.08	-0.01	-0.17	-0.01	-0.07	-0.01	-0.27	-0.01	-0.03	-0.05
ITALY	-0.04	0.00	-0.08	-0.01	-0.06	-0.11	-0.15	-0.03	-0.01	-0.08	-0.04	-0.10	-0.16
LATVIA	-0.25	-0.03	-0.02	-0.01	-0.10	-0.10	-0.04	-0.04	-0.09	-0.12	-0.09	0.00	-0.08

LITHUANIA	-0.09	-0.15	-0.34	-0.33	-0.10	-0.29	-0.45	-0.14	-0.04	-0.03	-0.22	-0.21	-0.40
LUXEMBOURG	-0.28	0.00	-0.40	-0.01	-0.40	-0.33	-0.73	-0.15	-0.33	-0.14	-0.12	-0.08	-0.18
NETHERLANDS	-0.23	-0.19	-0.18	-0.11	-0.06	-0.06	-0.01	-0.28	-0.11	-0.10	-0.06	-0.23	n/a
POLAND	-0.13	-0.13	-0.30	-0.01	0.00	-0.08	-0.10	-0.20	-0.01	-0.03	0.00	-0.03	-0.16
PORTUGAL	-0.10	-0.05	-0.25	-0.23	-0.19	-0.07	-0.17	-0.50	-0.26	-0.09	-0.09	-0.13	-0.32
ROMANIA	-0.24	-0.01	-0.28	-0.02	-0.15	-0.02	-0.21	-0.04	-0.88	-0.09	-0.11	-0.14	-0.19
SLOVAK_REPUBLIC	-0.20	-0.28	-0.21	-0.05	-0.07	-0.24	-0.03	-0.76	-0.29	-0.24	-0.03	-0.53	-0.08
SLOVENIA	-0.14	-0.03	-0.52	-0.41	-0.32	-0.03	-0.27	-0.12	-0.01	-0.18	-0.11	-0.29	-0.29
SPAIN	-0.15	-0.14	-0.29	-0.06	-0.13	-0.12	-0.28	-0.18	-0.02	-0.19	-0.04	-0.01	-0.14
SWEDEN	-0.01	-0.01	-0.16	-0.05	-0.04	-0.17	-0.07	-0.04	-0.08	-0.03	-0.04	-0.02	-0.29
SWITZERLAND	-0.39	-0.13	0.00	-0.08	-0.09	-0.08	-0.07	-0.03	-0.04	-0.10	-0.01	-0.09	-0.11
UNITED_KINGDOM	-0.09	-0.14	-0.07	-0.03	-0.03	-0.04	-0.25	-0.13	-0.07	-0.05	-0.04	-0.02	-0.15

Table 12…

Table 13. Synchronization ratio values for “patent applications”

OBS	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AUSTRIA	0.00	-0.02	-0.03	-0.07	0.00	-0.11	-0.07	-0.02	-0.05	-0.01	-0.07	-0.08
BELGIUM	-0.12	0.00	-0.02	-0.01	-0.15	-0.10	-0.05	-0.06	-0.07	-0.17	-0.27	-0.07
BULGARIA	-2.40	-1.20	-0.76	-0.34	-0.20	-0.27	-0.21	-0.27	-0.27	-0.40	-0.08	-0.24
CZECH_REPUBLIC	n/a	n/a	n/a	n/a	n/a	-0.18	-0.12	-0.14	-0.01	-0.04	-0.16	-0.11
DENMARK	-0.01	-0.14	-0.13	-0.04	-0.07	-0.08	-0.04	-0.06	-0.05	-0.12	-0.04	0.00
ESTONIA	n/a	n/a	n/a	n/a	n/a	n/a	-0.07	-0.41	-0.27	-0.25	-0.54	-0.04
EUROPEAN_UNION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	-0.04	-0.11	-0.04	-0.12	-0.02	-0.05	-0.04	-0.06	-0.12	-0.01	-0.09	-0.01
FRANCE	-0.06	-0.04	-0.02	-0.09	-0.02	-0.03	-0.06	-0.08	-0.07	-0.04	-0.08	-0.02
GERMANY	-0.03	-0.04	-0.05	-0.04	0.00	-0.04	-0.11	-0.01	-0.10	-0.01	-0.04	-0.01
GREECE	-0.10	-0.17	-0.24	-0.08	-0.03	-0.17	-0.07	-0.12	-0.14	-0.10	-0.06	-0.01
HUNGARY	-0.15	-0.01	-0.11	-0.48	-0.30	0.00	-0.01	-0.43	-0.04	-0.10	-0.06	-0.06
IRELAND	-0.06	-0.06	-0.07	-0.13	-0.02	-0.01	-0.10	-0.18	-0.05	-0.18	-0.10	-0.12
ITALY	n/a	n/a	n/a	n/a	-0.04	-0.03	n/a	n/a	n/a	n/a	n/a	-0.18
LATVIA	n/a	n/a	n/a	n/a	-0.72	-0.13	-0.23	-0.19	-0.14	-0.15	-0.87	-0.03
LITHUANIA	n/a	n/a	n/a	-1.44	-1.10	-1.32	-0.01	-0.18	-0.27	-0.03	-0.55	-0.31
LUXEMBOURG	-0.11	-0.29	-0.24	n/a	n/a	-0.40	-0.29	-0.28	-0.03	-0.12	-0.72	-1.22
NETHERLANDS	-0.07	-0.03	-0.29	0.00	-0.04	-0.01	-0.26	-0.02	-0.06	-0.01	-0.07	-0.07
POLAND	-0.12	-0.19	-0.19	-0.25	-0.11	-0.01	-0.04	-0.19	-0.04	-0.03	-0.16	-0.01
PORTUGAL	-0.52	-0.22	-0.01	-0.48	-0.21	-0.14	-0.17	-0.06	-0.15	-0.27	-0.28	-0.04
ROMANIA	-0.10	-0.70	-0.31	-0.41	-0.06	-0.13	-0.17	-0.11	-0.02	-0.31	-0.31	-0.10
SLOVAK_REPUBLIC	n/a	n/a	n/a	n/a	n/a	-0.15	-0.15	-0.44	-0.18	-0.09	-0.11	-0.06
SLOVENIA	n/a	n/a	n/a	-2.10	-0.36	-0.02	-0.16	-0.21	-0.03	-0.04	-0.21	-0.12
SPAIN	-0.19	-0.12	-0.02	-0.13	-0.01	-0.03	-0.03	-0.01	-0.03	-0.02	-0.04	-0.06
SWEDEN	-0.02	-0.05	-0.02	-0.05	-0.10	-0.03	-0.07	-0.08	-0.05	-0.07	-0.07	-0.02
SWITZERLAND	-0.06	-0.02	-0.01	-0.05	-0.05	-0.01	-0.02	-0.26	-0.01	-0.21	-0.17	-0.04
UNITED_KINGDOM	-0.01	-0.04	0.00	-0.11	-0.04	-0.04	-0.08	-0.14	-0.03	-0.05	-0.02	-0.01

Table 13…

OBS	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AUSTRIA	-0.02	-0.09	-0.10	-0.06	-0.03	-0.01	-0.05	-0.05	0.00	-0.07	-0.11	-0.06	-0.04
BELGIUM	-0.09	-0.08	-0.14	-0.01	-0.03	-0.05	-0.17	-0.23	-0.17	-0.08	-0.03	-0.18	-0.05
BULGARIA	-0.30	-0.05	-0.03	-0.06	-0.01	-0.07	-0.24	-0.16	-0.01	0.00	-0.08	-0.06	-0.14
CZECH_REPUBLIC	-0.12	-0.05	-0.18	-0.01	-0.04	-0.10	-0.02	-0.02	-0.12	-0.10	-0.10	-0.11	-0.13
DENMARK	-0.12	-0.06	-0.01	-0.06	-0.10	-0.09	0.00	-0.03	-0.06	-0.07	-0.03	-0.10	-0.04
ESTONIA	-0.43	-0.08	-0.04	-0.40	-0.14	-0.45	-0.11	-0.33	-0.22	-0.10	-0.30	-1.12	-0.23
EUROPEAN_UNION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	-0.02	-0.07	-0.08	-0.02	-0.07	0.00	-0.10	-0.01	-0.02	-0.04	-0.04	-0.04	-0.06
FRANCE	-0.07	-0.03	-0.01	-0.05	-0.03	-0.02	-0.08	-0.01	-0.02	-0.05	0.00	0.00	-0.01
GERMANY	-0.07	-0.02	-0.01	-0.01	-0.02	0.00	-0.10	-0.02	-0.01	-0.02	0.00	0.00	-0.02
GREECE	-0.33	-0.01	-0.05	-0.04	-0.22	-0.15	-0.02	-0.08	-0.12	-0.04	0.00	-0.13	-0.11
HUNGARY	-0.23	-0.06	-0.10	-0.01	-0.04	-0.02	-0.14	-0.02	-0.12	-0.15	-0.03	-0.05	-0.07
IRELAND	-0.20	-0.08	-0.05	-0.09	-0.02	-0.07	-0.08	-0.08	-0.01	-0.21	-0.39	-0.01	-0.39
ITALY	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.08	-0.04	-0.01	0.00	-0.03	-0.01
LATVIA	-0.28	-0.28	-0.49	-0.17	-0.06	-0.02	-0.10	-0.38	-0.17	-0.30	-0.02	-0.12	-0.16
LITHUANIA	-0.13	-0.25	-0.27	-0.09	-0.01	-0.04	-0.14	-0.33	-0.06	-0.17	-0.14	-0.17	-0.07
LUXEMBOURG	-0.41	-0.19	-0.93	-0.36	-0.06	-0.09	-0.65	-1.15	-0.24	-0.28	-0.08	-0.26	-0.04
NETHERLANDS	-0.05	-0.04	-0.08	-0.05	-0.03	-0.02	-0.14	-0.14	-0.08	-0.02	-0.03	-0.07	-0.02
POLAND	-0.01	-0.08	-0.01	-0.05	-0.14	-0.07	-0.01	-0.03	-0.17	-0.10	-0.20	-0.14	-0.04
PORTUGAL	-0.38	-0.23	-0.03	-0.02	-0.27	-0.16	-0.21	-0.41	-0.42	-0.13	-0.14	-0.09	-0.04
ROMANIA	-0.22	-0.30	-0.51	-0.06	0.00	-0.11	-0.08	-0.17	-0.07	-0.27	-0.04	-0.32	-0.03
SLOVAK_REPUBLIC	-0.14	-0.08	-0.20	-0.02	-0.31	-0.23	-0.12	-0.37	-0.07	-0.28	-0.04	-0.28	-0.09
SLOVENIA	-0.08	-0.03	-0.04	-0.10	-0.03	-0.18	-0.05	-0.11	-0.23	-0.17	-0.07	n/a	n/a
SPAIN	-0.03	-0.12	-0.03	-0.02	-0.08	-0.03	-0.05	-0.10	0.00	-0.01	-0.03	-0.04	-0.07
SWEDEN	-0.03	-0.13	-0.09	-0.09	-0.07	-0.02	-0.06	0.00	-0.14	0.00	-0.09	-0.14	-0.02
SWITZERLAND	-0.01	-0.01	-0.01	-0.05	-0.04	-0.06	-0.12	-0.07	-0.07	-0.04	-0.01	-0.07	-0.03
UNITED_KINGDOM	-0.07	-0.01	0.00	-0.06	-0.05	-0.01	-0.10	-0.06	-0.02	-0.03	0.00	-0.01	-0.02

Table 14. Synchronization ratio values for “patent applications”

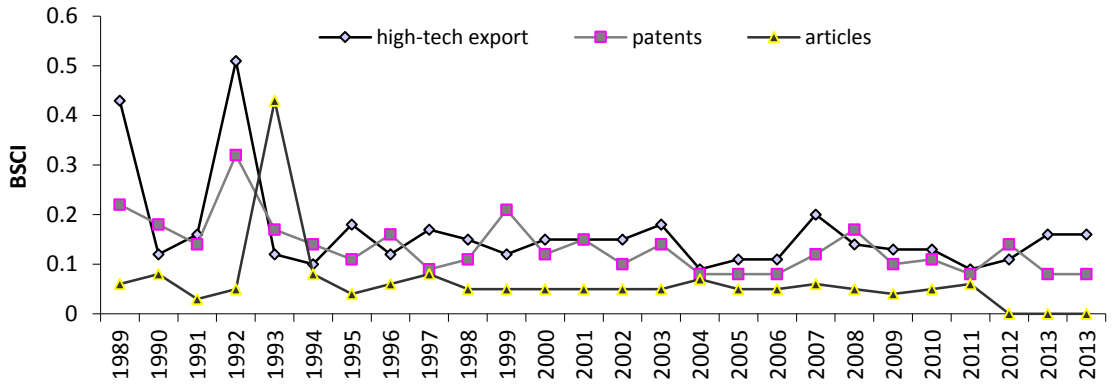
Countries	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
AUSTRIA	-0.10	-0.02	0.00	-0.02	-0.01	-0.03	-0.05	-0.02	-0.06	0.00	-0.01
BELGIUM	-0.01	-0.03	-0.01	-0.02	-0.01	-0.02	-0.02	-0.03	-0.03	0.00	-0.01
BULGARIA	-0.04	-0.02	-0.06	-0.04	-0.12	-0.37	-0.09	-0.05	-0.01	-0.09	-0.08
CZECH_REPUBLIC	n/a	n/a	n/a	n/a	n/a	-0.49	-0.13	-0.07	-0.03	-0.05	-0.03
DENMARK	0.00	-0.02	-0.01	-0.01	-0.03	-0.02	-0.05	-0.03	-0.03	0.00	0.00
ESTONIA	n/a	n/a	n/a	n/a	n/a	n/a	-0.04	-0.19	-0.19	-0.25	-0.10
EUROPEAN_UNION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	-0.01	-0.01	-0.02	-0.02	-0.04	-0.03	0.00	-0.02	0.00	-0.01	-0.03
FRANCE	-0.02	-0.01	0.00	-0.02	-0.01	0.00	0.00	-0.01	0.00	-0.01	-0.01
GERMANY	-0.01	-0.01	0.00	-0.02	-0.04	-0.01	0.00	0.00	-0.03	-0.01	-0.01
GREECE	-0.13	-0.10	-0.11	0.00	0.00	-0.04	-0.02	-0.05	-0.06	-0.04	-0.01
HUNGARY	0.00	-0.09	-0.03	-0.07	-0.07	-0.04	-0.03	-0.01	-0.07	-0.07	-0.01
IRELAND	-0.03	-0.07	-0.01	-0.05	-0.05	-0.08	-0.02	-0.01	-0.04	-0.11	-0.05
ITALY	n/a	n/a	n/a	n/a	-0.02	-0.04	n/a	n/a	n/a	n/a	n/a
LATVIA	n/a	n/a	n/a	n/a	-1.57	-0.20	0.00	-0.17	-0.08	-0.01	-0.09
LITHUANIA	n/a	n/a	n/a	n/a	-3.39	-0.17	-0.08	-0.01	-0.11	-0.15	-0.05

LUXEMBOURG	-0.37	-0.41	-0.15	n/a	n/a	-0.10	-0.04	-0.48	-0.61	-0.07	-0.12
NETHERLANDS	-0.05	-0.02	-0.03	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	-0.04
POLAND	-0.03	-0.08	-0.04	-0.04	-0.08	-0.02	-0.10	-0.05	-0.01	-0.02	-0.05
PORTUGAL	-0.10	-0.12	-0.06	-0.02	-0.10	-0.07	-0.06	-0.06	-0.11	-0.09	-0.18
ROMANIA	-0.19	-0.33	-0.02	-0.28	-0.12	-0.21	-0.02	-0.15	-0.08	-0.11	-0.07
SLOVAK_REPUBLIC	n/a	n/a	n/a	n/a	n/a	n/a	-0.09	-0.01	-0.09	-0.04	-0.16
SLOVENIA	n/a	n/a	n/a	n/a	-3.69	-0.06	-0.08	-0.05	-0.21	0.00	-0.12
SPAIN	-0.04	-0.09	-0.04	-0.16	-0.04	0.00	-0.05	-0.06	-0.02	-0.02	-0.04
SWEDEN	-0.01	-0.02	-0.03	-0.07	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01
SWITZERLAND	-0.03	-0.04	-0.01	0.00	-0.02	0.00	-0.04	-0.01	-0.01	-0.01	-0.01
UNITED_KINGDOM	-0.03	0.00	0.00	-0.02	-0.01	0.00	-0.02	-0.02	-0.03	-0.02	0.00

OBS	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AUSTRIA	0.00	-0.06	-0.01	-0.04	-0.02	-0.05	-0.02	-0.03	-0.02	-0.01	-0.01	-0.02
BELGIUM	-0.02	-0.03	-0.03	-0.03	-0.02	-0.01	-0.05	-0.04	-0.01	-0.01	-0.02	-0.01
BULGARIA	-0.02	-0.19	-0.08	-0.06	-0.02	-0.07	-0.03	-0.03	-0.07	-0.03	-0.09	-0.06
CZECH_REPUBLIC	-0.03	-0.04	-0.06	-0.01	-0.09	-0.02	-0.08	-0.02	-0.05	-0.01	-0.05	-0.03
DENMARK	0.00	-0.02	-0.04	-0.04	-0.02	-0.01	-0.02	-0.01	0.00	-0.01	-0.06	-0.06
ESTONIA	-0.06	-0.07	-0.08	-0.08	-0.07	-0.10	-0.01	-0.08	-0.07	-0.09	-0.01	-0.04
EUROPEAN_UNION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FINLAND	0.00	-0.03	-0.01	-0.02	0.00	-0.06	-0.02	-0.03	-0.01	-0.03	-0.02	-0.02
FRANCE	-0.02	-0.02	-0.01	-0.02	-0.04	-0.01	0.00	-0.03	-0.02	0.00	-0.02	-0.01
GERMANY	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	0.00	0.00
GREECE	-0.10	-0.08	-0.07	-0.03	-0.07	-0.07	-0.09	-0.01	-0.02	-0.01	-0.06	-0.04
HUNGARY	-0.04	-0.03	-0.04	-0.04	-0.04	-0.06	-0.04	-0.07	-0.02	-0.06	-0.08	-0.01
IRELAND	-0.06	-0.01	-0.02	-0.02	-0.12	-0.07	-0.05	-0.07	-0.05	-0.06	-0.08	-0.02
ITALY	-0.03	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.01	0.00	-0.02	-0.01
LATVIA	-0.21	-0.11	-0.05	-0.29	-0.15	-0.18	-0.14	-0.19	-0.07	-0.01	-0.19	-0.40
LITHUANIA	-0.07	-0.09	-0.16	-0.10	-0.25	-0.02	-0.21	-0.13	-0.10	-0.28	-0.09	-0.23
LUXEMBOURG	-0.30	-0.14	-0.15	-0.04	-0.45	-0.07	-0.07	-0.11	-0.40	-0.21	-0.08	-0.29
NETHERLANDS	-0.01	-0.01	-0.02	0.00	-0.02	-0.03	-0.03	0.00	-0.01	-0.02	-0.04	-0.02
POLAND	-0.05	-0.03	-0.06	-0.07	-0.01	-0.01	-0.02	-0.03	-0.04	-0.02	-0.03	-0.04
PORTUGAL	-0.07	-0.11	-0.11	-0.02	-0.14	0.00	-0.19	-0.07	-0.10	-0.08	0.00	-0.08
ROMANIA	-0.03	-0.04	-0.03	-0.11	-0.04	-0.08	-0.10	-0.20	-0.09	-0.02	-0.12	-0.03
SLOVAK_REPUBLIC	-0.03	-0.05	-0.03	-0.08	-0.15	-0.17	-0.06	-0.05	-0.09	-0.08	-0.04	-0.03
SLOVENIA	-0.21	-0.04	-0.01	-0.10	-0.05	-0.09	-0.01	-0.18	0.00	-0.05	-0.08	-0.06
SPAIN	-0.01	-0.05	-0.04	-0.01	-0.03	-0.05	-0.03	-0.06	-0.01	-0.01	-0.02	-0.02
SWEDEN	-0.03	-0.02	-0.02	-0.03	-0.01	0.00	-0.02	-0.03	-0.04	-0.02	-0.01	-0.01
SWITZERLAND	-0.01	-0.06	-0.01	-0.02	-0.04	-0.01	-0.02	-0.02	0.00	-0.02	-0.01	-0.02
UNITED_KINGDOM	0.00	-0.05	-0.03	0.00	-0.02	-0.02	-0.01	0.00	-0.03	-0.01	0.00	-0.02

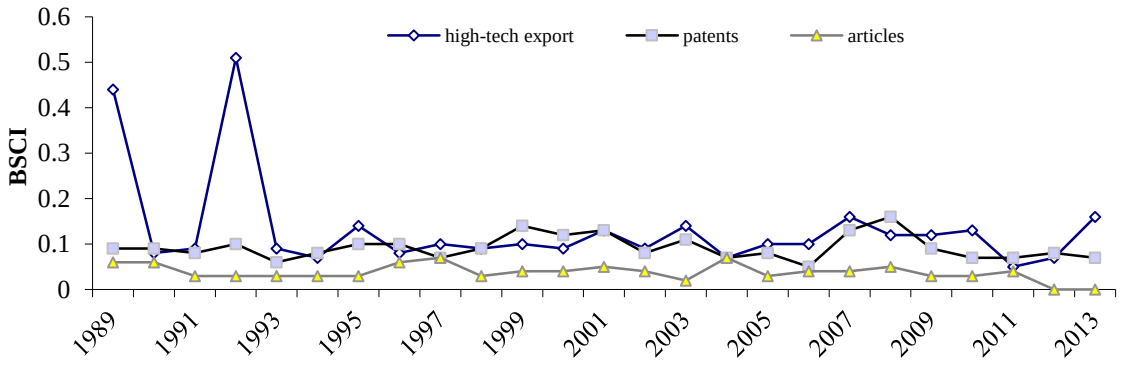
Figure 7 shows its dynamics for the EU area countries. The results illustrated can be interpreted as follows: BSCI index behavior shows no distinct trends towards growth or decline after the formal establishment of the EU (1994-).

Figure 7. Synchronization index dynamics of innovation activity in the “EU area” countries in 1989-2013



Part of the graph (before 1994) apparently shows that the establishment of the EU with its formal central authorities significantly boosted synchronization of innovative activity up to a certain level, which, however, failed to grow in the next two decades. Nevertheless, it is impossible to clearly prove the existing imbalances in the innovative activity in Europe because of the data absence for an 80-year period of the twentieth century.

Figure 8. Synchronization index dynamics for “Old EU countries” in 1989-2013



The data shown in Fig. 8 indicate that the synchronization dynamics index of “Old EU countries” has undergone no significant changes compared to the previous case. However, significant fluctuations of BSCI for “Patents applications” and “Scientific and technical journal articles” indicators prior to the EU establishment are missing. Thus, we can hypothetically suggest that the formal creation of the EU streamlined the innovation activity in Europe at the level of innovative products, but failed to influence much “deeper” levels of innovation activity: research

and their results. At these levels, certain synchronization had been historically formed in Europe long before the formation of the EU, whereas the establishment of common European institutions did not facilitate synchronization of innovative activity in European countries at these levels.

In order to identify differences in innovative activity synchronization in Europe, comparison of average values of the synchronization index for both countries in 1990-2001 and 2002-2013 according to Welch t test was carried out.

Table 15. Comparison of average values of indexes in 1990-2001 and 2002-2013

Indicators	Welch t-statistic value	Probability
EU area countries		
High-tech export	1.0941	0.2936
Patents applications	2.6262	0.0180
Scientific and technical journal articles	1.1151	0.2882
"Old EU countries"		
High-tech exports	0.6012	0.5582
Patents applications	-0.7518	0.4607
Scientific and technical journal articles	0.4747	0.6402

Source: calculated by the author according to Table 12-14

The data in Table 15 indicate that mean values do not differ in both periods for all three indicators on the significance level at 0.05 for the “Old EU members” group. As far as “EU area countries” are concerned, mean values of synchronization index for “High technology exports” and “Scientific and technical journal articles” indicators do not differ in both periods on the significance level at 0.05. However, differences between mean values of “Patents applications” indicator should be emphasized in 1990-2001 and 2002-2011. At the same time, this difference is obviously caused by addition of a large group of countries to the EU in the last period, in which patent law other than in the EU had been in operation.

In addition, differences in mean values of the correlation ratio between the two periods against the “High tech exports” indicator may be explained by local bursts of “imbalance” of innovative activity prior to the creation of the EU – in 1989 and 1992, respectively (see: Table 11, Figure 7).

In general, the results obtained from the synchronization dynamics indicators confirm absence of changes in the synchronization of the innovative activity. Thus, the impact of the EU strategy implementation towards the establishment of a single European innovation space remains low.

CONCLUSIONS

In the final analysis, based on the empirical study of the synchronization of innovative activity dynamics one can but cautiously admit a certain progress in the creation of the EU innovation space in the 2010s. Synchronization growth is observed within the “research - innovation - new innovative products” model. The results indicate certain progress in the integration of individual national innovation systems into the European innovation area only at the last level, which is directly related to the business part of the innovative activity. Therefore, synchronization growth of the innovative activity at this level may be due to the general trends of the business cycles synchronization in Europe and globally. The globalization of production and sales contributes to the synchronization growth in this sector.

In terms of “research” and “innovation results”, Europe remains a set of individual national innovation systems with weak connections between one another. Thus, the efforts by the European Commission and other EU bodies directed towards the formation of a pan-European innovation system or a single innovation space in the EU are insufficient. Low synchronization dynamics of “Patent applications” and “Scientific and technical journal articles” indicators with high synchronization of “High-tech exports” indicates two issues in the formation of a pan-European innovation system.

The first one is related to the fragmentation of research community in individual countries, as indicated by the lack of synchronization of their “Scientific and technical journal articles” results. Also, we must admit that no significant integration of the research community towards the East-West direction has taken place for more than a decade. Further studies need to identify the reasons for such disintegration of the research community.

Another issue is the gap in the “research - innovation - introduction of innovative products” chain. Otherwise we would observe the same synchronization dynamics at all stages of the chain.

Based on the solution of the two above issues the European policy must be directed at forming a single European space for innovation and European innovation system.

It should be noted some limitations of the given study which caused by the limitation of the volume of this paper. Only three indicators were investigated (Scientific and technical journal articles, Patent application, and High-technology exports). Of course, the small number of the indicators creates certain limitation and doesn’t give the possibility to investigate a synchronization of innovation activity at every stage more detailed. Those indicators may be investigated in future studies “Total researchers per thousand total employment”, “GERD per capita”, “GERD percentage of GDP”, High-technology exports at the products. Usage larger

number of indicators in future study gives the possibility to obtain new results and expand knowledge about innovation processes synchronization in EU.

In the article, synchronization of innovative processes investigated only within EU. It also imposes certain limitations on the results. There are other global centers of innovation activity, such as the US and Japan. Innovation processes in some EU countries can be synchronized with innovation processes in the US or Japan. But for confirmation this suggestion, the future studies are needed.

Another limitation is associated with the availability of data. The yearly data were used in this research because World Bank database contains only annual data. The quarterly data can be used in the future studies. It allows investigating a seasonal synchrony of innovation processes in EU and gives possibility receive more detailed results about synchronization of innovation processes in EU area.

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