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Product-Embodied Diffusion of Innovations in Poland: R&D Multiplier Analysis

Dyfuzja innowacji w polskiej gospodarce: analiza mnożników R&D

1. Introduction

The end of Fordism, with its rigid production principles, an outward symptom of which was the economic crisis of the 1970s started the gradual evolution of economies towards a knowledge-based model, which has a great influence on various aspects of a firm's behaviour, especially on interrelationships between firms. Suffice it to say that what was to succeed Fordism were small firms, typically located in some communities and intimately intertwined with each other, being able to compete successfully in international markets. As more and more firms realized that competitive success increasingly involves the development of new products, incorporating innovations and continuous quality improvements, so that R&D activities were now seen to be of crucial importance.

The concept of the link between R&D and such important economic indications as productivity or employment levels has attracted researchers' attention at least as far back as Z. Griliche [8], who proposed a theoretical framework for analysing the effect of R&D on productivity which was to become a model for this kind of empirical investigation. Griliches's approach is based on a production function, setting aside inter-industry relationships, and that is why it does not necessarily portray correctly the role of R&D activity as one of the factors causing changes in

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overall productivity. Another tradition of investigating the impact of innovations on the economic landscape of a certain country or region involves using input-output tables to measure R&D spillovers, incorporating backward and forward multipliers analysis, which has a long history in an input-output context.

It is hardly an exaggeration to say that the contribution of the input-output framework to the development of the study of R&D activities and their impact on processes in the real-world economy is impressive. The input-output framework explicitly expresses the relationships that exist between industries within an economy. Each of these industries is simultaneously a buyer of inputs required in its own production and a seller of part of its production to other industries which become inputs for their production. This framework therefore offers opportunities for extending the analysis of widely conceived innovations to encompass not only technological progress coming from innovation within a certain industry but also the possibility that any industry may derive benefits from the innovative efforts of all other industries within the economy (or abroad), which are embodied in their output, through purchasing intermediate inputs as well as capital goods required for further production. The availability of input-output tables, investment tables, or both, is usually an indispensable prerequisite for any examination of the product-embodied diffusion of innovations [9, 11, 12, 16].

Of course, not all innovation transfers have concrete consituents in which they are embodied and which can be traced through market transactions between operating firms. Take for example, the transmission of ideas or knowledge which are, by their nature, disembodied. One of the ways these can be studied is by scrutinizing patent-information flow matrices or patent citation matrices. In this regard, B. Verspagen [15] used three matrices of knowledge spillovers derived from information collected by the European and US Patent Offices. The 650 thousand patents included in the dataset were categorized as claimable and unclaimable knowledge. In a study by H. van Meijl [14] aiming to measure the effect of knowledge spillovers on productivity growth the Yale technology flow matrix was employed comprising approximately 200 thousand patents for Canada in the period from 1972 to 1989. Another way of dealing with disembodied diffusion is by analysing technological proximity matrices [7, 10].

Poland is one of the countries where there is an urgent need to scrutinize the role of R&D in the economy. For almost a forty-year period, after the second world war, the Polish economy functioned under a centrally planned regime. The low degree of innovative efforts in a Soviet-type economic system, such as that of Poland after the second world war, is well recognized in the economic literature [1]. The inability to maintain a sufficiently high level of innovations in the economy was presumably the main reason for the collapse of the centrally planned system which took place in Poland at the beginning of the 1990s. The consequent transition process towards a market economy should be evaluated, first and foremost, in terms of providing the new economic system with efficient mechanisms for generating and diffusing innovations throughout the economy.

Unfortunately, a problem that has particularly plagued research into the role of R&D in the Polish economy stems from limited data. Therefore, this study can be seen as a first step on the way to a better understanding of the importance of R&D in shaping the economic landscape of Poland by specifically examining the product-embodied diffusion of innovations, applying the concept of backward and forward R&D multipliers proposed by E. Dietzenbacher and B. Los [5].

The rest of the paper is organized as follows. Section 2 discusses the concept of backward and forward R&D multipliers, addressing concerns about the inconvenient interpretation of forward multipliers involving the supply-driven model (Ghosh model) being viewed as a price model. In Section 3 a brief description of the data is provided which includes, among others, the required adjustments of the initial data which must be carried out to guarantee the full compatibility of data coming from different sources. Our empirical results are reported in Section 4, while the last section summarizes and concludes the paper.

2. Backward and Forward Multiplier definitions

The very concept of backward and forward multipliers, although exploited within empirical implementations of the input-output framework in various ways, is one of the issues that poses many difficulties both from a theoretical standpoint as well as when we try to give any economic meaning to the obtained results in terms of impact analysis. A stormy discussion appears to be concentrated especially on the use of total backward and total forward multipliers. This stems from the fact that unlike their direct counterparts, total multipliers cannot be considered independently of a specific model which is assumed to be suited to portraying the real processes in an economy. When total backward linkages are exploited, it is always implicitly assumed that the economy under consideration proceeds according to a demand-driven model or Leontief's model. When using total forward multipliers it is assumed that the analysed economy follows a supply-driven input-output model or Ghosh's model. As E. Davar [3] recently pointed, out the differences between these two approaches are even more striking than was previously believed [4].

Despite more sophisticated techniques for measuring linkages between industries that have emerged on the basis of the traditional concept of backward and forward multipliers [2], the latter still remains the old work horse of researchers interested in analysing inter-industry relationships based on an input-output framework. The reasons for the great popularity of the traditional concept of backward and forward multipliers are certainly many but the most plausible one is simplicity, as both multipliers can be obtained almost immediately from input-output tables in the form in which they are usually published by national statistical offices.

As will become obvious later on, simplicity is also the feature that characterized the approach suggested by E. Dietzenbacher and B. Los [5], which is meant to gain an insight into the extent to which R&D expenditures are embodied in the final output of an individual industry, on the one hand, and the portion of R&D expenditures of an individual industry that are embodied in each category of final demand, on the other. Let **Z** and **x** respectively denote the square matrix of intermediate deliveries and the column-vector of total output by industry. The portion of total output of a certain industry which is neither used for further production nor supplied to other industries as inputs goes toward meeting the final users' demand (which for all industries can be expressed as the column-vector **y**). Assuming that the amount of output of *i*th industry requiring as input by *j*th industry is proportional to the total output of the purchasing industry, and that such direct input coefficients constitute the matrix **A**, accounting equality, in matrix form, is given by

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{1}$$

Rearranging equation (1) yields

$$\mathbf{x} = \left(\mathbf{I} - \mathbf{A}\right)^{-1} \quad \mathbf{y} = \mathbf{L}^{-1}\mathbf{y} \tag{2}$$

where $\mathbf{L}^{-1}$ stands for the Leontief inverse in which each element denotes the output of *i*th industry that is required (directly and indirectly) per zloty of final demand for *j*th product.

Keeping in mind that, following from the above, the *j*th column of Leontief inverse consists of the amounts of production of all industries required in order to satisfy one zloty of final demand for *j*th product, backward multipliers are immediately obtained as

$$\boldsymbol{\beta} = \boldsymbol{\rho}\mathbf{L}^{-1} \tag{3}$$

where $\boldsymbol{\rho}$ denotes the row-vector of R&D intensity by industry defined as the ratios of R&D expenditures to total output.

So far final demand has been conceived of as a homogeneous category, without any reference to its ingredients. It is perhaps useful to specify more clearly before defining the forward multipliers into which detailed categories the final demand falls. Of prime importance, in terms of its share in overall final consumption, is private consumption, that is, consumption realized by households. Consumption by non-profit organizations serving households and by governments make up the rest, together forming a general category which will be referred to as "consumption" (**c**). Another part of final demand can be attributed to gross capital formation (**i**) comprising such sub-categories as Gross fixed capital formation and Changes in inventories. And finally, the last is Export (**e**), that is, consumption abroad. Note also that equality (1) requires Import (**m**) to be deducted from the sum of the above-mentioned categories of final demand to yield **y**.

While the backward multipliers are grounded on the traditional model of Leontief expressed by equation (2), the forward multipliers are rooted in the supply-driven input-output model of [6] which is given by

$$\mathbf{x}' = \mathbf{v}'(\mathbf{I} - \mathbf{B})^{-1} = \mathbf{v}'\mathbf{G} \tag{4}$$

where **B** stands for the matrix of output coefficients, b_{ij}, indicating the share of the output of *i*th industry that is sold to *j*th industry, and **v** denotes the column-vector of value added.

Let $\boldsymbol{\delta}^k$ designate the column-vector of intensities of *k*-category of final demand by industry, the forward multipliers can be obtained as follows

$$\boldsymbol{\varphi}^k = \mathbf{G}\boldsymbol{\delta}^k \tag{5}$$

Originally, with R&D expenditures being conceived as if they are costs, the forward multipliers were interpreted in terms of the additional production costs that are created (directly and indirectly) when the primary costs in the *i*th industry are increased by one [5]. This reasoning is closely related to the view that the supply-driven model can allegedly be a rewritten form of the Leontief price model [5]. The non-equivalence of these two models was recently demonstrated by E. Davar [3], who argues that any concordance of the models' results can take place only by chance; the author specifies the two rather unrealistic and unusual cases in which it may happens.

Despite the fact that in the light of Davar's critique the interpretation proposed by Dietzenbacher and Los can no longer be held, the practical applicability of the forward R&D multiplier concept seems not to be menaced. This is especially true when the multiplier analysis is carried out as the first step towards discovering the role played by innovation processes in an economy, as a tool providing an insight, albeit a rough one, into the mechanisms by which innovations from one industry are passed on to others.

3. Data

One of the features that distinguishes out study is that we start with Supply and Use matrices as opposed to previous studies in which a symmetrical form of input-output matrix was chosen as the point of departure. In the case of this study, there exist, however, at least two reasons why Supply and Use matrices should be preferred over their symmetrical alternative.

Firstly, for a country in a transition process from a centrally planned to a market model, like Poland, even changes in the R&D multiplier values that took place in the course of a single year may be of crucial importance for a better understanding of the economy's evolution since such countries experience higher rates of transformation than would be the case in a country with a well-rooted market economy. However, symmetrical input-output tables are published in Poland on a five-yearly basis which is commonly used by other developed countries, thereby precluding insight into R&D backward and forward multipliers more frequently than once every five-years. In contrast to this, Supply and Use tables were provided by The Central Statistical Office (CSO) every year during the period from 1995 to 2000. Unfortunately, after that date no consecutive tables have been published.

Secondly, all squared input-output tables available in Poland were compiled only product-by-product while annual statistics concerning R&D expenditures pertain to individual industries, not products of a given type. Furthermore, in the light of the latest arguments in the debate on an appropriate type of classification to be used in the process of compiling symmetrical input-output tables [13], the common conviction that the assumption of a product technology is more persuasive than the assumption of fixed product sales structure, which posits when compiling industry-by-industry input-output tables, appears questionable.

Following standard practice in analysing technological progress, we use business enterprise R&D expenditures coming directly from the CSO for the period 1995–2000 as a proxy for innovation, incorporating improvements in product quality and/or the production process. The sector classification applied by the CSO is rather detailed in the case of manufacturing industries (up to 3-digit NACE codes) and less so for service-industries (only NACE sections). Reconciling the aggregation level used by R&D expenditure statistics with that of the Supply-Use system eventually leaves us with 33 sectors which can be taken from the Appendix, along with the corresponding 2-digit NACE codes. It deserves, however, to be emphasized that the compilation process of the symmetrical input-output tables was carried out first under as disaggregated a product classification as possible, that is, 55 products, and only then were they aggregated to 33 sectors.

As demonstrated by B. Thage [13], reversing this order would lead an escalation of error within the compilation process, thereby blurring the actual relationships between industries.

With intermediate deliveries being assumed to act as carriers of the improved technology, is important how they are measured. The original data are valued at purchasing prices and incorporate intermediate goods and services that are produced abroad (import). Unfortunately, taxes and transportation margins as well as the import of goods and services were compiled by the CSO across products and no data across industries is available. Therefore, it was decided not to adjust the original data for import, transportation margins and taxes, although we are clear about the consequences of such a procedure. In our opinion, however, applying any known non-survey method might sometimes lead to even worse approximations of actual interindustrial flows than leaving them untouched due to the shortage of data.

4. Empirical results

We begin the presentation of our empirical results with a note that the values of each multiplier are ranked, according to a decreasing order, for every analysed year, so that if a given sector is assigned the number one, it means the highest value of the multiplier. The first portion of the results, total backward R&D multipliers, is listed in Table 1.

Although the differences in multiplier values across the years are not so large, it may be disturbing that they tend to decline over time (the average total backward multiplier is down by almost 20% in 2000 as compared to 1996). This largely reflects a global trend in business enterprise R&D expenditures during that period which mostly rose at decreasing rates and in 2000 it even happens that the sum of R&D expenditures appeared to be below that of the preceding year. As far as sectors' relative positions are considered, one can find that the largest multiplier values were those of "other transport equipment" (23), "radio, television and communication equipment" (20), "electrical machinery and apparatus" (19). Also, "machinery and equipment" (17) deserves to be classified into the same group along with the above-mentioned ones. All the sectors have sufficient similarities in their scope of operation to be categorized under the general heading "high-tech industries". The reverse occurs in the case of "low-tech industries" such as "publishing and printing" (10), "financial intermediation" (31), "wholesale and retail trade" (28), and "hotels and restaurants" (29) which experienced the lowest multiplier values during the entire period under consideration.

Table 2 presents the forward multipliers with respect to consumption.

Table 1
Total backward R&D multipliers

Sector	Year				
	1996	1997	1998	1999	2000
1	0.254 [22]	0.213 [23]	0.216 [23]	0.224 [21]	0.205 [19]
2	0.377 [13]	0.365 [12]	0.405 [13]	0.401 [12]	0.384 [13]
3	0.209 [26]	0.202 [25]	0.187 [25]	0.178 [26]	0.172 [26]
4	0.283 [18]	0.212 [24]	0.190 [24]	0.358 [13]	0.439 [12]
5	0.649 [9]	0.520 [11]	0.541 [10]	0.473 [11]	0.516 [9]
6	0.207 [27]	0.146 [28]	0.120 [29]	0.108 [30]	0.126 [28]
7	0.213 [25]	0.246 [18]	0.244 [19]	0.199 [24]	0.180 [25]
8	0.278 [20]	0.244 [19]	0.242 [20]	0.323 [14]	0.182 [24]
9	0.220 [24]	0.189 [26]	0.187 [26]	0.185 [25]	0.185 [23]
10	0.105 [33]	0.094 [33]	0.096 [33]	0.088 [33]	0.100 [31]
11	0.290 [17]	0.223 [20]	0.245 [18]	0.231 [20]	0.195 [21]
12	1.333 [3]	0.944 [5]	1.108 [5]	1.054 [6]	0.863 [4]
13	0.918 [6]	0.935 [6]	0.724 [8]	0.493 [10]	0.362 [14]
14	0.409 [12]	0.251 [17]	0.295 [15]	0.281 [16]	0.193 [22]
15	0.536 [11]	0.531 [10]	0.524 [11]	0.576 [8]	0.478 [10]
16	0.322 [15]	0.270 [16]	0.278 [17]	0.292 [15]	0.236 [16]
17	1.139 [5]	1.055 [4]	1.401 [4]	1.743 [2]	1.118 [3]
18	0.294 [16]	0.323 [13]	0.431 [12]	0.274 [17]	0.620 [6]
19	1.256 [4]	1.445 [2]	1.737 [2]	1.507 [3]	0.861 [5]
20	1.444 [2]	1.371 [3]	1.791 [1]	1.479 [4]	1.624 [1]
21	0.640 [10]	0.605 [9]	0.938 [7]	0.683 [7]	0.614 [7]
22	0.746 [8]	0.867 [7]	0.960 [6]	1.060 [5]	0.586 [8]
23	1.934 [1]	1.967 [1]	1.679 [3]	2.034 [1]	1.538 [2]
24	0.280 [19]	0.315 [14]	0.300 [14]	0.234 [19]	0.212 [17]
25	0.764 [7]	0.766 [8]	0.620 [9]	0.557 [9]	0.457 [11]
26	0.206 [28]	0.216 [21]	0.226 [22]	0.207 [23]	0.210 [18]
27	0.262 [21]	0.216 [22]	0.230 [21]	0.215 [22]	0.198 [20]
28	0.139 [31]	0.116 [32]	0.117 [31]	0.109 [29]	0.094 [33]
29	0.140 [30]	0.120 [30]	0.117 [30]	0.105 [31]	0.125 [29]
30	0.363 [14]	0.313 [15]	0.293 [16]	0.256 [18]	0.245 [15]
31	0.128 [32]	0.118 [31]	0.106 [32]	0.093 [32]	0.095 [32]
32	0.225 [23]	0.179 [27]	0.144 [27]	0.138 [28]	0.123 [30]
33	0.168 [29]	0.144 [29]	0.141 [28]	0.148 [27]	0.139 [27]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

Table 2

Total forward R&D multipliers in terms of the Polish consumption

Sector	Year				
	1996	1997	1998	1999	2000
1	124.045 [5]	122.438 [5]	116.629 [4]	119.180 [4]	155.004 [2]
2	73.447 [13]	73.386 [13]	74.390 [11]	77.690 [12]	77.031 [13]
3	140.660 [2]	139.891 [2]	132.433 [3]	137.629 [3]	147.008 [3]
4	351.264 [1]	348.425 [1]	346.432 [1]	518.591 [1]	466.064 [1]
5	88.501 [10]	85.041 [10]	69.511 [14]	78.453 [11]	59.448 [17]
6	77.506 [12]	78.110 [12]	71.450 [12]	51.229 [18]	99.552 [6]
7	132.561 [3]	122.448 [4]	110.679 [6]	114.267 [5]	124.939 [5]
8	49.002 [24]	50.440 [22]	43.709 [21]	45.465 [21]	49.708 [21]
9	102.987 [7]	96.474 [7]	90.612 [8]	85.796 [9]	84.883 [10]
10	117.148 [6]	114.936 [6]	111.919 [5]	108.406 [6]	97.964 [7]
11	131.103 [4]	134.649 [3]	160.208 [2]	173.848 [2]	132.077 [4]
12	93.613 [9]	94.812 [9]	90.329 [9]	92.044 [8]	97.888 [8]
13	73.107 [14]	70.873 [14]	63.602 [16]	61.633 [16]	57.195 [19]
14	51.550 [22]	57.911 [18]	53.862 [18]	58.522 [17]	70.234 [16]
15	40.776 [27]	39.589 [28]	41.514 [24]	40.716 [24]	37.437 [27]
16	49.574 [23]	49.772 [23]	43.605 [22]	41.261 [23]	44.927 [22]
17	38.865 [29]	35.125 [29]	32.289 [30]	28.471 [32]	36.462 [28]
18	39.861 [28]	41.174 [27]	37.738 [28]	37.013 [28]	26.173 [31]
19	46.168 [25]	43.970 [25]	39.498 [27]	37.677 [26]	35.745 [29]
20	53.261 [19]	52.452 [19]	39.966 [26]	38.022 [25]	44.346 [24]
21	31.389 [31]	31.583 [31]	26.604 [32]	29.034 [31]	29.041 [30]
22	46.045 [26]	42.407 [26]	41.027 [25]	32.666 [30]	41.968 [25]
23	28.285 [32]	26.352 [33]	26.600 [33]	20.278 [33]	15.150 [33]
24	54.051 [18]	46.632 [24]	42.517 [23]	45.201 [22]	59.222 [18]
25	51.773 [20]	51.289 [20]	50.936 [19]	50.885 [19]	44.830 [23]
26	79.187 [11]	79.028 [11]	78.309 [10]	78.724 [10]	82.722 [11]
27	23.515 [33]	34.887 [30]	31.942 [31]	34.776 [29]	40.154 [26]
28	37.310 [30]	27.965 [32]	32.586 [29]	37.453 [27]	19.074 [32]
29	65.957 [17]	63.996 [17]	53.893 [17]	68.656 [15]	80.908 [12]
30	51.615 [21]	50.830 [21]	48.997 [20]	50.581 [20]	53.190 [20]
31	66.033 [16]	68.577 [16]	70.301 [13]	74.232 [13]	71.948 [14]
32	72.803 [15]	69.492 [15]	65.761 [15]	70.770 [14]	71.374 [15]
33	95.049 [8]	96.408 [8]	95.119 [7]	95.907 [7]	96.696 [9]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

One conclusion is that they all are relatively high, perhaps with the exclusion of those producing typically investment goods such as "transport equipment" (23), "machinery and computers" (18), "machinery and equipment" (17), and "construction" (27). This is due to the fact that in Poland the extent to which final demand deliveries are used for consumption purposes (private and governmental consumptions) remains relatively high. The largest values of multipliers can be observed in the case of "tobacco products" (4) as well as "food products and beverages" (3), whose production is directed almost exclusively to non-investing users.

Table 3

Total forward R&D multipliers in terms of the Polish investment

Sector	Year				
	1996	**1997**	**1998**	**1999**	**2000**
1	2.454 [30]	3.000 [30]	3.364 [30]	2.612 [30]	4.305 [28]
2	16.249 [19]	16.927 [17]	17.771 [18]	19.608 [18]	17.675 [16]
3	1.295 [31]	1.406 [31]	1.456 [31]	1.549 [32]	2.373 [31]
4	0.283 [33]	0.294 [33]	0.042 [33]	0.051 [33]	0.426 [33]
5	8.052 [22]	7.838 [24]	6.797 [24]	9.317 [22]	7.786 [22]
6	5.033 [27]	4.753 [28]	4.255 [28]	4.413 [29]	1.920 [32]
7	6.295 [24]	6.848 [25]	5.184 [26]	6.297 [26]	5.584 [26]
8	26.386 [14]	24.765 [14]	24.276 [14]	23.201 [15]	25.220 [15]
9	10.171 [21]	9.774 [21]	9.794 [21]	11.040 [21]	10.376 [21]
10	7.959 [23]	9.078 [22]	7.967 [22]	7.896 [24]	6.646 [23]
11	17.545 [17]	16.886 [18]	21.903 [17]	32.413 [12]	14.604 [18]
12	16.380 [18]	16.101 [19]	15.612 [19]	16.830 [19]	12.792 [20]
13	26.284 [15]	25.152 [13]	25.249 [13]	27.652 [14]	35.040 [10]
14	47.182 [6]	43.457 [8]	44.435 [6]	41.088 [9]	33.324 [11]
15	30.174 [11]	31.166 [11]	32.352 [11]	33.981 [11]	29.761 [13]
16	36.426 [8]	38.142 [9]	38.173 [9]	40.339 [10]	39.974 [8]
17	54.574 [4]	57.823 [5]	54.372 [3]	59.090 [3]	55.656 [4]
18	80.096 [1]	78.032 [1]	46.765 [4]	46.348 [6]	60.601 [2]
19	35.058 [9]	36.202 [10]	43.537 [8]	44.093 [8]	35.410 [9]
20	48.766 [5]	50.404 [7]	44.487 [5]	45.233 [7]	46.943 [7]
21	77.145 [2]	74.677 [2]	73.090 [1]	68.987 [1]	75.093 [1]
22	47.053 [7]	57.242 [6]	43.721 [7]	53.672 [4]	51.646 [5]
23	31.963 [10]	68.640 [3]	36.885 [10]	49.755 [5]	49.036 [6]
24	29.118 [12]	23.602 [15]	22.204 [16]	22.466 [16]	30.039 [12]
25	28.739 [13]	28.989 [12]	28.385 [12]	29.273 [13]	26.620 [14]
26	12.820 [20]	12.706 [20]	11.860 [20]	13.269 [20]	14.091 [19]
27	67.115 [3]	61.868 [4]	63.985 [2]	61.961 [2]	56.484 [3]
28	3.403 [29]	3.659 [29]	4.930 [27]	5.258 [28]	4.362 [27]

Table 3 cont.

29	4.971 [28]	5.085 [27]	3.994 [29]	5.334 [27]	3.368 [29]
30	6.254 [25]	5.813 [26]	5.994 [25]	7.421 [25]	6.385 [24]
31	5.404 [26]	8.301 [23]	7.803 [23]	8.390 [23]	6.318 [25]
32	19.153 [16]	19.656 [16]	22.284 [15]	19.686 [17]	16.206 [17]
33	0.701 [32]	1.064 [32]	1.408 [32]	1.639 [31]	2.557 [30]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

According to what has just been said, if industries whose production serve mostly consumption purposes have the highest multipliers, and those producing largely investment goods the lowest multipliers with respect to consumption, the reverse should be expected when focusing on forward multipliers with respect to investment. As demonstrated by the figures reported in Table 3, this presumption appears true. Of every (hypothetical) R&D zloty in “machinery and computers” (18), “medical, precision and optical instruments“ (21), “machinery and equipment” (17), and “construction” (27), up to 80 pennies (grosz) are embodied in investment goods. In contrast to this, for such industries as “tobacco products” (4) as well as “food products and beverages” (3), and “public administration and defence” (33) the corresponding ratios range from above 2.5% to almost 0.3%.

The total forward multipliers with respect to export are listed in Table 4. One can see, at first glance, that they vary more during the period under consideration than is the case of those presented so far, indicating that Polish export changed more rapidly as compared to other parts of the final demand. The pro-export industries experienced high values of the multiplier. Of these “wearing apparel and dressing” (6) and “textiles” (5) particularly deserve to be mentioned as, on average, almost 70 pennies (grosz) of every (hypothetical) R&D zloty spent by them are embodied in export goods. Other industries with the largest multipliers include “basic metals” (15) and “other transport equipment” (23). Industries in which export is almost entirely impossible like, for example, “public administration and defence” (33) and “wholesale and retail trade” (28) have the lowest values of the multiplier in the economy.

What cannot be gleaned from equations (3) and (5) are effects originating from other industries. Following the notation introduced by E. Dietzenbacher and B. Los [5], those R&D embodiments that originate from other industries will be referred to as induced components, and can be ascertained as:

$$\boldsymbol{\beta}^{ind} = \boldsymbol{\beta} - \boldsymbol{\rho}\left(\mathbf{I} - \hat{\mathbf{d}}_{\mathbf{A}}\right)^{-1} \tag{6}$$

$$\boldsymbol{\varphi}^{ind,k} = \boldsymbol{\varphi}^{k} - \left(\mathbf{I} - \hat{\mathbf{d}}_{\mathbf{B}}\right)^{-1} \boldsymbol{\delta}^{k} \tag{7}$$

where $\mathbf{d}_{\mathbf{A}}$ and $\mathbf{d}_{\mathbf{B}}$ stand for the main diagonals of the original **A** and **B** matrices.

Not surprisingly, it turned out that a large part of the total backward multiplier is attributable to intra-industry effects in the case of such sectors as “chemicals” (12), “radio, television and communication equipment” (20), and “motor vehicles” (23), whereas typically service-oriented industries like, for example, “wholesale and retail trade” (27), “hotels and restaurants” (28), and “financial intermediation” (31) are characterized by relatively higher inter-industry effects (see Table A.2 in Appendix). The small part of the total backward multiplier associated with intra-industry effects can also be observed in “wearing apparel” (6) as well as “publishing and printing” (10). Despite the great variation in the induced backward multipliers when compared to their total counterparts, focusing attention on the former yields almost the same results, in terms of the top ranked industries, as previously. Only “machinery and equipment” (17) and “radio, television and communication equipment” (20) now rank substantially lower. Simultaneously, among the industries which improved their positions on the list is “recycling” (25). Taking its particular role into account, this finding should be paid only scant attention.

Table 4

Total forward R&D multipliers in terms of the Polish export

Sector	Year				
	1996	1997	1998	1999	2000
1	16,563 [25]	19,158 [25]	19,112 [26]	17,801 [25]	21,273 [21]
2	41,796 [12]	41,851 [11]	40,366 [13]	41,170 [11]	42,177 [12]
3	17,215 [24]	20,101 [24]	18,217 [27]	15,841 [26]	18,075 [23]
4	48,948 [8]	46,148 [9]	41,105 [12]	43,499 [8]	11,385 [27]
5	53,327 [4]	57,064 [4]	68,130 [2]	55,427 [3]	82,984 [1]
6	70,897 [1]	73,755 [1]	74,234 [1]	93,615 [1]	61,889 [2]
7	46,485 [9]	61,072 [2]	58,274 [3]	52,664 [5]	55,079 [6]
8	50,457 [6]	51,238 [5]	52,987 [6]	52,655 [6]	59,324 [3]
9	37,763 [14]	40,996 [12]	41,263 [11]	40,812 [12]	42,899 [10]
10	14,181 [29]	15,787 [27]	15,430 [29]	14,153 [30]	11,052 [28]
11	50,145 [7]	47,877 [8]	57,593 [4]	57,219 [2]	34,810 [16]
12	44,668 [10]	40,041 [13]	37,828 [14]	34,396 [17]	34,102 [17]
13	42,004 [11]	43,393 [10]	41,945 [10]	41,857 [10]	38,338 [15]
14	33,633 [18]	30,872 [16]	30,042 [21]	29,410 [20]	28,887 [19]
15	57,653 [2]	57,472 [3]	52,943 [7]	54,006 [4]	57,547 [4]
16	35,744 [15]	35,067 [15]	35,827 [16]	36,155 [16]	41,676 [13]
17	27,846 [21]	26,017 [19]	27,175 [24]	25,307 [22]	29,763 [18]
18	11,930 [31]	12,224 [30]	30,302 [20]	31,547 [18]	16,381 [26]
19	38,219 [13]	38,059 [14]	35,954 [15]	37,382 [14]	48,387 [8]
20	29,291 [19]	26,577 [18]	35,520 [17]	36,910 [15]	39,264 [14]

Table 4 cont.

21	13,425 [30]	13,496 [29]	13,218 [30]	14,915 [28]	17,084 [25]
22	29,290 [20]	22,318 [22]	33,043 [19]	31,446 [19]	47,780 [9]
23	56,279 [3]	22,280 [23]	44,734 [8]	39,209 [13]	52,042 [7]
24	35,629 [16]	48,598 [7]	53,613 [5]	51,695 [7]	57,145 [5]
25	52,058 [5]	51,026 [6]	44,324 [9]	43,360 [9]	42,518 [11]
26	16,265 [26]	15,586 [28]	15,685 [28]	15,649 [27]	18,019 [24]
27	16,055 [27]	10,344 [31]	10,757 [31]	10,625 [31]	7,994 [30]
28	4,387 [32]	4,654 [32]	5,957 [32]	5,356 [32]	4,009 [32]
29	20,394 [23]	22,948 [21]	34,444 [18]	18,664 [24]	4,277 [31]
30	24,731 [22]	27,099 [17]	28,077 [22]	28,125 [21]	26,469 [20]
31	34,749 [17]	25,919 [20]	27,315 [23]	21,631 [23]	18,448 [22]
32	15,653 [28]	18,561 [26]	19,262 [25]	14,686 [29]	9,990 [29]
33	1,544 [33]	2,498 [33]	3,527 [33]	2,902 [33]	1,851 [33]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

Regarding the analogue of the forward multiplier based exclusively upon inter-industry effects with respect to consumption, it should be stated that the industries with the highest multiplier values include the primary industries "agriculture" (1), "mining and quarrying" (2) as well as "pulp and paper" (9) and "coke and refined petroleum products" (11) (see Table A.3 in Appendix). This means that relatively more R&D-intensive intermediate inputs are used up to maintain the production of these industries. The differences between the rankings of the industries are also observable when focusing on the multipliers with respect to investment and export as well (see tables A.4 and A.5 in Appendix). The extent to which every (hypothetical) R&D zloty is embodied in investment goods through inter-industry relationships is highest for "non-metallic mineral products" (14), "rubber and plastic products" (13), and "basic metals" (15). As far as the R&D embodiment in exporting goods is concerned, such industries as "recycling" (25), "coke and refined petroleum products" (11), and "textiles" (5) seem to be superior. Caution is indeed needed when trying to interpret the relatively high value of the multiplier in the case of the "recycling" sector for the same reasons as those mentioned above in the context of the induced backward multiplier.

5. Conclusions

Utilizing the concept of backward and forward R&D multipliers this study aims at providing a further insight into the process of creating innovations and their consequent spillover throughout the Polish economy. The most alarming finding is that the backward multipliers weaken over time, as a result of rates of R&D expenditure growth that appeared to be insufficient to offset the effects associated with the growth of the economy as a whole. Regarding differences in the backward R&D multiplier values across sectors it turned out that "high-tech" industries are characterized, in general, by large multipliers whereas low multipliers are rather typical of "low-tech" industries.

The promise of the forward R&D multiplier finds support within our study. By applying this concept it was possible to state that industries catering almost exclusively for final users have the largest multipliers with respect to consumption. The industries manufacturing capital (investment) goods, on the other hand, experienced the highest multipliers with respect to investment. Completing the results by singling out that part of the total multiplier being attributable to inter-industry transfers of innovation (induced effects) reveals differences in the rankings of the industries when intra-industry effects are set aside.

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Appendix

Table A.1

List of the sectors included in the study

No.	NACE	Description
1	A to B	Agriculture, hunting, forestry and fishing
2	C	Mining and quarrying
3	DA15	Manufacture of food products and beverages
4	DA16	Manufacture of tobacco products
5	DB17	Manufacture of textiles
6	DB18	Manufacture of wearing apparel; dressing; dyeing of fur
7	DC19	Tanning, dressing of leather; manufacture of luggage
8	DD20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
9	DE21	Manufacture of pulp, paper and paper products
10	DE22	Publishing, printing, reproduction of recorded media
11	DF23	Manufacture of coke, refined petroleum products and nuclear fuel
12	DG24	Manufacture of chemicals and chemical products
13	DH25	Manufacture of rubber and plastic products
14	DI26	Manufacture of other non-metallic mineral products
15	DJ27	Manufacture of basic metals
16	DJ28	Manufacture of fabricated metal products, except machinery and equipment
17	DK29	Manufacture of machinery and equipment n.e.c.
18	DL30	Manufacture of office machinery and computers
19	DL31	Manufacture of electrical machinery and apparatus n.e.c.
20	DL32	Manufacture of radio, television and communication equipment and apparatus
21	DL33	Manufacture of medical, precision and optical instruments, watches and clocks
22	DM34	Manufacture of motor vehicles, trailers and semi-trailers
23	DM35	Manufacture of other transport equipment
24	DN36	Manufacture of furniture; manufacturing n.e.c.
25	DN37	Recycling
26	E	Electricity, gas and water supply
27	F	Construction
28	G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
29	H	Hotels and restaurants
30	I	Land transport; transport via pipelines; water transport; air transport; supporting and auxiliary transport activities; activities of travel agencies; post and telecommunications
31	J	Financial intermediation
32	K	Real estate, renting and business activities
33	L to Q	Public administration and defence, compulsory social security; education; health and social work; other community, social and personal service activities; private households with employed persons; extra-territorial organizations and bodies

Table A.2

Induced backward R&D multipliers

Sector	Year				
	1996	1997	1998	1999	2000
1	0.168 [23]	0.134 [24]	0.143 [21]	0.137 [18]	0.118 [19]
2	0.136 [29]	0.124 [26]	0.126 [24]	0.123 [23]	0.107 [22]
3	0.183 [18]	0.150 [20]	0.149 [20]	0.135 [19]	0.137 [10]
4	0.173 [21]	0.119 [28]	0.114 [29]	0.076 [31]	0.096 [25]
5	0.230 [10]	0.174 [15]	0.170 [17]	0.132 [20]	0.123 [18]
6	0.180 [20]	0.146 [21]	0.120 [25]	0.108 [26]	0.126 [15]
7	0.213 [14]	0.184 [12]	0.182 [14]	0.127 [22]	0.111 [21]
8	0.195 [15]	0.161 [18]	0.170 [16]	0.160 [14]	0.132 [12]
9	0.164 [24]	0.135 [23]	0.131 [22]	0.119 [24]	0.124 [17]
10	0.102 [31]	0.091 [31]	0.094 [31]	0.087 [30]	0.084 [29]
11	0.156 [26]	0.130 [25]	0.130 [23]	0.139 [17]	0.106 [23]
12	0.156 [25]	0.138 [22]	0.119 [26]	0.110 [25]	0.091 [27]
13	0.334 [2]	0.237 [5]	0.244 [7]	0.223 [5]	0.178 [2]
14	0.216 [13]	0.178 [13]	0.178 [15]	0.163 [12]	0.113 [20]
15	0.266 [5]	0.224 [7]	0.207 [9]	0.196 [8]	0.149 [6]
16	0.256 [7]	0.219 [8]	0.221 [8]	0.211 [7]	0.180 [1]
17	0.224 [11]	0.201 [9]	0.197 [12]	0.185 [10]	0.146 [7]
18	0.189 [16]	0.198 [10]	0.245 [6]	0.194 [9]	0.069 [32]
19	0.259 [6]	0.230 [6]	0.255 [5]	0.239 [4]	0.169 [3]
20	0.255 [8]	0.243 [3]	0.265 [3]	0.216 [6]	0.097 [24]
21	0.188 [17]	0.173 [16]	0.204 [10]	0.153 [16]	0.129 [14]
22	0.288 [3]	0.258 [2]	0.261 [4]	0.307 [1]	0.131 [13]
23	0.272 [4]	0.241 [4]	0.306 [1]	0.280 [2]	0.159 [5]
24	0.237 [9]	0.194 [11]	0.200 [11]	0.178 [11]	0.141 [9]
25	0.336 [1]	0.304 [1]	0.265 [2]	0.246 [3]	0.164 [4]
26	0.171 [22]	0.166 [17]	0.167 [18]	0.158 [15]	0.145 [8]
27	0.216 [12]	0.174 [14]	0.182 [13]	0.162 [13]	0.134 [11]
28	0.136 [28]	0.114 [30]	0.115 [28]	0.107 [27]	0.091 [26]
29	0.140 [27]	0.120 [27]	0.117 [27]	0.105 [28]	0.125 [16]
30	0.183 [19]	0.158 [19]	0.156 [19]	0.128 [21]	0.089 [28]
31	0.128 [30]	0.118 [29]	0.106 [30]	0.093 [29]	0.069 [31]
32	0.091 [32]	0.083 [32]	0.080 [32]	0.076 [32]	0.074 [30]
33	0.087 [33]	0.073 [33]	0.076 [33]	0.066 [33]	0.063 [33]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

Table A.3

Induced forward R&D multipliers in terms of the Polish consumption

Sector	Year				
	1996	**1997**	**1998**	**1999**	**2000**
1	73.520 [3]	75.495 [3]	71.225 [3]	68.870 [3]	101.782 [1]
2	60.700 [5]	61.436 [4]	60.096 [4]	63.807 [4]	71.871 [4]
3	20.597 [23]	17.473 [24]	16.044 [23]	19.058 [22]	30.518 [16]
4	3.245 [33]	2.561 [33]	0.952 [33]	1.334 [33]	7.063 [32]
5	49.623 [9]	45.600 [9]	33.740 [15]	32.137 [15]	38.770 [11]
6	21.068 [22]	19.409 [23]	15.608 [25]	15.705 [27]	9.479 [29]
7	38.904 [13]	35.753 [16]	17.332 [22]	17.831 [24]	11.541 [27]
8	38.194 [14]	36.536 [15]	30.136 [16]	30.563 [16]	36.117 [12]
9	90.531 [1]	79.703 [1]	73.989 [2]	70.531 [2]	75.137 [3]
10	53.290 [7]	52.523 [6]	49.277 [6]	44.569 [7]	41.544 [10]
11	85.677 [2]	76.625 [2]	95.650 [1]	119.719 [1]	77.803 [2]
12	56.592 [6]	49.913 [8]	46.285 [8]	44.218 [8]	49.045 [6]
13	65.290 [4]	58.711 [5]	50.978 [5]	49.506 [5]	46.616 [8]
14	39.315 [12]	44.309 [10]	40.757 [10]	42.163 [10]	47.106 [7]
15	36.343 [16]	34.308 [18]	35.784 [13]	34.970 [13]	32.934 [14]
16	41.107 [11]	42.075 [12]	35.329 [14]	33.807 [14]	35.852 [13]
17	29.839 [19]	27.186 [19]	24.193 [17]	18.828 [23]	25.443 [18]
18	20.517 [24]	21.926 [22]	22.330 [19]	22.194 [19]	17.541 [23]
19	34.965 [17]	35.229 [17]	23.803 [18]	23.475 [18]	32.750 [15]
20	13.818 [30]	11.194 [31]	22.195 [20]	22.128 [20]	13.758 [25]
21	16.863 [26]	16.475 [25]	13.907 [27]	16.791 [26]	17.958 [22]
22	14.953 [27]	11.216 [30]	12.768 [30]	5.946 [32]	10.639 [28]
23	14.415 [28]	12.535 [28]	15.862 [24]	8.980 [29]	8.833 [30]
24	20.446 [25]	15.423 [26]	11.415 [31]	7.401 [30]	24.647 [20]
25	50.074 [8]	49.962 [7]	49.065 [7]	48.891 [6]	42.172 [9]
26	46.828 [10]	42.415 [11]	39.931 [11]	42.735 [9]	57.876 [5]
27	13.921 [29]	13.903 [27]	13.065 [29]	16.838 [25]	15.261 [24]
28	11.399 [31]	12.443 [29]	13.633 [28]	14.123 [28]	7.519 [31]
29	23.168 [21]	22.079 [21]	15.405 [26]	19.424 [21]	12.943 [26]
30	24.932 [20]	22.542 [20]	21.709 [21]	23.807 [17]	24.811 [19]
31	32.716 [18]	38.199 [13]	43.008 [9]	40.805 [11]	24.276 [21]
32	38.148 [15]	37.045 [14]	35.854 [12]	39.563 [12]	27.783 [17]
33	3.331 [32]	4.991 [32]	5.893 [32]	6.559 [31]	5.506 [33]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

Table A.4

Induced forward R&D multipliers in terms of the Polish investment

Sector	Year				
	1996	1997	1998	1999	2000
1	2.620 [28]	2.662 [29]	3.059 [27]	3.073 [28]	3.865 [24]
2	16.072 [10]	16.752 [9]	17.331 [8]	19.153 [7]	17.375 [8]
3	1.216 [31]	1.325 [31]	1.404 [31]	1.493 [32]	2.285 [28]
4	0.167 [33]	0.165 [33]	0.041 [33]	0.060 [33]	0.410 [33]
5	7.537 [18]	7.244 [19]	5.795 [21]	8.149 [18]	6.796 [15]
6	4.889 [24]	4.611 [24]	4.044 [25]	4.185 [24]	1.735 [31]
7	5.462 [22]	6.093 [21]	3.045 [28]	4.376 [23]	5.120 [21]
8	23.331 [6]	20.734 [7]	19.473 [7]	18.796 [8]	21.028 [6]
9	10.151 [13]	9.753 [14]	9.675 [16]	10.911 [14]	10.250 [12]
10	6.673 [20]	7.715 [18]	7.794 [17]	7.718 [20]	5.645 [19]
11	17.509 [8]	16.852 [8]	21.899 [5]	32.409 [2]	14.588 [9]
12	16.193 [9]	15.912 [10]	15.519 [10]	16.740 [10]	12.594 [11]
13	25.369 [4]	24.282 [5]	22.692 [4]	24.883 [5]	30.775 [2]
14	46.522 [1]	42.820 [1]	43.175 [1]	39.907 [1]	31.980 [1]
15	24.127 [5]	24.762 [3]	26.542 [3]	27.249 [4]	26.226 [3]
16	23.191 [7]	23.107 [6]	20.601 [6]	22.267 [6]	23.690 [5]
17	11.670 [11]	12.443 [11]	10.935 [13]	9.902 [16]	10.035 [13]
18	8.460 [15]	9.302 [15]	15.179 [12]	15.252 [12]	8.609 [14]
19	25.530 [3]	24.346 [4]	16.842 [9]	16.752 [9]	19.650 [7]
20	7.526 [19]	6.427 [20]	15.282 [11]	15.399 [11]	4.656 [22]
21	7.859 [17]	8.459 [16]	7.364 [18]	9.102 [17]	5.203 [20]
22	4.572 [26]	3.964 [27]	5.291 [23]	3.011 [29]	3.558 [25]
23	4.701 [25]	4.337 [26]	6.509 [20]	3.997 [25]	2.178 [29]
24	7.899 [16]	5.995 [22]	4.732 [24]	3.008 [30]	4.396 [23]
25	28.580 [2]	28.831 [2]	28.135 [2]	29.003 [3]	26.045 [4]
26	10.896 [12]	10.875 [12]	10.655 [14]	12.163 [13]	13.218 [10]
27	2.012 [30]	2.157 [30]	2.255 [30]	3.520 [26]	3.051 [27]
28	2.445 [29]	2.784 [28]	2.976 [29]	3.399 [27]	1.867 [30]
29	4.325 [27]	4.502 [25]	3.342 [26]	4.775 [22]	3.226 [26]
30	5.632 [21]	5.214 [23]	5.398 [22]	6.836 [21]	5.954 [18]
31	4.968 [23]	7.835 [17]	7.362 [19]	7.896 [19]	6.318 [17]
32	9.900 [14]	9.800 [13]	10.296 [15]	10.417 [15]	6.637 [16]
33	0.634 [32]	1.005 [32]	1.343 [32]	1.578 [31]	1.225 [32]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.

Table A.5
Induced forward R&D multipliers in terms of the Polish export

Sector	Year				
	1996	**1997**	**1998**	**1999**	**2000**
1	11.198 [17]	13.061 [13]	12.787 [13]	10.976 [15]	15.985 [11]
2	20.961 [6]	21.043 [5]	21.125 [4]	21.230 [5]	23.153 [3]
3	3.043 [31]	3.190 [30]	3.146 [31]	3.203 [29]	4.304 [24]
4	0.487 [33]	0.451 [33]	0.155 [33]	0.191 [33]	0.642 [33]
5	24.229 [4]	25.491 [3]	20.113 [7]	22.107 [3]	23.566 [2]
6	5.449 [27]	5.211 [25]	4.664 [27]	4.734 [25]	2.066 [30]
7	12.084 [16]	12.292 [15]	6.548 [22]	7.451 [21]	7.853 [17]
8	16.024 [11]	17.133 [9]	16.257 [9]	15.519 [9]	18.299 [6]
9	18.593 [8]	18.150 [7]	17.723 [8]	16.361 [8]	15.961 [12]
10	10.596 [18]	11.524 [18]	11.300 [16]	9.550 [18]	6.939 [20]
11	26.713 [3]	25.614 [2]	32.502 [2]	37.906 [2]	22.170 [5]
12	21.392 [5]	20.236 [6]	20.217 [6]	18.717 [7]	16.166 [10]
13	27.199 [2]	25.030 [4]	23.070 [3]	22.090 [4]	17.026 [8]
14	18.127 [9]	14.848 [11]	15.014 [11]	14.395 [11]	14.628 [13]
15	20.039 [7]	17.667 [8]	20.926 [5]	19.968 [6]	22.498 [4]
16	17.305 [10]	16.962 [10]	15.200 [10]	15.110 [10]	17.327 [7]
17	12.462 [14]	10.741 [19]	10.522 [18]	8.327 [20]	9.709 [15]
18	6.398 [23]	6.692 [21]	10.167 [19]	9.976 [17]	7.520 [18]
19	14.592 [12]	12.368 [14]	10.616 [17]	10.291 [16]	13.057 [14]
20	6.558 [22]	4.938 [26]	9.693 [20]	9.548 [19]	3.802 [27]
21	6.363 [24]	6.097 [23]	5.970 [25]	6.932 [22]	4.467 [23]
22	5.272 [28]	4.080 [28]	6.019 [24]	2.706 [30]	3.875 [26]
23	6.344 [25]	5.730 [24]	7.034 [21]	3.748 [28]	3.338 [29]
24	5.831 [26]	4.443 [27]	3.871 [29]	2.542 [31]	4.580 [22]
25	46.836 [1]	45.563 [1]	39.872 [1]	38.457 [1]	29.156 [1]
26	14.581 [13]	13.926 [12]	14.077 [12]	13.635 [12]	16.323 [9]
27	3.073 [30]	3.188 [31]	3.450 [30]	4.343 [26]	3.374 [28]
28	3.081 [29]	3.420 [29]	3.904 [28]	3.886 [27]	2.030 [31]
29	7.342 [20]	7.535 [20]	5.502 [26]	6.266 [23]	3.972 [25]
30	6.884 [21]	6.287 [22]	6.508 [23]	6.185 [24]	6.476 [21]
31	7.989 [19]	11.540 [17]	12.061 [14]	11.235 [14]	7.134 [19]
32	12.220 [15]	11.779 [16]	12.017 [15]	12.532 [13]	8.165 [16]
33	1.019 [32]	1.783 [32]	2.299 [32]	2.323 [32]	1.338 [32]

The values are expressed in percentages. Ranks, according to a decreasing order, are shown in the parentheses.