Analysis of R&D Spillovers in the Ukrainian Economy

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Abstract. In this paper we study the product-embodied diffusion of the negative R&D spillovers that occurs via interindustry technological linkages. We calculate forward R&D price multipliers and price effects of R&D expenditures by industry for the Ukrainian economy. We present and discuss the estimates of the indicators for the period of time from 2001 till 2009.

1. Introduction

Stimulating innovation for sustainable economic growth is one of the main goals of the Ukrainian economy development. At the present stage of transformation processes in the national economy, a rational practical solution of this problem requires the elaboration of innovation-driven industrial policy which should be based on scientifically substantiated reliable estimations of innovation needs and opportunities of economic system. Such estimations should underlie the criteria elaboration of industrial priorities for effective industrial policy concepts, strategies and programs.

Technological progress is nowadays still a main, yet largely misunderstood contributor to total factor productivity growth in economic theory. The process of devising a new idea or thing, or improving an existing idea or thing, what is called innovation, is seems to be the major source of technological change. As a rule, innovation is a result of the research and development (R&D). Therefore the understanding of the R&D influence on economic growth is of great interest to economists.

In general, R&D activities in one industry can have repercussions in other industries of an economy. There are positive externalities in an economic system,

if both product quality and total factor productivity in an industry depend on R&D expenditures in other industries (see Wolff, 1997). Diffusion of these positive spillovers from one industry to another can be product-embodied and disembodied. It should be noted that, in the case of product-embodied diffusion which usually occurs via interindustry technological linkages and intermediate inputs, R&D expenditures diffusion takes place as well. The latter is known as one of the negative externalities of R&D expenditures (see Dietzenbacher & Los, 2002). Hence, in order to develop a successful industrial policy, it is important to understand both positive and negative externalities of R&D expenditures along with the channels of their diffusion within an economic system. The industry opportunities to create such externalities can be a criterion of industrial priorities of economic policy.

The amount, the direction, the channels of transmission and the effects of R&D spillovers has been quantified by various researchers (see Griliches, 1992; Mohnen, 1996; and the references cited therein). The econometric estimation of R&D spillovers consists of connecting a performance indicator in one industry to the R&D knowledge accumulated in other industries. Input-output analysis is a useful tool for this estimation (see Mohnen, 1997, as well as the other articles in the special issue of *Economic Systems Research*, 1997).

In this paper, we present and discuss the estimates of negative R&D spillovers in the Ukrainian economy for the period of time from 2001 till 2009 that have been obtained using the approach based on the Ghosh price model as described in Dietzenbacher & Los (2002). Following the used approach authors, we study product-embodied diffusion of negative R&D spillovers via intermediate inputs and assume that technological progress is proportional to R&D expenditures, and that the R&D embodiment in a product is the same for each of its purchasers, and that large parts of R&D expenditures are passed on to customers of the industry that engages in R&D, through higher prices. We try to define what proportion would the output value of (and the price charged by) industry *j* rise if the R&D costs incurred by industry *i* were increase by one unit.

The remainder of the paper is composed of three sections. We describe the model and statistical data using for estimating negative R&D spillovers in Section 2. Our estimation results are presented in Section 3. The final section concludes the paper.

2. Estimation model and statistical data

Following Dietzenbacher & Los (2002), we consider an input-output table where **Z** denote the matrix of domestic intermediate deliveries, **x** the vector of gross outputs, and **r** the vector of the R&D expenditures. Then, the typical element $b_{ij} = z_{ij} / x_i$ of matrix **B** denotes the share of the output of industry *i* that is sold to industry *j* and the inverse matrix can be computed as $G = (I - B)^{-1}$. Its typical element g_{ij} denotes the additional production costs in industry j that are made (directly and indirectly) when the primary costs in industry j are increased by one unit.

The negative R&D spillovers can be calculated using two types of forward multipliers, both measuring the total output increase as a percentage of the total output volume. The first type of multipliers considers such effects per one unite of R&D expenditures in industry *i* and is defined by the formula:

$$\frac{\sum_j g_{ij}}{\sum_j x_j}. \qquad (1)$$

The second type gives the effects for the actual R&D expenditures in industry *i* and is defined by the formula:

$$\frac{\sum_j r_i g_{ij}}{\sum_j x_j}. \qquad (2)$$

The multipliers in equations (1) and (2) describe the average percentage price increase in the economy, due to R&D expenditures (either one unit or the actual value) in industry *i*.

In this paper, the Ukrainian Input-Output Tables (see, for example, (Ukraine's Input–Output Table…, 2011)) and the statistical data regarding R&D

expenditures for the period of time from 2001 till 2009, which is contained in the official publications of the State Statistics Committee of Ukraine (see, (Scientific and Innovation Activity …, 2010)), has been used as the information base for the estimation of the forward multipliers in the national economy.

To calculate the estimations values for the CRO and the factor groups influence, we have used the data for 26 types of economic activity (such as agriculture, forestry, fishery, production of energy materials, production of non-energy materials, food-processing industries, textile and leather industry, woodworking, pulp and paper industry, publishing, manufacture of coke products, petroleum refinement and processing of nuclear fuel, manufacture of chemicals, rubber and plastic products, manufacture of other non-metallic mineral products, metallurgy and metal processing, manufacture of machinery and equipment, other production, electric energy, gas supply and water supply, construction, trade, hotels and restaurants, transport, post and telecommunications, financial intermediation, real estate transactions, renting and services to legal entities, public administration, education, health care and social assistance, community, social and personal service activities, and other activities).

Results of our estimations have been presented in the paper for 12 industries (such as production of energy materials, production of non-energy materials, food-processing industries, textile and leather industry, woodworking, pulp and paper industry, publishing, manufacture of coke products, petroleum refinement and processing of nuclear fuel, manufacture of chemicals, rubber and plastic products, manufacture of other non-metallic mineral products, metallurgy and metal processing, manufacture of machinery and equipment, other production, electric energy, gas supply and water supply).

3. Results of estimation

Our estimations of total forward R&D price multipliers computed by means of equation (1) are shown in Table 1. We report the estimation results obtained if only induced effects are taken into account in Table 2.

The first entry in Table 1, for example, indicates that an increase of R&D expenditures in production of energy materials amounting to 10^7 of Ukrainian hryvnia (UAH) would have yielded a 15.97 % increase of the output volume-weighted price index in 2001. The first entry in Table 2 shows that this UAH 10^7 increase in R&D expenditures of production of energy materials induces price increases in all other industries which, together, yield an increase of the national gross output value of 13.21 %. The difference between the values in Table 1 and Table 2 which is equal to 2.76 %, in this example, indicates an increase of the national gross output value caused by price increase in production of energy materials.

Table 1. Total forward R&D price multipliers for the Ukrainian economy in 2001-2009*

Type of economic activity	2001	2003	2005	2007	2009
Production of energy materials	15,97	11,86	7,57	4,21	3,28
Production of non-energy materials	5,52	3,97	2,72	1,72	1,26
Food-processing industries	2,73	2,18	1,33	0,74	0,59
Textile and leather industry	4,33	3,04	1,61	0,75	0,57
Woodworking, pulp and paper industry, publishing	7,01	5,83	3,12	1,88	1,35
Manufacture of coke products, petroleum refinement and processing of nuclear fuel	5,64	3,96	2,58	1,77	1,35
Manufacture of chemicals, rubber and plastic products	5,93	4,63	2,79	1,86	1,49
Manufacture of other nonmetallic mineral products	4,77	3,44	2,35	1,59	1,35
Metallurgy and metal processing	3,91	2,80	1,83	1,19	0,94
Manufacture of machinery and equipment	4,49	3,17	2,02	1,12	0,89
Other production	2,66	2,25	2,21	1,38	0,92
Electric energy, gas supply and water supply	5,92	4,51	2,74	1,60	1,31

* The values in the table should be divided by 10^9 to obtain the multiplier values.

As follows from Table 1 and Table 2, values of forward R&D price multipliers decreased for all types of economic activity from 2001 to 2009. This

tendency had been also observed for the U.S. economy (see Dietzenbacher & Los, 2002). Therefore, it can be considered as a positive trend of the structural change in the Ukrainian economic system.

Table 2. Induced forward R&D price multipliers for the Ukrainian economy in 2001-2009*

Type of economic activity	2001	2003	2005	2007	2009
Production of energy materials	13,21	10,01	6,52	3,59	2,78
Production of non-energy materials	3,38	2,39	1,80	1,15	0,82
Food-processing industries	0,35	0,26	0,20	0,09	0,07
Textile and leather industry	1,42	1,02	0,44	0,11	0,08
Woodworking, pulp and paper industry, publishing	4,06	3,46	1,77	1,04	0,74
Manufacture of coke products, petroleum refinement and processing of nuclear fuel	3,31	2,31	1,63	1,14	0,85
Manufacture of chemicals, rubber and plastic products	3,29	2,55	1,58	1,03	0,88
Manufacture of other nonmetallic mineral products	2,63	1,82	1,33	0,94	0,84
Metallurgy and metal processing	1,31	0,85	0,59	0,43	0,37
Manufacture of machinery and equipment	2,19	1,25	0,81	0,38	0,37
Other production	0,47	0,55	1,08	0,69	0,41
Electric energy, gas supply and water supply	3,68	2,82	1,75	0,99	0,82

* The values in the table should be divided by 10^9 to obtain the multiplier values.

However, the values of forward R&D price multipliers computed for some types of economic activity in the U.S. economy are 50 times smaller than corresponding values for the economy of Ukraine. It confirms that the Ukrainian economy still uses backward technologies and has relatively high share of intermediate consumption in GDP compared to developed countries of the world.

It should be noted that increase in R&D expenditures for the majority of industries would have yielded increases of prices in other economic activities to a greater extent than in the industry. Production of energy materials and electric energy, gas supply and water supply had relatively high values of ratios of induced

multipliers to total multipliers. But these economic activities are linked to energy supply of whole economic system and they are at an initial phase of interindustry technological process. They are also the priority industries in the Program of investment and innovation activity in Ukraine approved by the Ukrainian government (see, (Program…, 2011)).

In general, the effect level of industry R&D expenditures to prices in other economic activities is stipulated by the industry product place in the social production process. If the industry product share in intermediate consumption is relatively high then R&D expenditures of the industry have also greater influence on the prices increases in other industries than on its own price increase.

Table 3. Total price effects of R&D expenditures by industry for the Ukrainian economy in 2001-2009*

Type of economic activity	2001	2003	2005	2007	2009
Production of energy materials	9,99	5,57	9,48	7,35	5,72
Production of non-energy materials	1,88	13,06	1,84	2,09	1,54
Food-processing industries	2,84	1,86	0,22	0,70	0,56
Textile and leather industry	0,24	0,15	0,30	0,04	0,03
Woodworking, pulp and paper industry, publishing	0,04	0,00	0,54	0,00	0,00
Manufacture of coke products, petroleum refinement and processing of nuclear fuel	1,76	1,08	2,04	3,84	2,92
Manufacture of chemicals, rubber and plastic products	12,09	9,14	24,22	23,31	18,73
Manufacture of other nonmetallic mineral products	0,37	0,78	0,63	0,50	0,43
Metallurgy and metal processing	5,08	0,93	2,23	2,74	2,17
Manufacture of machinery and equipment	49,56	75,21	95,90	86,21	68,29
Other production	0,06	0,01	0,00	0,01	0,00
Electric energy, gas supply and water supply	1,88	0,12	0,73	0,68	0,56

* The values in the table should be divided by 10^5 to obtain the multiplier values.

Estimation results of total price effects of R&D expenditures obtained by application of equation (2) to Ukrainian data are shown in Table 3. We also present the estimations computed if only induced effects are taken into account in Table 4.

Table 4. Induced price effects of R&D expenditures by industry for the Ukrainian economy in 2001-2009*

Type of economic activity	2001	2003	2005	2007	2009
Production of energy materials	8,26	4,70	8,17	6,26	4,85
Production of non-energy materials	1,15	7,88	1,21	1,40	0,99
Food-processing industries	0,36	0,22	0,03	0,08	0,06
Textile and leather industry	0,08	0,05	0,08	0,01	0,00
Woodworking, pulp and paper industry, publishing	0,02	0,00	0,31	0,00	0,00
Manufacture of coke products, petroleum refinement and processing of nuclear fuel	1,04	0,63	1,29	2,46	1,85
Manufacture of chemicals, rubber and plastic products	6,72	5,03	13,71	12,88	11,05
Manufacture of other nonmetallic mineral products	0,20	0,41	0,36	0,30	0,27
Metallurgy and metal processing	1,70	0,28	0,72	0,98	0,85
Manufacture of machinery and equipment	24,19	29,78	38,48	29,59	28,67
Other production	0,01	0,00	0,00	0,00	0,00
Electric energy, gas supply and water supply	1,17	0,07	0,46	0,42	0,35

* The values in the table should be divided by 10^5 to obtain the multiplier values.

The first entry in Table 3, for example, indicates that actual R&D expenditures in production of energy materials have yielded a 0.00999 % increase of the output volume-weighted price index in 2001. The first entry in Table 4 shows that the expenditures induces price increases in all other industries which, together, yield an increase of the national gross output value of 0.00826 %. The difference between the values in Table 3 and Table 4 which is equal to 0.00173 %, in this example, indicates an increase of the national gross output value caused by price increase in production of energy materials.

As follows from Table 3 and Table 4, R&D expenditures in manufacture of machinery and equipment, manufacture of chemicals, rubber and plastic products, production of energy materials were sources of the largest negative spillovers in the Ukrainian economy from 2001 to 2009. The price effects of R&D expenditures in various industries had multidirectional dynamics. The negative spillovers induced by production of energy materials, production of non-energy materials, food-processing industries, textile and leather industry, woodworking, pulp and paper industry, publishing, metallurgy and metal processing, other production, electric energy, gas supply and water supply decreased during the analytical period. The indicators for other industries had opposite dynamics.

Thus, R&D expenditures in manufacture of machinery and equipment, production of energy materials caused the largest negative spillovers in the Ukrainian economy during the analytical period. But these types of economic activity are the priority industries in the Program of investment and innovation activity in Ukraine (see, (Program…, 2011)). Therefore, our estimation results cast doubt on the validity of the industrial priorities of the Program. For example, the choice of production of energy materials as a priority industry for the implementation of innovative projects is questionable. However, the development of specific proposals to improve the industrial policy requires further research of R&D spillovers.

4. Conclusions

In this paper, we have considered the product-embodied diffusion of negative R&D spillovers via intermediate inputs and interindustry technological linkages. We have described the model and statistical data using for estimating negative R&D spillovers. We have computed the indicators of both the forward R&D price multipliers and the price effects of R&D expenditures by industries for the Ukrainian economy for the period of time from 2001 till 2009.

The analysis of the indicators estimation results has shown that the Ukrainian economy remained technologically backward compared to developed

countries in 2001-2009. The ratio of R&D expenditures to GVA in the Ukrainian economy was significantly lower than in the leading countries of the world.

The level of industry R&D expenditure impact on prices in other economic activities has been caused by the industry product place in the technological process. If the industry product share in intermediate consumption was higher than other industries shares then R&D expenditures of the industry had also greater influence on the prices increases in other industries than on its own price increase.

However, we have found some positive tendencies in the Ukrainian economy structural indicators dynamics. For example, the values of forward R&D price multipliers have decreased for all industries.

The largest values of negative price effect have been observed for manufacture of machinery and equipment, manufacture of chemicals, rubber and plastic products, production of energy materials for the analytical period. At the same time, the validity of the choice of production of energy materials as a priority industry in the Program of investment and innovation activity in Ukraine is questionable. Estimates of positive R&D spillovers indicators by industries and their comparison with the values of the negative R&D spillovers can be very useful for the development of specific proposals to improve the industrial policy in Ukraine.

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