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The Impact of FDI on Innovation and Networking Activity in Central and Eastern Europe - A Patent Analysis

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The Impact of FDI on Innovation and Networking Activity in Central and Eastern Europe

Preliminary Draft

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Abstract:

Since the fall of the Iron Curtain, the Central and Eastern European Countries (CEECs) experience a considerable increase in their foreign direct investment (FDI) inflows. As it is obvious that they made significant steps forward in attracting foreign capital over the last two decades, it is now interesting to make a statement about FDI-related technological diffusion effects. Moreover, apart from this, by means of Social Network Analysis (SNA), the role of the CEECs within the innovation network is examined. Both analyses are conducted for ten CEECs which are further divided into two groups; the first one (group 1) consists of Poland, Hungary, the Czech Republic, Slovakia, and Slovenia, and the second one (group 2) encompasses Bulgaria, Estonia, Latvia, Lithuania and Romania. The results of the first analysis show that FDI has a significant positive impact on innovation activities for both groups. However, the findings show that the role of knowledge and experts, represented by employees in R&D and expenditures on human resources, still play a more important role within group 1. Besides, the results of the SNA demonstrate that some CEECs are already involved in close network collaborations, partially bridging clusters, and hence, spreading information around the network; this finding accounts especially for Hungary and Poland of group 1, and Bulgaria and Romania of group 2.

Keywords: Innovation Activity, Foreign Direct Investment, Central and Eastern Europe, Patent Analysis, Social Network Analysis.

1 Introduction

Since the fall of the Iron Curtain, most countries in Central and Eastern Europe (CEE) have begun the transition from communist states to market economies. Simultaneously, a flood of literature has emerged addressing this issue and advising how to best achieve this transition. Many have stressed the importance of integrating this region into the global economy, emphasising that FDI could play a significant role in supporting these 'latecomers' in their development. So, it is not surprising that many countries in the region established agencies to attract transnational investors (see Bailey et al., 1999). Hence, the collapse of communism has led to a large inflow of FDI. In economic literature, it has widely been accepted that FDI advanced the transition of the CEECs to a market-based economy (see Dunning, 1993; Ozawa, 2000; Pavlinek, 2002). However, recent literature dealing with the role of FDI has increasingly highlighted the importance of technological aspects. In this context, the role of FDI-related technological diffusion effects is emphasised (see Damijan et al., 2001).

The aim of this paper is to firstly explore the impact of FDI on innovation activity and on networks of inventors in CEE. Moreover, apart from FDI-related technological diffusion effects, by means of SNA, the development of the Central and Eastern European networking activity is pointed out. In this context, it is examined how many linkages they possess within the innovation network, and to what extent they are needed as a link in the chains of contacts.

The data set used for this examination mainly consists of patent data provided by the EPO¹ Worldwide Patent Statistical Database Version October 2009 (PATSTAT) and of FDI inflows into this region. The analysis is carried out for a time period from 1990 until 2006, respectively 2007, and it is implemented for ten CEECs. The ten CEECs are further divided into two groups; the first one (group 1) consists of Poland, Hungary, the Czech Republic, Slovakia, and Slovenia, and the second one (group 2) encompasses Bulgaria, Estonia, Latvia, Lithuania and Romania. The classification has been conducted due to GDP growth rates from 1990 up to 2004, hence, group 1 stands for the so-called forerunners, and group 2 can be referred to as latecomers of CEE (see Cernat et al., 2002).

¹ European Patent Organisation

In order to achieve the objective drawn above, the paper is structured as follows. Section two deals with the theoretical background, illustrating the relevance of knowledge and technology advance regarding sustainable economic growth rates. Section three provides the methodology and the data of the analysis. Here, all instruments are introduced that give insight into the role of FDI on innovation and networking activity in CEE. Besides, SNA is illustrated. By means of SNA, the degree to which the CEECs are integrated into the international innovation network is presented. This section finishes with the data set used for the analyses. Section four is based upon the development of FDI inflows into CEE, as well as with the patenting and networking behaviour of this region. In this context, Germany, France and Great Britain are taken as benchmark in terms of FDI inflows into this region and their patenting behaviour. After elaborating upon these facts, section four presents the empirical results of the conducted analyses, while section five presents the conclusion of this paper.

2 Theoretical Background

It is not a new phenomenon that economists appreciated the importance of technological progress. Adam Smith (1776) already referred in his book 'An Inquiry into the Nature and Causes of the Wealth of Nations' to the advantages of technical advance through his famous description of productivity improvement in the making of pins. He explicitly suggested that by means of technical progress "each individual becomes more expert in his own peculiar branch, more work is done upon the whole, and the quantity of science is considerably increased by it" (Smith, 1776, p. 8). Later on, it was Schumpeter (1911) who pointed out that sustainable economic growth rates can be achieved through new technology and innovation. But, due to the limited mathematical capabilities applied on economies at this time, his work has not been displayed in a formalised way. Even though his work has not been considered for further developments of innovation theories for a long time, he has later on strongly influenced all further innovations theories. Solow (1956), for example, was able to approximate the relevance of technical advance for economic growth. He illustrated that the two factors, namely labour and capital, of the classical Cobb-Douglas production function do not fully explain economic growth in the USA. For him, a third factor, namely the input of

technology, was essential for sustainable economic growth. Later theorizing on economic growth highlights the importance of knowledge inflows as source of endogenous economic growth (see Grossman and Helpman, 1991 and Romer, 1990). Moreover, regarding Romer (1996), countries need to understand the importance of technical advance, building up a knowledge-based economy to retain stable economic growth rates. Thus, it has widely been accepted that the ability to create, access and use knowledge and technology is becoming a fundamental determinant of long-term development and competitiveness. This growing interest and the increasing economic significance of knowledge and technology are of particular relevance to the former centrally-planned economies of CEE. After the impact of four decades of socialism, the CEECs were mostly endowed with obsolete and backward technology. Besides, one of the major characteristics of these countries was the absolute priority given to military Research and Development (R&D) and to military production (see Piech and Radosevic, 2006). To foster economic growth and competition within these economies, knowledge and technology transfer as well as modernisation were vital, as they needed to transform their centrally-planned economies to market-oriented ones, simultaneously shifting away from their heavy-industry-oriented systems to knowledge-based ones (see Bailey et al., 1999). As almost all CEECs have successfully transformed their centrally-planned systems to market-oriented ones, it is now interesting to evaluate to what extent FDI helps to build up an own knowledge and technology base. Here, attention is especially given to quality patterns, i.e. not only the quantity of FDI is important, but the handling with it.

3 Methodology and Data of Analysis

In order to give insight into the assumption drawn above, we apply an econometric regression model to analyse several variables. First, it is assumed that there is coherence between the rise of patent filings (*PAT*) and the increase of FDI inflows (*FDI*). The second analysis is based upon the assumption that FDI inflows also affect networking activity (*NET*) of the CEECs. Besides our independent variable *FDI*, four additional independent variables are taken to test coherence. They are as follows:

1. Research and development (R&D) expenditure (*expRnD*)
2. Expenditure on human resources (*expHumanRes*)²
3. R&D employees (*persRnD*)
4. Ph.D. students in science and economics (*drRnD*)

These variables are taken because they are considered to support patenting and networking activity, as all variables refer to creative work undertaken on a systematic basis in order to increase the stock of knowledge.

In our regression model, we insert control variables. They are integrated to increase model fit; they take the values 0 or 1 to indicate the absence or presence of some categorical effect that are expected to shift the outcome. In this case, country variables (δ_{cntry}) are used. The first regression model has the following structure:

$$PAT_i = \beta_0 + \beta_1 FDI_i + \beta_2 expRnD_i + \beta_3 expHumanRes_i + \beta_4 persRnD_i + \beta_5 drRnD_i + \delta_{cntry} + \epsilon_i$$

The second regression model looks as follows:

$$NET_i = \beta_0 + \beta_1 FDI_i + \beta_2 expRnD_i + \beta_3 expHumanRes_i + \beta_4 persRnD_i + \beta_5 drRnD_i + \delta_{cntry} + \epsilon_i$$

where δ is the coefficient of the dummy variable and ϵ_i is the disruptive factor.

Finally, it is examined to what extent the CEECs are involved in networks of innovators. Here, the Social Network Analysis (SNA) is used. The SNA method is generally designed to “[...] discover patterns of interaction between social actors in social networks” (Xu and Chen (2005) p.105). It implements this by revealing the overall network structure, as well as that of subgroups within the network, then examining the patterns of interaction among these various groups. As aforementioned, knowledge transfer is crucial for catch-up processes in innovation activity. Breschi and Lissoni (2003) already remarked that networks that include members from more than one company spread knowledge freely among the various countries. Moreover, recent work on local economic development has focused on network

² All public expenditures on education are meant (see Eurostat data base)

building due to the fact that networks facilitate economic growth. Thus, networks are seen as a kind of construction through which productive resources, social values and economic interests can freely circulate (see Glückler, 2007). It can be generally illustrated how countries, regions, firms or individuals cooperate with each other, thus, demonstrating the development of the regional, national or international connectivity. Networks are mostly described by a graph³, consisting of nodes joined by lines, i.e. SNA treats individuals as nodes and the relationship between individuals as linkages (see Wasserman and Faust, 2008). In the following, it is illustrated how a network can be constituted:

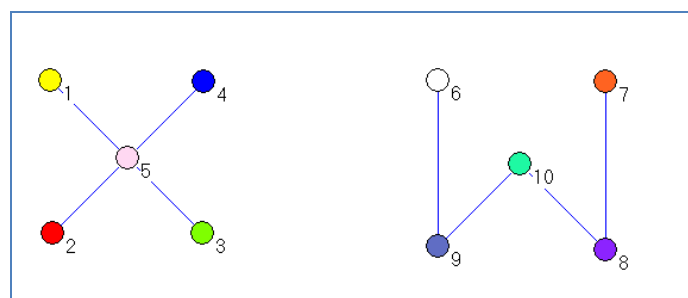


Figure 1: Star- and Line-Networks.
Source: Nooy et al., 2005, S. 125.

Figure 1 shows two possible forms of a network. On the left side, a so-called star network is pictured. Such a network is characterised by only one central node (node 5) which is linked to all other nodes (nodes 1 to 4). Here, it is very feasible to determine which node the most centralised one is (node 5). On the right side, a so-called line-graph is illustrated which makes it much more difficult to find out which node is the most centralised one. Therefore, network characteristics have to be used in order to determine which actor might be the most linked one within a network (see Nooy et al., 2005). In this context, patent data are used again to picture patterns of interaction between social actors in social networks. Thus, the aim is to shed light on the linkages between individuals or firms coming from different countries but working on the same patent. In this context, applicant-relationships are examined. In order to formally analyse networks, concepts regarding density and centrality are usually used. The concept of density displays how many linkages are realised in a network, shedding light on the connectivity of a group. Even though it is quite feasible to

³ See Wassermann and Faust (2008): Social Network Analysis; Cambridge University Press for further information on graph theory.

measure the density of a network, it is not a very useful measurement. The reason for that lies in the fact that density provides no information about the size of a network, i.e. the density of a network with many actors can be similar to the density of a network with only a few actors. It is therefore better to look at the number of linkages in which each node is involved. The concept of centrality permits to display the relevance of the nodes within a network (see Nooy et al., 2005). Due to this fact, the latter concept is used to shed light on the patterns of interaction radiating from the CEECs. First, the value of degree-centrality of all CEECs is explored, i.e. the number of neighbours of each node. 'Since this measure depends on the size of the network, it is meaningful to consider this indicator in relation to the maximum degree that can be achieved in a network of the same size' (Haller, 2009, p.128). The normalized degree-centrality can be expressed with the following equation:

$$C_d = d_i / (g - 1)$$

g - Number of actors of the network (size of the network)

d_i - Number of linkages (degree)

C_d - Degree-centrality

The higher the degree-centrality the more active is the actor within the network (see Wassermann and Faust, 2008).

Afterwards, betweenness-centrality is measured. The centrality of a country depends on the extent to which it is needed as a link in the chains of contacts that facilitate the spread of information in the network, i.e. this measure takes into account the connectivity of the node's neighbours, giving a higher value for nodes which bridge clusters (see Nooy et al., 2005). Betweenness-centrality is defined as:

$$C_b(n_i) = \sum_{j < k} g_{jk}(n_i) / g_{jk}$$

g - Number of actors in the network

n_i - Actor_i

C_b - Betweenness-centrality

By means of both values, it is demonstrated how far the CEECs are integrated in the international innovation network. On the one side, it is shown how many linkages to other countries exist, and on the other side, it is demonstrated to what extent the CEECs already bridge clusters, i.e. how important they are within the innovation network.

As aforementioned, for all analyses patent data are the basis. A patent is a temporary monopoly, issued by an authorized governmental agency. It grants the right to exclude anyone else from the commercial production or use of a specific new device, apparatus, or process. This right is given to the inventor of this innovative device or process after an examination that pays attention to the novelty of the claimed item and its potential utility. Of course, the inventor can assign the right to use the patent to somebody else, usually to its employer, a corporation, or sold to or licensed for use by somebody else (see Griliches, 1990). Patent statistics are a crucial tool for scientists, statisticians and policy makers interested in innovation and intellectual property rights (IPR), as they measure the successful output of R&D efforts (see Carpenter and Narin (1983), Griliches (1984), Schmoch et al. (1988), and Grupp (1998)). As innovation-indicator, patents refer to technological innovations, mirroring a part of the existing technological knowledge stock of a sector, region, or economy (see Frietsch et al., 2008). This study concentrates on patents which are filed at the EPO or went through the Patent Cooperation Treaty (PCT) filing process at the World Intellectual Property Organisation (WIPO). In doing so, it is assured that we deal with patents with a high-expected economic value (see Frietsch et al., 2008). Besides, some data from the Statistical Office of the European communities (Eurostat) and from the Organisation for Economic Co-operation and Development (OECD) are used.

4 Overview of FDI Inflows into and Innovation Activity in CEE

This section provides facts and figures of the development of FDI inflows into CEE, as well as of their patenting and networking activity. It illustrates basic insights into the development of the CEECs, simultaneously delivering background information for further analyses and discussions.

4.1 The Development of FDI Inflows into CEE

The transition countries from CEE have generally seen a large boom of FDI since the fall of the Iron Curtain. It is not surprising that all Central and Eastern European governments had considerable incentives to attract foreign capital, as the impact of four decades of socialism was very negative in this field. The following figure illustrates FDI inflows into all ten CEECs between 1990 and 2007, demonstrating that they experienced a significant increase in their FDI inflows during this time period.

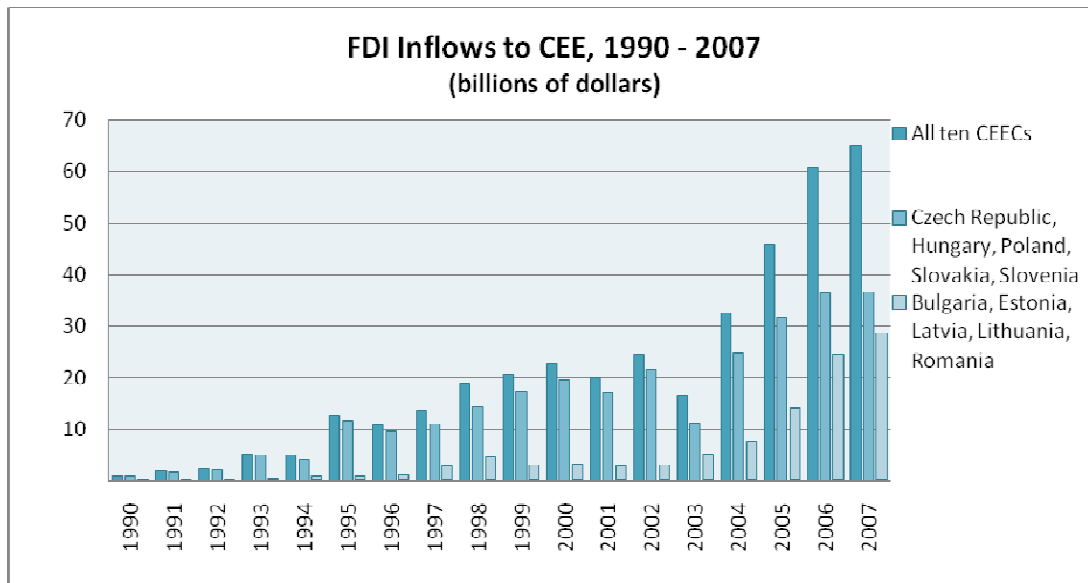


Figure 2: FDI Inflows to CEE, 1990-2007 (billions of dollars) – own illustration.
Source: OECD, World Bank.

Directly after the fall of the Iron Curtain, CEE had still some difficulties in attracting foreign investment due to the enormous complexity the transformation process brought about. But only a few years later, FDI into CEE increased by more than 50%, from US\$ 5,4 billion in 1993 to US\$ 12,5 billion in 1995. After a minimal decrease in 1996, the CEEC experienced a continuous rise in FDI until 2002. In 2000, almost US\$ 23 billion have been invested in this region, whereas the region's largest privatization and FDI transaction occurred in Poland, when France Telecom purchased a majority share of about US\$ 4 billion in Telekomunikacja Polska (see UNCTAD PR/26 2001). In 2002, CEE reached its temporarily peak regarding FDI inflows with a new high of US\$ 24,6 billion. Due to this persistent increase in foreign capital, this region is increasingly being viewed by investing firms as a stable location for FDI (see UNCTAD PR/89 2003). But, Off the US\$ 24,6 billion invested in this region, almost 90% were undertaken in group 1, with US\$ 8,4 billion invested in the Czech Republic, US\$ 4,1 billion in

Poland, US\$ 4,1 billion in Slovakia, US\$ 3 million in Hungary and US\$ 2 billion in Slovenia. Compared to the overall investments made in group 1, the investments undertaken in group 2 have rather been a trickle. So, Romania accounts for US\$ 1,1 billion, Bulgaria for US\$ 0,9 billion, Lithuania for US\$ 0,7 billion, Estonia for US\$ 0,3 billion and Latvia for US\$ 0,28 billion, thus, group 2 still saw marginal FDI inflows. Overall, Poland and the Czech Republic jointly accounted for approximately 50% of the total FDI inflows into all ten countries in 2002. In 2003, FDI inflows into this region fell from record levels in 2002 to a new low of US\$ 16,5 billion. The measured decline was, for example, due to the end of privatization in the Czech Republic and Slovakia. In this connection, it is striking that only group 1 saw their combined FDI inflows shrink from US\$ 21,6 billion in 2002 to US\$ 11,3 billion in 2003. Contrary, group 2 experienced a rise in their FDI inflows (from US\$ 3 billion in 2002 to US\$ 5,2 billion in 2003), even though their share of the overall FDI inflows is still relatively small. One reason for this development can be seen in several privatization deals implemented by the ‘South-Eastern’ European members of this group, such as by Romania and Bulgaria (see UNCTAD PR/027 2004); both FDI inflows rose more than 50% from 2002 to 2003. In 2004, Romania recorded FDI inflows of US\$ 5,2 billion, mainly due to the result of privatization of its downstream oil company, Petrom, through acquisition by Austria’s leading oil company OMV (cf. UNCTAD PR/038 2005). In all, recent surveys from 2007 indicate a combined inflow of FDI into all ten CEECs of US\$ 65,2 billion.

The next figure demonstrates the four leading investors of CEE between 1990 and 2007.

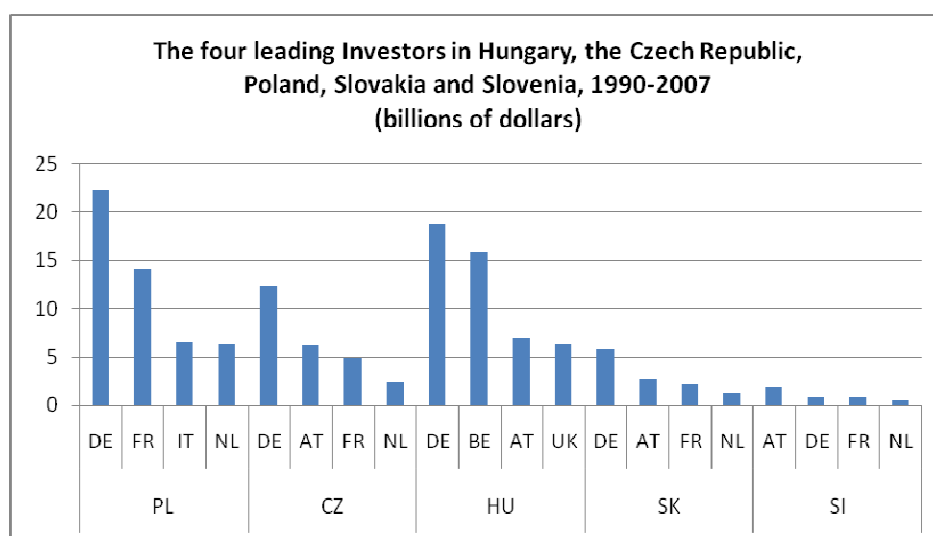


Figure 3a: The four leading Investors in Hungary, the Czech Republic, Poland, Slovakia and Slovenia, 1990-2007 (billions of dollars) – own illustration.
Source: OECD, World Bank.

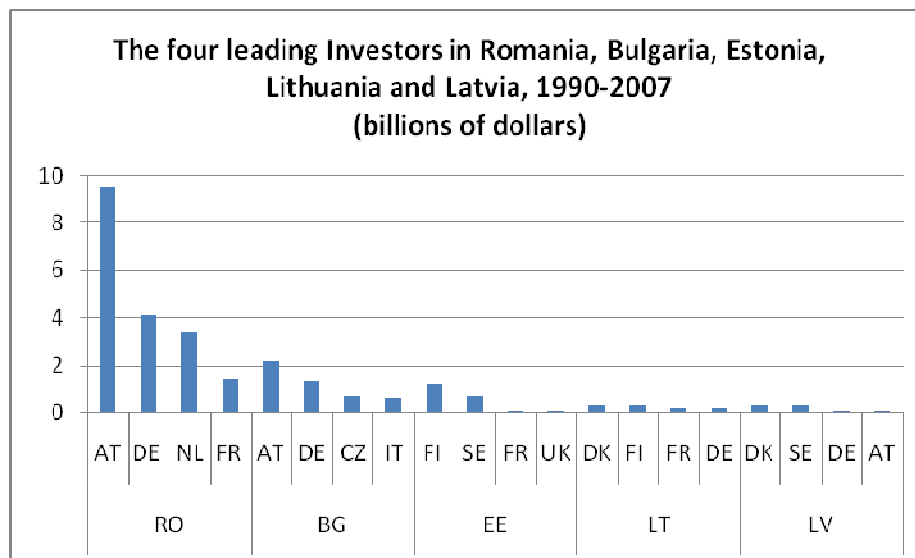


Figure 3b: The four leading Investors in Romania, Bulgaria, Estonia, Lithuania and Latvia, 1990-2007 (billions of dollars) – own illustration.
Source: OECD, World Bank.

As can be seen again from the figure above, the overall share of FDI inflows is much higher for group 1 than for group 2. However, it can also be demonstrated again that particularly the countries from South-Eastern Europe, like Romania and Bulgaria, are catching up. Besides, it is apparent that Germany is all in all the leading investor in CEE over the last 20 years. Off the US\$ 165,17 billion invested in this region, almost 40% were undertaken by Germany, followed by Austria (almost 20%) and France (almost 15%). For group 1, it is apparent that Germany occupies first place in four of five countries with an invested volume of US\$ 59,8 billion; that makes almost 45% of all investments, followed by France (around 16%), and Austria (around 13%). For group 2, it is Austria that has invested most into these countries with an invested volume of US\$ 11,75 billion, that also accounts for almost 45% of all investments. Second and third place is occupied by Germany (almost 22% of all investments) and the Netherlands (almost 15% of all investments).

Of course, there is a wide range of factors influencing FDI inflows into this region. One of the most important of these factors seems to be the degree to which the countries have made steps forward in their transition from a centrally-planned system to a market economy. But, meanwhile, the presence of human resources or the rising relevance of well-structured and financial supported R&D divisions become fundamental in attracting foreign capital.

4.2 Patenting and Networking Activity in CEE

Coming to the patenting activity in CEE, it is obvious that on the basis of size, both groups make up only a small fraction of patent filings compared to Germany, France and Great Britain. The following figure firstly illustrates the development of patenting activity in CEE.

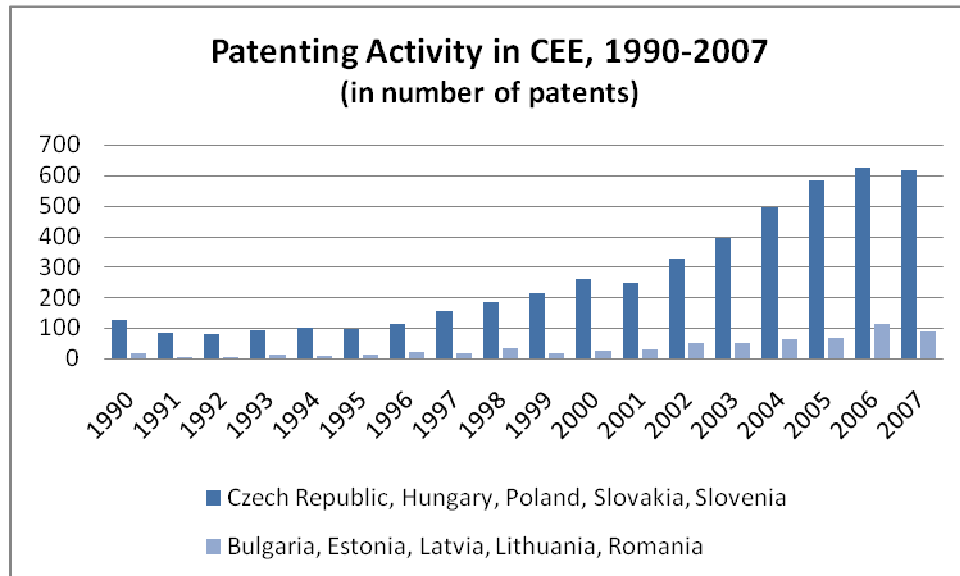


Figure 4: Patenting Activity in CEE, 1990-2008 (in number of patents) – own illustration
Source: PATSTAT.

As can be seen from the figure above, CEE experienced increasing patent filings, even though it has to be distinguished again between group 1 and group 2. The development of patenting activity considerably increases for group 1, but is rather a trickle for group 2, even though an increase can be found for group 2, too. What can be especially pointed out for group 1 is the decline in the number of patents between 1990 and 1992. This development resembles the differences in relative decreases of GDP from their 1989 level (see Radosevic and Kutlaca, 1999).⁴ However, it is apparent that group 1 is patenting much more than group 2. Off the 1806 filed patents, group 1 accounts for almost 90%, occupying the highest share of all filed patents in CEE. Nevertheless, the share of filed patents is also slowly rising for group 2.

To achieve a better overview of the patenting activity in CEE, the next table demonstrates the patenting activity in numbers between 1990 and 2006 compared to Germany, France and Great Britain.

⁴ The reasons of GDP decline in most CEECs are discussed in detail in Westernhagen (2002)

Development of Patenting Activity in CEE and Germany, France and Great Britain, 1990-2006 (in number of patents)						
	1990-1992	1993-1995	1996-1998	1999-2001	2002-2004	2005-2006
Germany	13157	15244	22523	29392	32400	24855
France	4776	5025	6365	7699	8907	6100
Great Britain	3229	3376	4164	5114	4837	2281
Hungary	66	42	59	90	115	150
Poland	9	11	22	34	88	129
Czech Republic	14	17	30	55	90	129
Slovenia	5	20	25	47	84	161
Slovakia	1	6	14	15	28	38
Bulgaria	5	6	7	8	18	21
Romania	3	4	8	5	15	23
Latvia	1	1	2	3	8	24
Estonia	0	1	5	5	9	13
Lithuania	0	1	1	2	3	10

**Table 1: Development of Patenting Activity in CEE and Germany, France and Great Britain, 1990-2006 (in number of patents – own illustration.
Source: PATSTAT.**

As can be seen from table 1, the patenting activity of the CEECS is hardly comparable with the one of Germany, France and Great Britain. Overall, Germany, France and Great Britain account for around 99% regarding all filed patents in this regard. Comparing only the three benchmark countries, it is Germany that is at the forefront, accounting for almost 70% of all filed patents in these three countries. But, while the patenting activity was declining in the last time period within the three benchmark countries, the CEECs saw increasing patent filings during this time period. It can be assumed that the CEECs will see a forthcoming rising trend in their patenting activity. Moreover, in terms of the relative development of patent-filings of group 1, it can be stated that it is comparable to the one of Germany, France and Great Britain. But, this finding does not hold for group 2; its development path regarding patent-filings is still quite unsteady. The next figure demonstrates the development of patent-filings of the CEECs compared to the three benchmark countries visually. Thereby, Germany has been excluded from the figure, because of its strong position within the area of patenting activity, even compared to France and Great Britain. In doing so, a clearer development and, in particular, comparison can be required. Moreover, the left axis of the figure is related to France and Great Britain with a different scaling compared to the CEECs; the CEECs belong to the right axis.

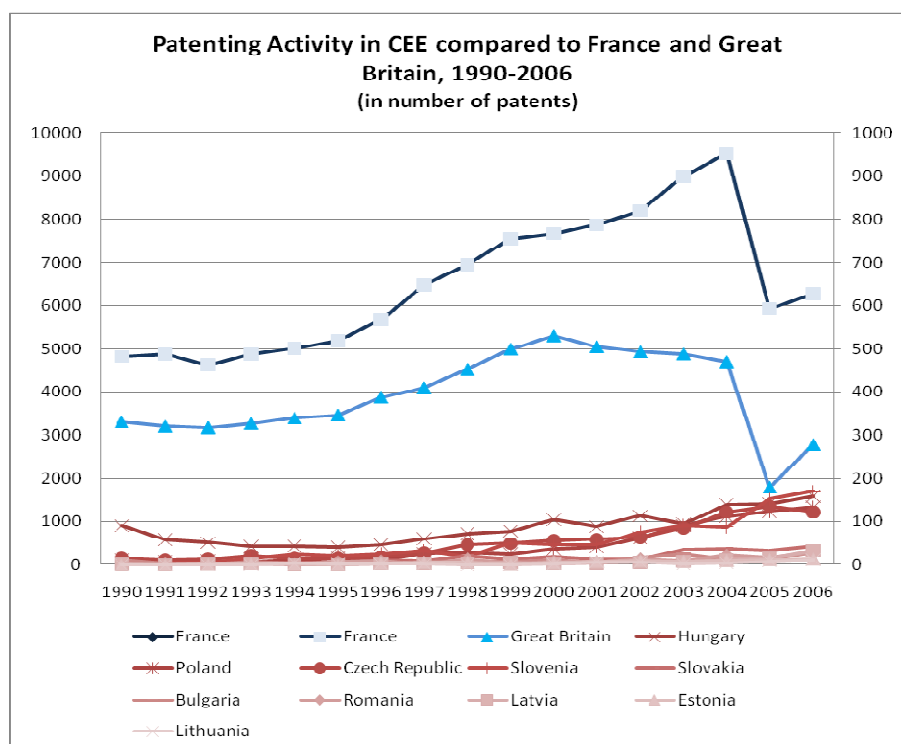


Figure 5: Patenting Activity in CEE compared to France and Great Britain, 1990-2006 (in number of patents) – own illustration.
Source: PATSTAT.

In the following, the development of the networking activity in CEE is demonstrated. This illustration is based upon patent data, which means that any collaboration that occurs between any of the CEECs and another country (referred to as patenting partner) is counted. For group 1, it is Hungary that occupied first place regarding its networking activity between 1990 and 2005, followed by the Czech Republic and Poland. Of all 4018 collaborations, Hungary accounts for almost 35%, the Czech Republic and Poland each for almost 25%. Slovakia and Slovenia only make up a small share of all network collaborations. For the same time period, group 2 is involved in 708 network collaborations. Besides, all five countries do not differ in the number of collaborations; they all range between 115 and 175. The following figure now demonstrates the four leading patenting partners of group 1.

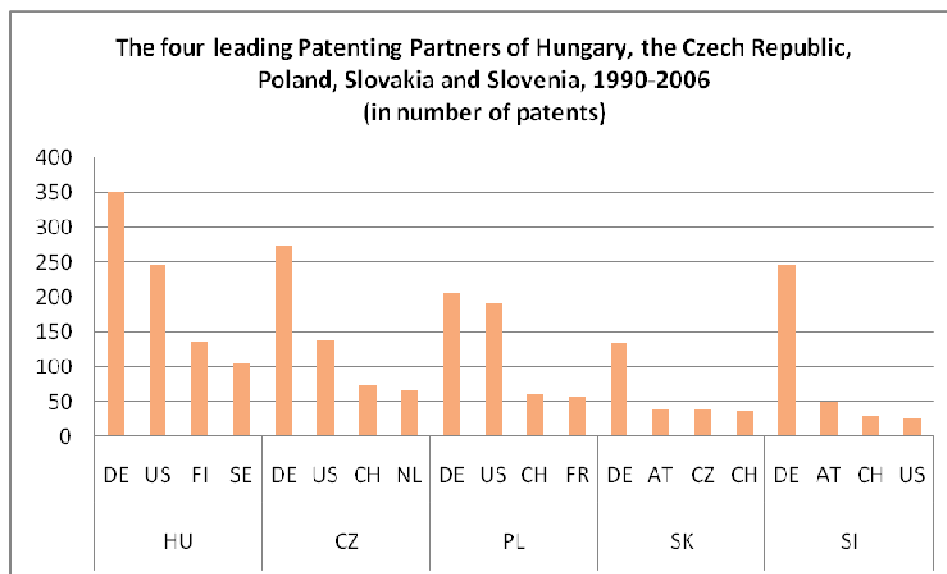


Figure 6: The four leading Patenting Partners of Hungary, the Czech Republic, Poland, Slovakia and Slovenia, 1990-2006 (in number of patents) – own illustration.
Source: PATSTAT.

As can be seen from figure 6, Germany accounts for the biggest partner regarding network collaborations in all five countries. Thereby, Germany is involved in around 1200 collaborations, followed by the US (around 600 collaborations) and Switzerland (around 200 collaborations).

The same analysis is done for group 2 and is demonstrated through the following figure.

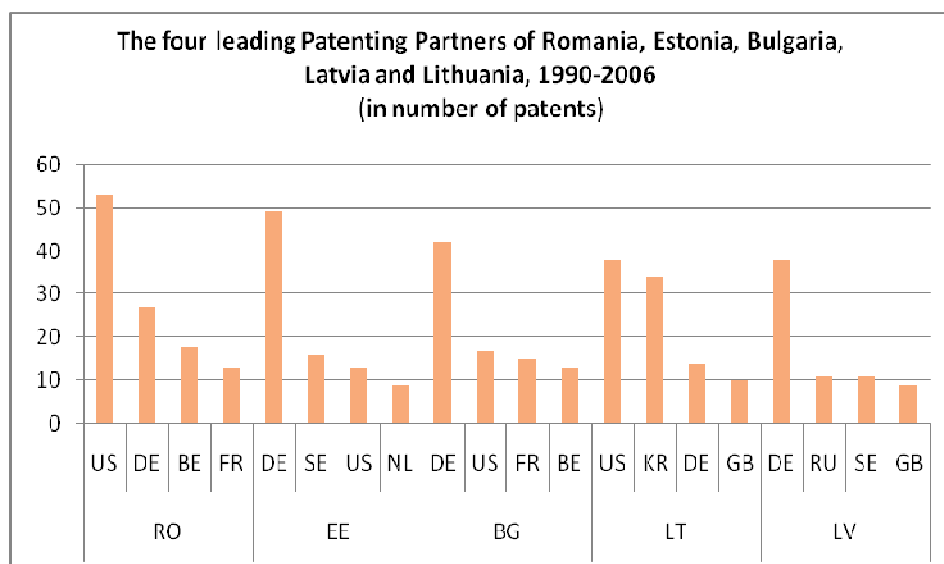


Figure 7: The four leading Patenting Partners of Romania, Estonia, Bulgaria, Latvia, and Lithuania, 1990-2006 (in number of patents) – own illustration.
Source: PATSTAT.

It is quite obvious that it is again Germany with the most network collaborations (around 170 collaborations), followed again by the US (around 120 collaborations) and Croatia (around 40 collaborations). In all, off all 2955 leading collaborations, Germany accounts for almost 50%.

After elaborating upon the development of FDI inflows to CEE, their patenting and networking activity, it is now interesting to shed light on the inherent economic value of FDI, as well as shedding light on their networking activity, in general, via the SNA.

5 Empirical Results

This Section firstly introduces the empirical results of the regression models introduced in section two, demonstrating to what extent FDI inflows affect the innovation and networking activity in CEE. The second part of this section demonstrates the results of the SNA, firstly for the value of degree-centrality, and secondly for the value of betweenness-centrality.

5.1 Results of the Regression Models

First, it is expressed to what extent the five independent variables affect the patenting activity of both groups. Second, it is pointed out how far the networking activity is influenced by these independent variables. The analyses are conducted from 1990 until 2007, and are implemented for both groups separately.

The results of the first regression model of group 1 are as follows:

Results of the first Regression Model (group 1)	
VARIABLES	PAT
FDI	0.00587*** (0.00115)
expRnD	-73.60 (73.02)
expHumanRes	41.33** (17.91)
drRnD	19.76 (48.38)
persRnD	149.0* (75.77)
dummycz	-24.25 (49.83)
dummypl	-108.9***

	(39.71)
dummyhu	-35.76
	(25.31)
dummysk	-96.00***
	(34.19)
dummysi	0
	(0)
Constant	-109.5
	(74.78)
Observations	42
R-squared	0.866
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Table 2: Results of the first Regression Model (group 1).

As can be seen from the table, FDI inflows affect the patenting activity of group 1. The result is significant with a standard error less than 1%. However, referring to the coefficient, it is not clear how strong this impact is, because the coefficient is very low. A second significant result (standard error less than 1%) comes along with expenditures on human resources. In this context, it is striking that the impact of this variable is much stronger than the impact of FDI inflows. This finding can be derived from the differences in their coefficients. As can be seen from the table, the coefficient of expenditures on human resources is much higher compared to the one of FDI inflows. A third influencing variable is persons employed within the R&D sector. We have again a significant result, with a standard error less than 10%. Referring again to the coefficient, it can be stated that the impact of this variable is stronger than the impact of FDI inflows; its coefficient is even stronger than the one of expenditures on R&D. But, it is interesting to notice that we have a significant result for two control variables, namely for Poland and for Slovakia; both significant levels are higher than 99%. From this, we can draw the conclusion that we are confronted with any country effects, i.e. the control variable shows that both countries have negative effects on their patenting activity in general. It is, for example, possible that Poland and Slovakia have been less active in patenting than the other countries, also compared to their FDI inflows. To achieve comprehensible reasons for this result, further regional studies need to be made.

As it is widely known, the effect of human capital and its influences on innovation activity is familiar (see Romer, 1990). This effect is also confirmed by the findings of this analysis. Its

role is crucial, and even exceeds the role of FDI in the regression model. Thus, discussions on the importance of FDI need to consider the transfer of knowledge and technology through human capital. According to our regression model, the hypothesis drawn above can be partially confirmed. But, it is important for future work on this topic that the structure of FDI needs to be exploited in more detail. A clarification of certain kinds of FDI, classified in groups, such as pure monetary FDI or research and scientific FDI, can be feasible in such analyses.

The following table displays the results of group 2:

Results of the first Regression Model (group 2)	
VARIABLES	PAT
FDI	0.00208*** (0.000459)
expRnD	21.18 (14.06)
expHumanRes	-2.905 (2.521)
drRnD	-26.58 (23.17)
persRnD	2.514 (20.13)
dummyee	-3.102 (10.50)
dummylt	-6.207 (10.89)
dummylv	2.852 (7.723)
dummybg	0.729 (5.049)
dummyro	0 (0)
Constant	14.55 (13.47)
Observations	35
R-squared	0.754
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Table 3: Results of the first Regression Model (group 2).

Coming to the results of the regression model for group 2, it can also be stated that FDI inflows affect their patenting activity. The coefficient of FDI is significant at the 1% level with a positive sign. However, the coefficient is very low so that we cannot state how strong the impact of this variable is. However, all other tested variables have no significant impact on the patenting activity of group 2, and can be ignored for the analysis. Coming to the control variables, it is obvious that we are not confronted with any country effects, i.e. the results hold for all five countries.

The results of the second regression model regarding networking activity in CEE do not offer many significant results. For both groups, FDI inflows do not have a significant impact on the networking activity of this region. However, for group 1, the coefficient of expenditure on human resources is significant at the 5% level with a positive sign, hence, advancing the development of their networking activity. Referring to the first analysis, it is again the variable expenditure on human resources which is significantly important to increase their networking activity. Unfortunately, the regression model does not deliver significant results for group 2.

For further studies, it is now interesting to explore which other independent variables promote an increase in their networking activity, apart from expenditure on human resources. Nevertheless, in absolute numbers, it could be discovered that there is coherence between the origin of FDI inflows and the origin of networking partners of this region. Section three identified the four leading investors in CEE, as well as the four leading patenting partners of this region, demonstrating that in particular Germany and France are investing most in these countries and possess the most collaboration. Nevertheless, it needs to be further examined which other variables advance the development path of their networking activity with other countries.

5.2 Results of the SNA

This part firstly shows the value of degree-centrality of both groups, i.e. it is displayed how many neighbours each country of CEE possess. Afterwards, the value of betweenness-centrality is pointed out, illustrating the importance of each CEEC within the innovation network. The analysis is conducted in 6 time periods, for both groups separately.

The following figure now demonstrates the results of degree-centrality of group 1.

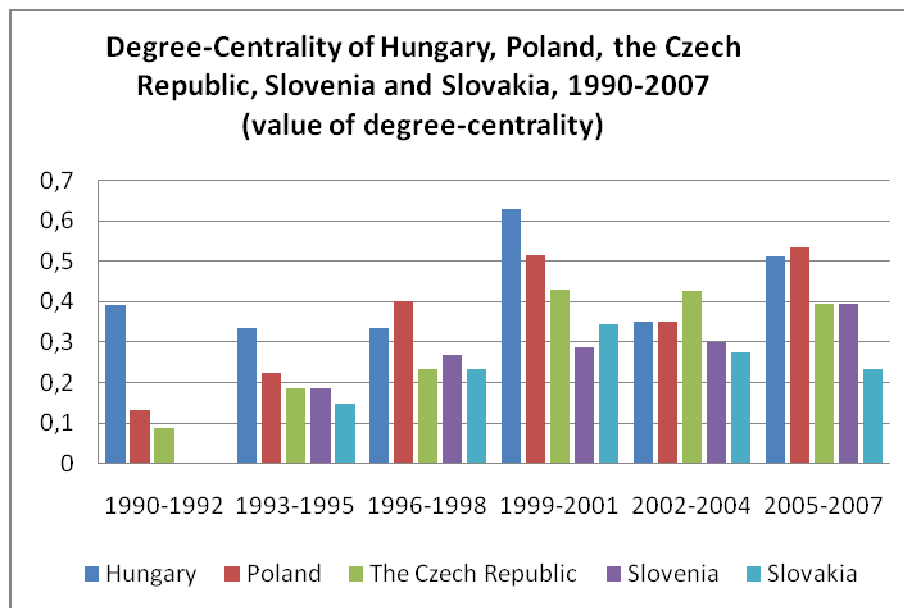


Figure 8: Degree-Centrality of Hungary, Poland, the Czech Republic, Slovenia and Slovakia, 1990-2007 (value of degree-centrality) – own illustration.
Source: PATSTAT.

Generally, it can be stated that the development of networking activity regarding the linkages of each country have mostly increased over the whole time period. Again, since the measure depends on the size of the network, the indicator is expressed in relation to the maximum degree that can be achieved in a network of the same size. It is obvious that Hungary is at the forefront regarding its linkages. Within the first time period, Hungary's value of degree-centrality is 0,3913043, followed by Poland (0,1304348), and the Czech Republic (0,0869565). Between the first and second time period, it is also apparent that the value of degree-centrality of Hungary decreases. Especially for Hungary, the number of filed patents does possess a similar development during this time. The reason might be also due to the differences in relative decreases of GDP from its 1989 level. Until 2001, it is apparent that the value of degree-centrality of Hungary, Poland, and the Czech Republic continuously increase. Within the fourth time period, the value of degree-centrality of Hungary is 0,6285714, again followed by Poland (0,5142857), and the Czech Republic (0,4285714). Besides, coming to the development of the value of degree-centrality of Slovenia and Slovakia, it is shown that they occupy last places. Within the first time period, both countries have not been involved in any network collaboration, i.e. they were isolated and could not profit from any knowledge flows. However, they start to catch up during the following time periods. Within the fourth period, the value of degree-centrality of Slovakia is 0,3428571,

and of Slovenia 0,2857143. Another striking factor can be seen within the fifth time period. Here, a considerable decrease of linkages in almost all five countries can be observed. This can be due to a range of reasons. One reason could be the end of privatisation measures in some of these countries, as FDI inflows or patenting activity also declined around this time period. On the other side, the burst of the dotcom bubble⁵ could be responsible for the decline of linkages. In all, a quite positive development for all five countries can be observed which means that they are well-positioned within the innovation network. Thereby, it is obvious that especially Hungary and Poland are best integrated within the innovation network, i.e. both countries can use their position to influence others, simultaneously getting more information.

Now, the results of betweenness-centrality are presented.

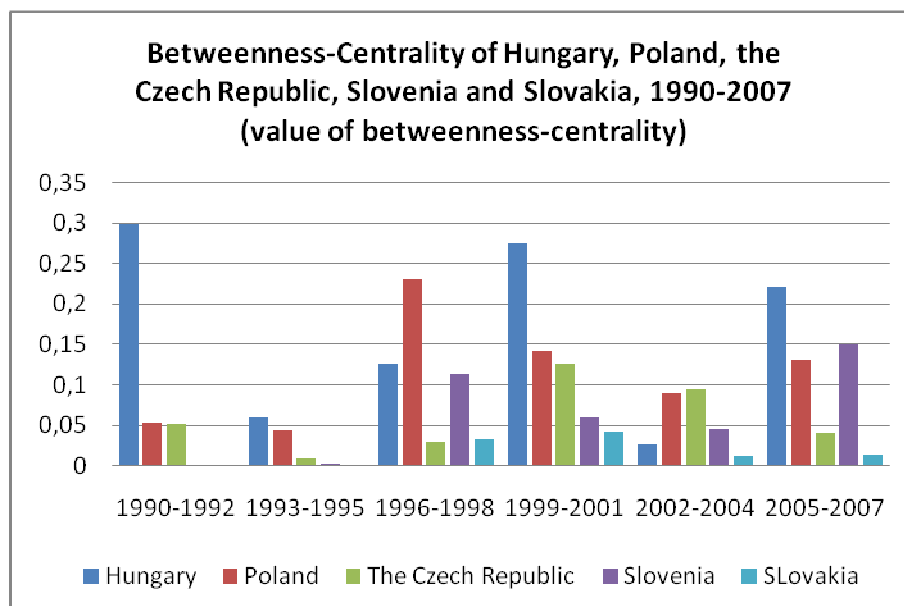


Figure 9: Betweenness-Centrality of Hungary, Poland, the Czech Republic, Slovenia and Slovakia, 1990-2007 (value of betweenness-centrality) – own illustration.
Source: PATSTAT.

As can be seen from figure 9, the value of betweenness-centrality is quite unsteady over the whole time period, and does also considerably differ between all five countries. It is again obvious that Hungary seems to be mostly needed as a link in the chains of contacts, even

⁵ The dotcom bubble was a speculative bubble between 1995 and 2000. During this time period, stock markets in industrialized nations saw their equity value rise rapidly from growth in the more recent Internet sector and related fields. A combination of rapidly increasing stock prices, individual speculation in stocks, and widely available venture capital created an exuberant environment in which many of these businesses dismissed standard business models, focusing on increasing market share at the expense of the bottom line.

though its values differ during the whole time period. Hungary's value is 0,298419 between 1990 and 1992, noticeably decreasing within the second time period. The same development, in fact not as strong, can be observed for Poland and the Czech Republic, too. The reason might be again due to the differences in relative decreases of GDP from its 1989 level. Between 2002 and 2004, a considerably decline of betweenness-centrality is again illustrated for all five countries. However, the extent to which Slovenia and Slovakia are needed as a link is not given at all between 1990 and 1992. Slovakia even has a betweenness-centrality value of 0 within the second time period. From 1999 until 2007, their development path is relative similar to the one of Hungary, Poland and the Czech Republic. In all, it can be observed that the extent to which they are needed as a link in the chains of contacts that facilitate the spread of information still differ too much so that a clear result regarding their importance within the innovation network can hardly be given. It is to be expected that off all five countries Hungary plays the most important role regarding its relevance for knowledge transfer. However, for further studies, it needs to be examined how this unsteady development occur.

The next figure illustrates the values of degree-centrality of group 2.

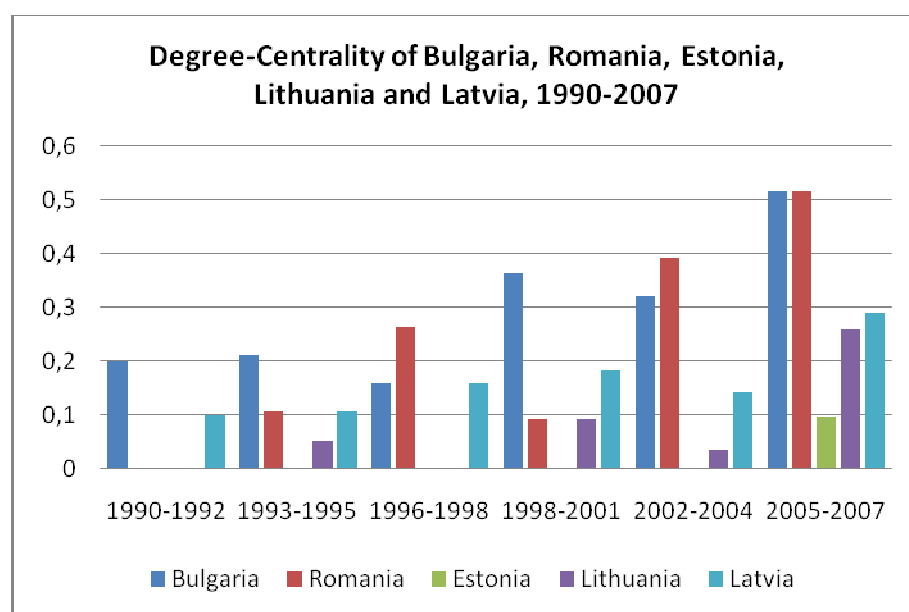


Figure 10: Degree-Centrality of Bulgaria, Romania, Estonia, Lithuania and Latvia, 1990-2007 (value of degree-centrality) – own illustration.
Source: PATSTAT.

As can be seen from the figure above, the value of degree-centrality mostly increases for all five countries over the whole time period, even though the share of linkages of group 2 is

relative small, especially at the beginning of the 1990s. It is obvious that Bulgaria is at the forefront regarding its linkages to other countries. Within the first time period, Bulgaria's degree of centrality is 0,200000, followed only by Latvia (0,100000). Estonia, Lithuania and even Romania have not been involved in any network collaboration during this time period, i.e. they were isolated and could not profit from any knowledge flows. However, Romania developed quite quickly regarding its linkages over the time. Meanwhile, Romania even occupies first place, together with Bulgaria, possessing a value of degree-centrality of 0,5161290. Estonia and Lithuania developed worst, even though Lithuania is catching up better than Estonia. But, in contrast to the development of the linkages of group 1, group 2 does not suffer a decrease in the value of degree-centrality from the fourth to the fifth time period. This kind of observation has also been made in the context of FDI inflows into these countries. In all, their development path regarding their value of degree-centrality can be compared with the development of FDI inflows into these countries. While Romania and Bulgaria are catching up with Hungary, Poland and the Czech Republic, and are even overrunning Slovenia and Slovakia, the role of Estonia, Lithuania and Latvia regarding their individual linkages is still quite small.

The next figure now demonstrates the value of betweenness-centrality of group 2.

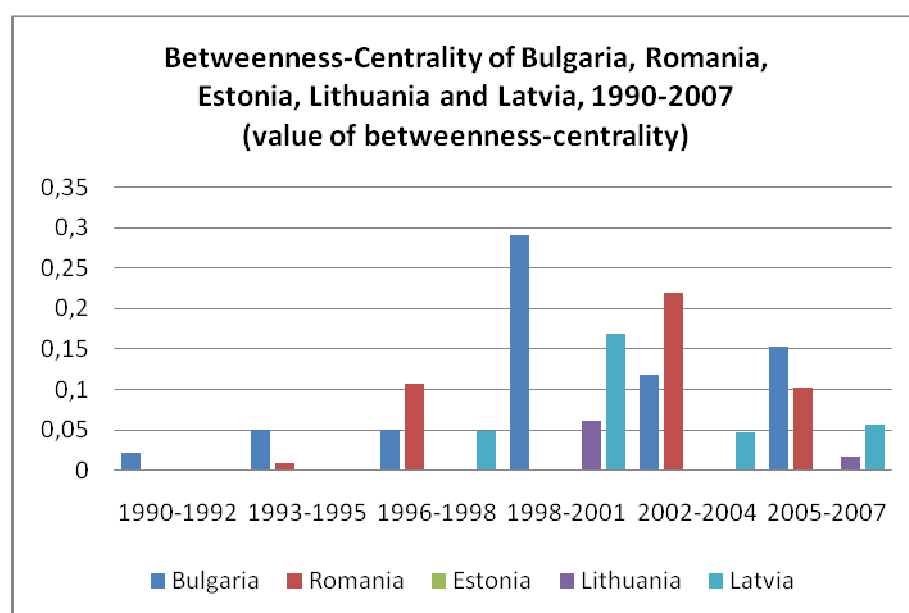


Figure 11: Betweenness-Centrality of Bulgaria, Romania, Estonia, Lithuania and Latvia, 1990-2007 (value of betweenness-centrality) – own illustration.
Source: PATSTAT.

It is again obvious, that within the innovation network of group 2, Bulgaria and Romania are at the forefront regarding their importance as a link in the chains of contacts. Within the first time period, it is only Bulgaria that is needed as a link that facilitates the spread of information within the network. All other countries are isolated. From 1993 until 1995, Romania starts to become more important within the innovation network, while the values of betweenness-centrality of Estonia, Lithuania and Latvia are still zero, i.e. they are still isolated from any network collaboration and do not bridge any cluster. While Latvia and Lithuania become more important over time, Estonia does not play any role within the innovation network. However, compared to group 1, it can be observed that the extent to which most of the countries of group 2 are needed as a link in the chains of contacts is still very low. This does not necessarily account for Bulgaria and Romania, but for Estonia and Lithuania and partially for Latvia. It is especially Bulgaria that starts to bridge clusters, becoming more important within the innovation network.

In all, comparing both groups, it can be stated that the relevance of group 1 is higher than the one of group 2. Of course, it should not be neglected that especially Romania and Bulgaria are catching up, almost overrunning Slovenia and Slovakia. However, it can generally be observed that the CEECs are already involved in close network collaborations, partially bridging clusters, and hence, spreading information around the network.

5 Conclusion

In this paper, we analyse the impact of FDI on innovation activity and on networks of inventors in CEE. Moreover, apart from FDI-related technological diffusion effects, by means of SNA, the development of the Central and Eastern European networking activity is pointed out. In this context, it is examined how many linkages they possess within the innovation network, and to what extent they are needed as a link in the chains of contacts. All analyses are conducted for ten CEECs for a time period from 1990 to 2006, respectively 2007. The ten CEECs are further divided into two groups; the first one (group 1) consists of Poland, Hungary, the Czech Republic, Slovakia, and Slovenia, and the second one (group 2) encompasses Bulgaria, Estonia, Latvia, Lithuania and Romania.

First of all, it is apparent that especially group 1 experienced a considerable increase in their FDI inflows during this time period; this finding also accounts for their patenting and networking activity. Even though group 2 saw also increasing FDI inflows, patent filings and networking activity, it has rather been a trickle compared to group 1. But, it should not be neglected that particularly the countries from South-Eastern Europe, like Romania and Bulgaria, are catching up, even partially overrunning Slovakia and Slovenia.

Being aware of the fact that the quantity of FDI inflows, patent filings and networking activity generally increases, the results of the regression model as well as of the SNA are now discussed in the following.

The first regression model shows a positive significant effect of FDI inflows on the patenting behavior of CEE; this finding accounts for both groups. However, for group 1, expenditures on human resources and the amount of persons employed within the R&D sector also possess a positive significant effect on their patenting activity. The effect of human capital and its influences on innovation activity is familiar, as it is also confirmed by the findings of this analysis. But, its role even exceeds the role of FDI in our regression model. However, these findings do not deliver clear results for Poland and Slovakia, as their control variables have a negative significant impact on their patenting activity. To achieve comprehensible reasons for this result, further regional studies need to be made. The second regression model shows for both groups that FDI inflows do not have a significant impact on the networking activity of this region. Only for group 1, the coefficient of expenditure on human resources is significant at the 5% level with a positive sign, hence, advancing the development of their networking activity. As we achieved no significant results for group 2 in this regard, it is of interest to explore which variables help to increase their networking behaviour.

In all, discussions on the importance of FDI need to consider the transfer of knowledge and technology through human capital. Hence, it is important for future work on this topic that the structure of FDI has to be exploited in more detail. A clarification of certain kinds of FDI, classified in groups, such as pure monetary FDI or research and scientific FDI, can be feasible in such analyses.

The SNA shows that we have differing results regarding the value of degree- and betweenness-centrality for both groups. For group 1, it can be concluded that they all

experienced a quite positive development regarding their linkages to other countries. But, it is obvious that especially Hungary and Poland are best integrated within the innovation network, i.e. both countries can use their position best to influence others, simultaneously getting more information. Regarding the value of betweenness-centrality, it can be stated that the extent to which all countries of group 1 are needed as a link in the chains of contacts still differ too much; hence a clear result regarding their importance within the innovation network can hardly be given. It is to be expected that Hungary plays the most important role regarding its relevance for knowledge transfer. However, for further studies, it needs to be examined how this unsteady development occur. For group 2, the development of the value of degree-centrality can be compared with the development of FDI inflows into these countries. While Romania and Bulgaria are catching up with Hungary, Poland and the Czech Republic, and are even overrunning Slovenia and Slovakia, the role of Estonia, Lithuania and Latvia regarding their individual linkages is still quite small. Here, it is to be expected that the role of group 2 regarding their individual linkages to other countries will advance over the next time. Regarding the value of betweenness-centrality, it can be observed that the extent to which most of the countries of group 2 are needed as a link in the chains of contacts is still very low. This does not necessarily account for Bulgaria and Romania, but for Estonia and Lithuania and partially for Latvia. It is especially Bulgaria that starts to bridge clusters, becoming more important within the innovation network.

To sum up, the impact of FDI inflows on the patenting activity of CEE is observable, even though we are well aware that this work is a first step of our research work. The SNA also provides a first insight into the role of the CEECs within the innovation network, and needs to be analysed in detail, too. However, in this regard, it can generally be observed that the CEECs are already involved in close network collaborations, partially bridging clusters, and hence, spreading information around the network.

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