Direct and indirect effects of technology transfer through foreign direct investments: The case of Slovakia

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Abstract

In this article, we evaluate the technology flows in Slovak economy, based on augmented input-output model for foreign direct investment. Several studies suggest that FDI were the main driver of technological development in Slovakia in recent years. Thus, this analysis could provide a better picture of technology flows in Slovakia then previous studies that are based on R&D expenditure vector. Technology flows based on FDI are analyzed in standard and actual structure. We identify the most important sectors of Slovak economy which purvey new technology to other sectors, as well as the sectors which benefit the most from diffusion of new technology. We also estimate the embodied and disembodied technology transfer when we purge FDI vector from foreign investments in Slovakia associated with privatization.

Keywords:
technological flows, spillovers effects, input-output analyze, foreign direct investment

Introduction

Rising of living standards is closely linked to technological progress. Acquire new technology or knowledge can happend by their generation or by its transfer. Cration of new technology is intensive to investments. For developing and transition countries, including the Slovak Republic is technology transfer a major determinant of economic development and modernization. Transfer is much faster and especially cheaper way to get new technologies with which it is associated a significant increase in labor productivity and other positive effects. The technology transfer occurs through multiple channels, but most important, to which virtually all attention focused is foreign direct investment (FDI). Foreign investors bring macroeconomic incentives, help reduce unemployment in the host economy, they are also associated with the growth of total factor productivity and the efficient use of resources.

FDI are bearer of spillover effects, which are defined as the impact of foreign investments on domestic enterprises in the sector wherein it operates and, consequently, the entire domestic economy. Spillover effects are positive economic externalities that means, they have impact beyond their direct benefits expressed at market prices, and are not fully reflected in market transactions and therefore not represent the cost for those who have benefited from them. Economic theory distinguishes between two kinds of spillover effects: horizontal and vertical. Horizontal or intra-sectorial spillovers have impact on domestic firms in the same industry of foreign investment. Empirical studies investigating the effects of horizontal spillovers conclude that spillovers have largely neutral effect in some cases even negative effect for domestic firms (Damijan, and col. 2003; Djankov, Hoekman, 2000). It is caused mainly, because a foreign investor is in competition with domestic companies and he is reluctant to share with them his advanced technology and know-how. Vertical or cross-sectorial effects have impact on domestic firms in other sectors of the economy. Studies investigating vertical spillovers bring much more positive findings (Damijan, and col. 2003; Hanousek and col. 2012; Gorg, Strobl, 2001), than in the case of horizontal spillovers.

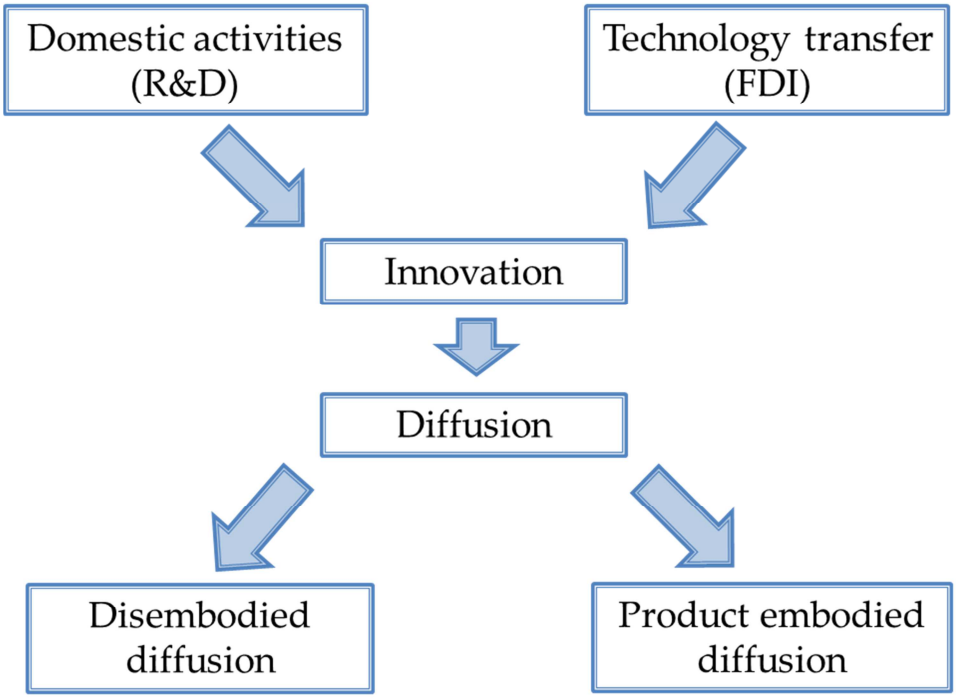
Vertical spillovers are much more desirable for foreign investors, because if domestic firm implement some kind of new technology, afterwards foreign investors may benefit from better performance and quality of production produced by domestic companies. The vertical spillover effects between domestic and foreign enterprises occur in two ways: through forward and backward linkages. Backward linkages bind to spillovers affecting efficiency, which was gained by domestic firms supplying products to foreign investors, while spillover transfer is directly proportional to the extent of cooperation between enterprises. These spillovers arise mainly via direct transfer of knowledge from a foreign investor to domestic supplier; through stringent demands on product quality and the timeliness of supply required by foreign investors (Watanabe 1983, Smarzinska – Javorick 2003). Foreign investors generally provide information or assistance to local suppliers for the purchase of raw materials, and modernization of production facilities in order to improve the quality of supplied materials and semi-finished products. Forward linkages arise when the positions of the supplier of inputs is a foreign investor. They appear if the domestic entrepreneurs become more productive thanks to access to more advance or cheaper inputs supplied by foreign investors (Smarzinska - Javorick 2003).

Dietzenbacher and Loss (2002) examining technology transfers based on research and development expenditure reported: Where will investment in science and research successful and appears some inventiveness, one of the main factors that affect the social contribution of invention is the ability of the economy to exploit its full potential. In this perspective, the most important are

opportunities for a wide diffusion of invention across sectors. The same applies to FDI. If one sector benefits from the new technology imported by foreign investors, is good for the economy spread new technology across sectors.

Diffusion of innovation and knowledge takes place via two possible channels. The first channel is disembodied technology transfer, which involves direct transfers of skilled experts, literature, imitation, ideas and knowledge (Luptáčik, 2006). The second channel is an embodied technology transfer. Those transfers run through commodities that are inputs for further production or investment goods, which involve a new technology (Lábaj, Luptáčik, Rumpelová, 2008). Dietzenbacher and Los (2002) also explain that, diffusion through the goods occurs when the initial innovation is embodied in sector´s products, which may be a completely new product or innovation that enhances the quality of existing commodities. Whereas other industries use this commodity as an intermediate goods for further production, respectively, as a capital good, so innovation becomes part of a much larger number of products.

Picture No. 1: Diffusion of technologies



Source: graphical interpretation of author

The main argument for the existence of positive spillover effects of embodied technology transfer is that better intermediate goods and investment goods leads to increased productivity in sectors that use them. If a provider of new technology has limited market power, he cannot itself appropriate all its benefits and some is taken by other sectors. Nevertheless, depending on the market structure, there may appear negative spillover effects. For example: when sector using new technology is forced to pay higher prices for intermediate and investment goods, but is unable to take advantage of their increased productivity or decrased market price (for a more detailed view of the negative spillover effects, see Dietzenbacher - Los, 2002).

Direct observation of the technological flows or spillover effects is not possible. Out to get the answer to the question, how many spillover revenues from the acquisition of new technology in

other sectors occur, should be monitored not only direct but also indirect connections (including intermediate consumption products). We used input output analysis to reveal all technological flows and possible spillover effects between sectors in the Slovak economy. Leontief inverse matrix augmented by a vector of expenditure in R&D and quality aspects are commonly used to detect the characteristic structure of the national economy and to identify and display the most significant technological flows in the economic system. This paper reports the modification of this approach, when we replace the vector of expenditure in R&D by vector of foreign direct investment. So we capture the positive effects spread across sectors, caused by the presence of new technologies from foreign direct investment. The disadvantage of the chosen method - it allows to watch only vertical spillover effects, while spillover effects within the industry remain hidden.

Methodology and Data

The basic static Leontief model has the form

$$x = (I - A)^{-1} y \tag{1}$$

To extended Leontief´s model by technological flows of foreign direct investment we introduce vector of FDI (**v**) into the basic model. If you multiply the vector of FDI by inverse output matrix, you get vector **p**. The components of this vector can be interpreted: how much FDI were invested in the economy per unit of output:

$$\hat{p} = \hat{v}.(\hat{x})^{-1}$$

If we multiply vector **p** by Leontief´s inverse matrix, we get matrix $\mathbf{Z^{st}}$. This matrix records flows of foreign direct investment in the economy for the unit vector of final demand.

$$Z^{st} = \hat{p}.R = \hat{v}.(\hat{x})^{-1}.(I - A)^{-1}$$

"Individual elements z_{ij}^{st} can be interpreted as the volume of FDI induced by production of commodity *i* when we deliver one unit of commodity *j* to final use. The sum of the elements in the column matrix $z_{.j}^{st}$ then shows us how much foreign direct investment directly or indirectly were used in the entire national economy in the delivery of one unit of commodity *j* to final use. These elements are denoted as cumulative coefficients of foreign direct investment "(Lábaj, 2012, p. 138).

Elements on the main diagonal of the matrix $\mathbf{Z^{st}}$, that is if *i = j*, indicate how much foreign direct investment directly and indirectly were used in the production of commodity *i*. Sum of all elements of this matrix in row *i,* $\left(Z_{i.}^{st} = \sum_{j=1}^{n} z_{ij}^{st} \right)$ determine how much foreign direct investment sector *i* spread to the whole national economy to satisfy one unit of final use of all commodities. Sum of the elements in the row *i* without the corresponding element on the main diagonal can be called spillover effect of foreign direct investment of sector *i* to all other sectors of the national economy. In a similar way, we can subtract elements on the main diagonal coefficients of cumulative foreign direct investment, and so we get information on how the sector j "absorbs" foreign direct investment from other sectors of the national economy. Comparing the sum of the elements in the columns $z_{.j}^{st}$ with sum of the elements in the rows $z_{i.}^{st}$ for all *i = j* we obtain information about whether the sector

is a “supplier” or “disseminator” of foreign direct investment $\left(z_{i.}^{st} > z_{.j}^{st}\right)$, or vice versa “customers” of FDI $\left(z_{i.}^{st} < z_{.j}^{st}\right)$. For key sectors of the national economy in terms of foreign direct investment, we will consider those industries that have above-average values as suppliers and customers of FDI. If we again did not take into account the elements on the main diagonal, so we can see which sectors are crucial to the indirect effects of foreign direct investment.

When we multiply the matrix of cumulative coefficient of FDI by diagonal matrix of final demand, we get the matrix of FDI flows in the current version:

$$Z^{ak} = Z^{st}.\hat{y} = \hat{v}.(\hat{x})^{-1}.(I - A)^{-1}.\hat{y}$$

"The elements of the matrix z_{ij}^{ak} in this equation, tells us how much foreign direct investment has been used in the production of commodity *i* in the delivery of appropriate volume of commodity *j* to final use. The sum of column *j* can be interpreted as the amount of foreign direct investment, which is used directly and indirectly in the whole national economy to deliver the appropriate volume of commodity *j* to final use. Analysis of spillover effects, suppliers and customers of foreign direct investment, as well as an analysis of key sectors can be done in a similar manner as mentioned in the case of standard structure (Lábaj, 2012, p. 139)."

On the application of the method described above, namely the analysis of the direct and indirect effects of foreign direct investment in the Slovak Republic we used the symmetric input - output tables, variant domestic production at basic prices, commodity - commodity structure for year 2008. Information on stocks of direct foreign investment in the Slovak Republic, 2009, we used the website of the National Bank of Slovakia. The data for the year 2009 are preferred over those of 2008, because they are already reported under the new revised version of NACE and 2008 data are available only in the old broken down NACE. This time inconsistency of the data is not particularly serious, because we assume that the structure of the economy in the short term does not change and therefore SIOT 2009 would be almost identical to 2008. The National Bank of Slovakia use manual issued by the International Monetary Fund for reporting FDI. FDI data are available in the sectoral breakdown.

To calculate input-output analysis augmented by FDI we used stock of foreign equity and reinvested earnings, so we have abstracted from other capital, because we assume that foreign investment included in other capital are not prerequisites for the spreading of spillover effects. It should be noted that the vector FDI was in the sectoral structure. This may lead to the fact that the analysis results will be less accurate than using the vector in the commodity structure. Results of input-output analysis augmented by foreign direct investment are linked to the year 2009. We have worked with 66 industries.

We used the database of the World Bank - privatization transactions to obtain data of privatized enterprises needed for estimation of embodied and disembodied spillover effects of technology transfer. Database contains information about privatization transactions in a minimum amount of one million dollars in the period 2000-2008. This time period is appropriate because there was a conceptual Slovakia encourages foreign direct investment in 1999. Moreover, there was a low which which excluded the participation of foreign investors in the privatization of strategic enterprises.

Results

We interpret the results, received by processing input-output analysis augmented by FDI vector in this section. We assume that FDI are carriers of spillover effects of technology transfer; likelihood and intensity of transmission is directly proportional to the intensity of industry links and the amount of FDI in different sectors.

Analysis of spillover effects of technology transfer

In the table below are shown the sectors with highest amount of FDI per unit of output (coefficient of FDI). The highest values of the coefficients of FDI in Slovakia reached in 2009 industries: financial services, except insurance and pension funding (2.18), mining support service activities (1.77) and insurance, reinsurance, pension scheme (1.28).

Table No. 1: Coefficient of FDI

No.	Sector	Coefficient of FDI
1	Financial services, except insurance and pension funding	2.179
2	Pomocné činnosti pri ťažbe	1.770
3	Poistenie, zaistenie, dôchodkové zabezpečenie	1.283
4	Výroba farmaceutických výrobkov	0.827
5	Telekomunikácie	0.530
6	Administratíva, pomocné kancelárske a iné obchodné činnosti	0.518
7	Ostatné vedecké a technické služby	0.446
8	Dodávky elektriny, plynu, pary, vody a studeného vzduchu	0.433
9	Výroba papiera a papierenských výrobkov	0.366
10	Výroba koksu a rafinéria ropných produktov	0.363

Source: own calculations

The following table shows the spillover effects of technological transfer induced by forward linkages that means how FDI affected the sectors which consume products of industries in which foreign investment was located. Largest disseminators of spillover effects of technology transfer in 2009 were folowing Industries: Financial services, except insurance and pension funding (FINSL) with a total effect of about 5.2 billion of euro. Effects within the sector were 3.3 billion euros and effects on other sectors were worth 1.9 billion of euros. If the sector has generated the production of 1 million of euros, spreads into other sectors spillover effects of technology transfer in the amount of 1.6 million of euros. Electricity, gas, steam, water and air sector (ENERG), generated lower overall spillover effects of technology transfer (4.6 bn. of euros), but produced a larger effects outside the industry (2.4 bn. of euros) than sector of financial services. Also spillover effects spread per unit of production were more pronounced 1.8) than in the previous sector. It can be concluded that the energy sector is in spreading spillover effects of technological transfer slightly more efficient than the industry FINSL. High values of spillover effects in these two sectors can be explained by the sector's products are used across all sectors in economy and therefore new technology used in these sectors has a significant effect on other sectors.

Table No. 2: Spillover effects of technology transfer induced by forvard linkages in thousand of EUR

No.	Sector	Total effects	Intra sectoral effects	Inter sectorall effects	Per unit of production
1	ENERG	4 649 475	2 191 238	2 458 237	1,795
2	FINSL	5 198 248	3 332 690	1 865 558	1,603
3	VOBCH	1 396 451	452 812	943 639	0,611
4	MOBCH	1 288 507	847 031	441 476	0,273
5	KOKS	1 450 539	1 027 792	422 747	0,309
6	TELEK	1 174 023	833 984	340 039	0,405
7	POMTA	322 621	4	322 616	0,341
8	NEHNUT	773 720	520 826	252 894	0,231
9	NEKOV	517 394	266 414	250 980	0,113
10	ADMIN	247 537	9 524	238 013	0,196

Soource: own calculation

Spillover effects of technological transfer induced backward lilnkages in selected sectors of the Slovak economy in 2009 shows the following table. Biggest "consumer" of spillover effects of technology transfer was the motor vehicle sector (MOTOR) with a total effect of 3.8 billion of euros, most of these spillovrov occurred within the industry (3 bilion of euros). Spillover effects worth only 0.8 billion of euro affected other sectors of the Slovak economy. Effects per unit of production were very low in this sector. To generate production of 1 million of EUR in automobile industry were absorbed spillover effects of technology transfer in the amount of 63,000 euros. But even at this low value spillover effect per unit of production, the overall effect is highest; this is due to a high proportion of automotive industry on total production in Slovak economy.

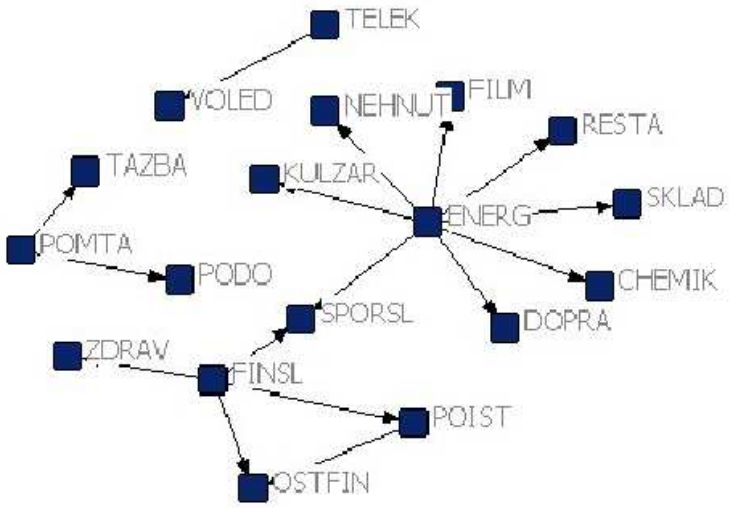
Table No. 2: Spillover effects of technology transfer induced by backward linkages in thousand of EUR

No.	Sector	Total effects	Intra sectoral effects	Inter sectorall effects	Per unit of production
1	MOTOR	3 763 855	2 994 395	769 460	0,063
2	STAVB	1 069 439	345 883	723 556	0,088
3	OSTOSL	677 316	2 227	675 089	0,115
4	NEHNUT	1 035 906	520 826	515 079	0,122
5	DOPRA	516 362	24 414	491 948	0,157
6	POCIT	1 303 707	896 710	406 997	0,066
7	ZAKOV	1 693 261	1 290 894	402 367	0,090
8	MOBCH	1 247 009	847 031	399 979	0,096
9	ZDRAV	432 591	69 735	362 856	0,134
10	POTRA	708 750	367 251	341 498	0,121

Source: own calculations

In the next figure is drawn the most important spillover effects of technology transfer between industries per unit of production (induced by forward and also backward linkages). Significant spillover effects per unit of production were observed mainly in two sectors: electricity, gas, steam, water and air (ENERG); Financial services, except insurance and pension funding (FINSL).

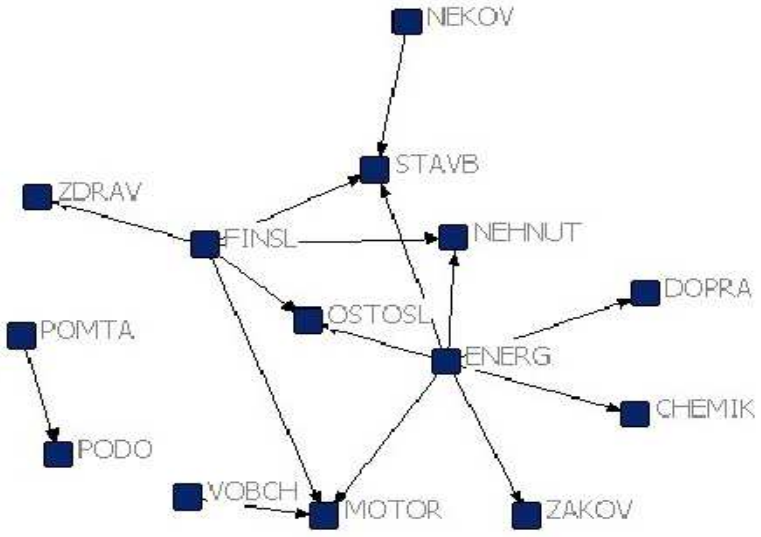
Figure No. 2: The most important linkages between sectors in the standard structure



Source: graphical display based on own calculations

Linkages in the current structure no longer display spillover effects of technology transfer per unit of output but the overall technology transfer as streamed on their total values. The most significant linkages between industries are drawn in next figure.

Figure No. 2: The most important linkages between sectors in the current structure



Source: graphical display based on own calculations

Analysis of embodied spillover effects of technology transfer

Two sectors have shaped as the largest disseminators of spillover effects of technology transfer induced by FDI in Slovak Republic in 2009: financial services sector and electricity, gas, steam, water and air sector. The fact is, these two sectors were almost entirely privatized by foreign investors. We believe that privatization of these sectors, did not bring any new embodied technology, but it was only a transfer of property ownership from the seller to the buyer subject. The innovation process as efficient organization of work, better work ethic, and know-how which contributed to an increase in labor productivity have been definitely linked with this transfer of ownership, but the transfer of new technology in the form of machinery or software, we can almost certainly exclude. Based on this assumption, we decided to subtract FDI related to privatization by foreign investments and thus estimate the embodied technology transfer. Value 30.432 billion EUR of FDI which in 2009 were located in Slovakia, was decreased by 7.147 billion of euros, what is the amounth of FDI related to privatization by foreign investors.

In the table no. 5 we can see the value of embodied spillover effects of technology transfer induced by forward linkages. The financial services industryremains the largest disseminator of spillover effects of technology transfer, but has a significantly lower value for spillover effects. Total embodied spillover effects of this sector were EUR 3.7 billion euros, therefore we record decline of 1.5 billion euros. This value can be attributed to disembodied spillover effect of technology transfer. Embodied effects in the sector were worth 2.4 billion euros and effects outside the industry 1.3 billion euros. The financial services sector also recorded impairment in spillover effects per unit of production, where the generation of output in value of one million spread into other sectors embodied spillover effects of technology transfer in value 1.16 million euros.

Table No. 5: Embodied spillover effects of technology transfer induced by forvard linkages in thousand of EUR

No.	Sector	Total effects	Intra sectoral effects	Inter sectorall effects	Per unit of production
1	FINSL	3 770 468	2 417 315	1 353 153	1,163
2	VOBCH	1 372 991	445 205	927 786	0,601
3	MOBCH	1 288 507	847 031	441 476	0,273
4	KOKS	1 144 629	811 037	333 592	0,244
5	POMTA	322 621	4	322 616	0,341
6	NEHNUT	773 720	520 826	252 894	0,231
7	NEKOV	517 394	266 414	250 980	0,113
8	ADMIN	247 537	9 524	238 013	0,196
9	ENERG	446 975	210 654	236 321	0,173
10	PORAD	264 243	32 801	231 442	0,190

Source: own calculations

Most industries in the table show the same values as in Table No. 2, because these sectors have not been privatized by foreign investors. Sector of electricity, gas, steam, water and air in the case of embodied spillover effects of technological transfer induced by forward linkages is no longer as crucial as In case of the overall spillover effects of technology transfer. Total embodied effects of the sector were worth of 0.4 billion euros that means a fall of 4.2 billion euros. This enormous

decline is due to the fact that most foreign investment in this sector has been associated with privatization.

Embodied spillover effects of technological transfer induced by backward linkages in selected sectors are shown in table bellow. The biggest "consumer" of embodied spillover effects remains the motor vehicle sector. Total embodied effects (3.6 billion euros) are only by 0.2 billion euros lower than the overall effect. This slight decline was caused by the absorption of embodied spillover effects of technology transfer from other sectors of the Slovak economy.

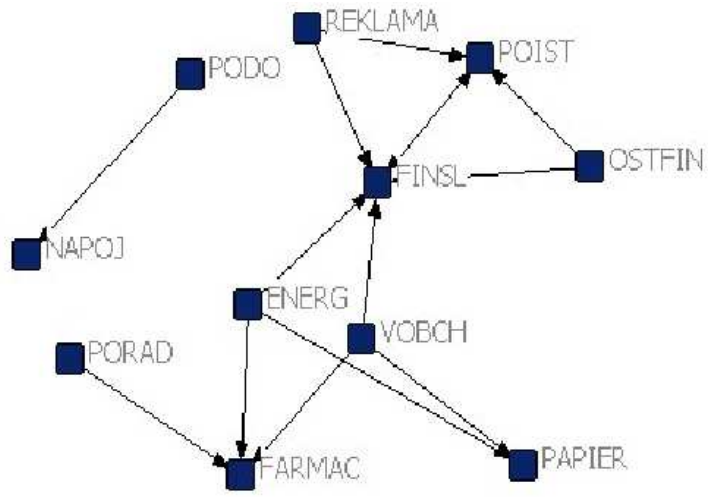
Table No. 5: Embodied spillover effects of technology transfer induced by backward linkages in thousand of EUR

No.	Sector	Total effects	Intra sectoral effects	Inter sectorall effects	Per unit of production
1	MOTOR	3 564 448	2 994 395	570 053	0,047
2	STAVB	878 203	345 883	532 320	0,065
3	OSTOSL	401 257	2 227	399 030	0,068
4	POCIT	1 230 950	896 710	334 240	0,054
5	DOPRA	314 871	24 414	290 457	0,093
6	MOBCH	1 134 266	847 031	287 235	0,069
7	ZAKOV	1 403 905	1 155 522	248 383	0,055
8	POTRA	608 509	367 251	241 258	0,085
9	NEHNUT	759 354	520 826	238 527	0,057
10	ZDRAV	306 952	69 735	237 217	0,088

Source: own calculations

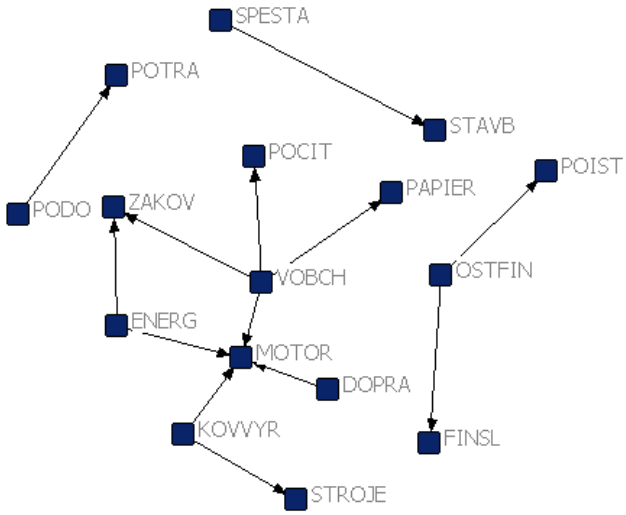
The following figures shows graphicall records of the most significant linkages between sectors in the context of embodied spillover effects of technology transfer in standard structure and actuall structure.

Figure No. 4: The most significant linkages between sectors of embodied spillover effects in standard structure.



Source: own calculations

Figure No. 4: The most significant linkages between sectors of embodied spillover effects in actuall structure.



Source: own calculations

The most important flows of embodied spillover effects of technology transfer in the actuall structure after adjusting for privatization sales were especially around the motor vehicles sector (MOTOR), which absorbed embodied spillover effects from the Land transport and transport via pipelines sector (TRANSPORT); Fabricated metal products, except machinery and equipment sector (KOVVY) Sector of electricity, gas, steam, water and air (ENERG) and sector of wholesale (VOBCH).

The following table illustrating the proportion of disseminated spillover effects of technology transfer for selected industrie.[1] The sectors: General Labour in mining, Employment activities, Office administrative, office support and other business support services disseminated over a hundred times more spillover effects as received. This high figure can be explained by the fact that they almost don´t use technology-intensive inputs. Sector of Electricity, gas, steam and air is really intristing. This sector was a clear disseminator of total spillover effects but in the case of embodied spillover effects of technology transfer ratio of consumed and disseminated spillovers is almost equal (1.2).

Tabuľka č. 7: Pure disseminator of technological spillovers of technology transfer

No.	Sector	Total spillover effects	Embodied spillover effects
1	General Labour in mining	>100	>100
2	Employment activities	>100	>100
3	Office administrative, office support and other	>100	>100
4	Security and investigation activities	87,3	>100
5	Repair and install. of machinery and equipment	44,0	57,8
6	Financial services	19,0	18,3
7	Advertising and market research	15,8	22,4
8	Head offices; management consultancy activities	13,9	21,7
9	Electricity, gas, steam and air	11,6	1,2
10	Other professional and technical services	7,9	11,9

Source: own calculations

[1] If the proportion is greater than 1 sector spread more spillover effects into other sectors of the national economy than it absorb. So we can check for the net multipliers of spillover effects of technology transfer. Conversely, if the share is less than one sector can be described as pure "consumer" of spillover effects of technology transfer.

Discussion

Analysis of technological flows based on the Leontief matrix augmened by vector of foreign direct investment is a new method; it wasn't introduced in any scientific literature. With the new methodology, there is the examination of issues related to the adequacy of the chosen instrument to solve discused issue. Leontief matrix augmented by expenditure on R&D is commonly used to investigate the diffusion of innovation across sectors and, consequently, to identify the core of the national innovation system, but foreign direct investment are different in nature and therefore we must very carefully evaluate possible spillover effects induced by foreign investment across sectors.

The advantage of input-output analysis is, it captures both direct and indirect cross-sectoral flows. Drawback is the possibility of examining only the vertical spillover effects , while potential horizontal spillover effects remain largely invisible, since the source data - symmetric input - output tables, do not distinguish the origin of firm ownership, and therefore can not be determined with certainty , whether the manufacturing process of the company in the hands of foreign investors were utilized from domestic firms or foreign investor ensured all the necessary inputs by himself (it is only input from the industry in which the foreign investor operates). In analysis of cross-sectoral spillover effects ownership problem still remains, but foreign investor is no longer capable of producing all the necessary inputs for the production of their commodities. There will inevitably arise technology flows and spillover effects caused by the foreign direct investment between different sectors of the national economy. We assume that the more intense the links between different sectors are, the more likely occures vertical spillover effects induced by FDI.

Since symetric input-output tables lump forms of business ownership, used analysis cannot explain how foreign investors affect domestic firms in the sector in which they operate or in other sectors of the national economy. If we wanted to watch the inside of sectoral or cross-sectoral impact of foreign investors on domestic firms, we must examine the degree of foreign presence in various sectors (or another suitable indicator). While we can assume the lower is presence of foreign investors in sector (but not negligible), the more likely is that the inputs / outputs used in the sector are delivered / consumed by domestic enterprises. Thus, there is the impact of foreign investor to resident company.

We also need to rethink the nature of individual foreign direct investments and exclude those which don´t carry embodied or disembodied technology transfer from FDI. For example, in the banking sector, where foreign investors poured into privatized subsidiary banks significant amounts of finance, but not intended for acquisition of new technologies, but for the purpose of lending.

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