Analysis of the US technological spillovers over the Mexican economy.

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Abstract

The paper focus on the international transfer of technology from developed to developing countries and its dissemination in the later ones. In general terms, it can be assumed that one of the channels for the international diffusion of technology is the import of components technologically intensives that are later incorporated to the productive process spreading out their embodied technology. We will use an input-output framework along with the expenditures in R&D to study the interindustrial structure of technological flows between U.S. and Mexico. We will obtain a general picture of the sectoral structure of the innovation system, which allows us to analyse the producers and users of the technology generated in the economy. In order to obtain an estimation of the US innovation embodied in the Mexican imports we will use the matrix of intersectoral technology investment flows and the trade statistic among both countries.

Keywords: International R&D transfer, trade, input-output analysis

JEL classification: C67, F1O3,

1.- Introduction.

The understanding of the technology role in economic growth is a topic of great interest among economists. Endogenous growth theories introduced technology in the growth equation and emphasized the importance of Research and Development (R&D) spillovers.

There are many channels of innovation transmission and each one generates a particular diffusion pattern. Moreover, they affect in different ways industrial productivity growth, competitiveness and firm's incentives to invest in innovation. This transmission can be embodied in the description of new process or tradable products or it can also be disseminated through conferences, as part of the human capital that researches and scientists take with themselves when migrating, through merger and acquisition operations or others cooperation alliances between companies.

International transfer of technology begins with the generation of an innovation, which implies the development of a new idea that ends up being introduced in the productive process. The next step concerns the transfer and dissemination of that innovation either at a national or international level. This process uses several channels, including trade of goods and services, foreign direct investment, alliances between firms or others institutions and the migration of scientists and researches.

In terms of the agents involved in the whole process, innovations and its diffusion is concentrated inside multinationals. Those, in turn, concentrates their R&D activity in developed countries, whereas local subsidiaries in developing countries are generally focused on the adaptation of products to the local market demand or to some sort of technical support to production in certain industries. This implies an important distinction between net suppliers and adopters of technology. The first ones are mainly developed countries while the second are developing ones.

This paper is aimed to develop an approach to the analysis of potential transfer of technology from a net producer of innovation like US to a net user of that innovation, like Mexico. In order to do that we will estimate the technology embodied in the commerce between those countries, using as a measure of the innovation efforts the expenditures in R&D. The total technology investment embodied in the US exports to Mexico can be used as a proxy to the potential technology transferred from USA to Mexico by trade. Obviously, this is just one of the several channels for international transfer of technology and the results should be completed taking into account the other channels mentioned.

2.- Theoretical framework and model specification.

The notion of technology diffusion must be taken to "include adoption by other users as well as more extensive use by the original innovator. More generally it encompasses all those actions at the level of the firm or organization taken to exploit the economic benefits of the innovation" (OECD, 1988). It is important to distinguish two shorts of technology diffusion regarding whether it is embodied or not in products, as they use different channels for that process. The diffusion of technology not embodied in products generates externalities that characterize innovation spillovers that arise when the firm that develops the innovation is not able to capture all the benefits implied in that new idea. On the contrary, the diffusion of technology through machinery implies a process by which innovation is transmitted by the trade of machinery, components and equipment intensive in technology.

Focusing in the last case, the traditional interpretation of the technology dissemination process describes the introduction in the production process of machinery, components and equipment that incorporates new technologies. Through the interindustry trade a few industries acts as suppliers of innovations, selling intermediate and capital goods intensive in new technologies. These industries are usually part of R&D intensive manufacturing sectors and receive a small amount of embodied R&D inflows from other industries, using mainly their own technologies to improve productivity.

The technological innovation is not only useful for the innovation producer but also for other economic agents, who in turn not always pay the "total" price for the use of those innovations. This implies the existence of some externalities that at the beginning of the 90' lead to rethink the neo-classical growth theory (Grossman and Helpman, 1991; Romer, 1990). In the empirical field, Griliches (1979) introduced the analytical distinction between "rent spillovers" and "knowledge spillovers" in the analysis of relationships between productivity growth and innovation.

Rent spillovers are related to the idea that usually innovating firms, under competitive pressure, are not fully able to increase the prices of their products and services proportionally to their improvements in quality. Therefore the ratio quality/price rises leading to spillovers for the firms that use those products and services as intermediates of capital inputs. Knowledge spillovers are directly related to the knowledge involved in innovation and they arise when an innovation developed in one sector can be used by other industries, obtaining a benefit from that use without having to pay the fully cost of that new idea. In this case, the spillovers are not necessarily related to economic transactions like rent ones. However, we should point out the difficulty in dissociating both spillovers when estimating them. There are several reasons for this to happen but we can remark the data and technical limitations and the existence of different types of rent and knowledge spillovers.

The definition of innovation makes difficult to directly observe its effect over industrial development. Both knowledge and technology have some public good characteristics (non rivalry and partially excludable) although they are privately provided by firms that invest on R&D and other activities related to technology. Therefore the benefits from innovation are not limited to the industry where it is developed and to some extend they can benefit the rest of the economy. The extend to which this process takes place depends on the channels and actors described in the introduction.

The empirical literature concerning the dynamics of technology dissemination uses several methodologies including the analysis of data about innovations, patents and trade in intermediate and capital goods intensives in technology. Bruno Van Pottelsberghe de la Potteire (1997) distinguishes three approaches when analysing externalities related to R&D efforts. The differences among them come from the way in which R&D efforts are weighed to describe interindustry flows using either input-output matrices, technology flows matrices or technological proximity matrices. The use of an input-output matrix is related to the idea of transmission of embodied technology through economic transactions.

As we already said most of the direct ways for observing technology flows are not available for the moment and we need to develop indirect ways to have some sort of measure for these relations. The empirical studies use different indicators as a proxy including expenditures in innovations or R&D, patents, R&D capital stock and R&D human capital. In order to have a complete picture of technology links we should include all of them at the same time, but the difficulty in combining them leads us to focus on only one measure. This implies a result that only shows a partial vision of a complex phenomenon and therefore should be completed taking into account the rest of determinants.

Hermann Schnabl (1995) uses the expenditures in R&D and the productive structure of the economy described in the input-output matrix to determine the most relevant technological links (or innovation clusters) between industries. Taking as a starting point the potentiality of an innovation to be used by several industries, the author analyses the interindustry technological flows. The innovation proxy used implies a subestimation of the innovations efforts as statistically it covers about half of the real investment in innovation. This is particularly important in activities like production engineering, software and design, service sector and small entrepreneurs. Therefore, although R&D expenditures are frequently used as a proxy for new technology flows studies they show some limitations that need to be taking into account.

The estimation of the technological content of the US exports to Mexico is based on the concept of subsystem developed by Sraffa (1976) and Pasinetti (1973) and used within the input output framework. The starting point is the basic open Leontief model:

$$x = Ly \tag{1}$$

where "L" is the Leontief inverse matrix, "y" is the final demand vector which, in this first step, has all cero values except for one element:

$$y = y_j \begin{cases} 0 & \forall j \neq k \\ 1 & j = k \end{cases}$$

Therefore, the resulting vector "x_j" contains exactly the k^{th} column of the Leontief inverse matrix "L". Sraffa called this vector a subsystem which values are defined in the same way as the multipliers of the Leontief inverse matrix. Hence "x_j" specifies the contribution of all sectors leading to the production of a unity of the k^{th} final demand element. In particular, each element of "x_j" shows the contribution of one particular sector to the production of a complete final unity of the sector k.

We now consider a vector "y_j" with the absolute amount of final demand instead of the former unit value for the k^{th} entry. Therefore we will obtain a vector "x_j" that shows the absolute requirements of all sectors implied in the production of the final product of the sector k.

In a next step we substitute the defined values for “y_j” for the complete final demand vector. In order to calculate in a simultaneous way the requirements for all sectors we will use a final demand diagonal matrix $\langle y \rangle$ (square matrix with the final demand values in the principal diagonal). The final result is a quadratic matrix X_{NN} that contents by columns the different “n” subsystems of production. By rows it shows how are distributed the production effort of sector “i” (for row i) in the production of all final demand products. Thus, the sum by rows gives us the value of the total production of sector i (x_i).

If we divide the matrix X_{NN}, row by row, by the corresponding value of production “x_i” we will obtain the sector entries “s_{ij}” for each production subsystems of the final demand “y”. This operation means a row normalization of “s_{ij}”. It is important to point out that this normalization implies that the calculated matrix $\langle x \rangle$ contents the production resulting from the model $(I - A)^{-1}\langle y \rangle$, which in turn is a function of the values considered in the matrix $\langle y \rangle$. The new matrix is the so-called “Sraffa operator” or “S-operator”:

$$S = \langle x \rangle^{-1}(I - A)^{-1}\langle y \rangle \qquad (2)$$

Finally, if we multiply from the left the S-operator by a diagonal matrix with the values for the innovation indicator for each productive sector $\langle INN \rangle$, we will obtain a new matrix:

$$XIN = \langle INN \rangle \langle x \rangle^{-1}(I - A)^{-1}\langle y \rangle \qquad (3)$$

The matrix *XIN* can be interpreted as a imputation of the total expenditures in R&D in the production of each one of the productive industries that contributes to production of the final demand products of each sector.

This matrix shows by rows how are distributed the expenditures in R&D of each sector. In particular the values of the *i*th row will describe to which sectors (besides the own *i*th one) are devoted the expenditures in R&D of sector i. Hence, we can aggregate the values by rows obtaining the total expenditures in R&D imputed to each sector.

By columns we can observe the total quantity of innovation expenditures (either from its own sector or from another one) that each subsystem has incorporated in a direct or indirect way in the production of the final demand products. Thus, we can have an estimation to the amount of innovation expenditures incorporated to a particular sector production, including those incorporated in an indirect way. In this sense the subsystem matrix *XIN* represents an approach to the interindustry innovation flows through interindustry trade.

The calculated matrix leads to two different applications depending on the matrix $\langle y \rangle$ used to obtain the S-operator. If we use the original vector “y_j” of absolute values for final demand we can represent the current structure of the technological content of production. This matrix shows which quantity (or percentaje) of the innovation expenditures is incorporated directly or indirectly in the production of the total final demand products of each sector. If we instead use a unity final demand vector, we will obtain the standard structure of the R&D expenditures distribution. In the latter option, the results are not influenced by the size or structure of the final demand.

The above described matrix can be used to see which are the net suppliers and users of innovation and technology developments. In particular, the elements XIN_{ij} show the proportion of expenditures in R&D realised by the sector i and incorporated in the production of sector j.

The final accumulative effect of the R&D expenditures incorporated directly and indirectly to the production of one sector can be calculated by adding all the elements of the *j*th column of the *XIN* matrix defined in equation 3. The result is a vector XIN_j defined in the following way:

$$XIN_j = \sum_i XIN_{ij} \tag{4}$$

Using the current structure of the imputed technology flows to calculate the matrix *XIN*, the results for equation 4 will show the total content of innovation expenditures incorporated directly and indirectly to the final demand production of the *j*th sector.

International trade is one of the several channels through technology can be transferred from one country to others. With this idea in mind, we are going to combine the information obtained in the vector XIN_j with the trade data between US and Mexico to obtain a first approach to the technological content of the trade among them.

Part of the final demand of US production has the international market as its destiny and thus we can use vector XIN_j from the current structure of S-operator to obtain the R&D expenditures imputed to the US exports to Mexico. In order to do that we first need to estimate the amount of investment content in one single unit produced in a particular sector. Using the results from equation 4 we can obtain this unity value dividing the total innovation expenditures captured in XIN_j by the total sector output x_j.

$$UXIN_j = \frac{XIN_j}{x_j} \tag{5}$$

The vector $UXIN_j$ measures the proportion of R&D expenditures embodied directly and indirectly in one monetary produced unit of the *j*th sector. Multiplying that vector by a vector XS_j with the values of US sector exports to Mexico yields a new vector:

$$XUXIN_j = XIN_j * XS_j \tag{6}$$

This vector $XUXIN_j$ shows the proportion of total R&D expenditures embodied (directly and indirectly) in the US exports to Mexico for the *j*th sector. Then, it can be used as an instrument to measure one aspect of the international transfer of technology, particularly through economic transactions.

3.- Empirical Results.

The matrix *XIN* defined in the last section is based on two sets of data. The first one is the productive structure of US described in the last Input-Output available. It is published by the Bureau of Economic Analysis (BEA) for 1997 and classified in 131 sectors according to the North American Industry Classification System (NAICS). This original data are reclasifficated in this paper in order to match the sectoral breakdown used in the R&D expenditures and US exports to Mexico. In order to do this we construct a concordance matrix that allows us to aggregate some branches and create a special service sector that contains the services for which there were no R&D desegregated data.

The final aggregation includes a 27 sectors[1] breakdown definition is based on the classification ISIC rev.3 (International Standard Industrial Classification) that labels the US R&D expenditures and trade statistics.

Export data utilised include commodities and services that US exports to Mexico in 1997, in current millions of US dollars. The commodities statistics are taken from the United States International Trade Commission (USITC) and do not present any particular problem in their aggregation. The services data set is from Bureau of Economic Analysis and refers to the US international services trade statistics. These data are based on estimations as it is difficult to directly compute the value of service trade transactions. Moreover, there is no desagregation for the case of affiliated trade within multinationals, something that implies an important source of subestimation. Despite the increasing importance of this kind of trade between US and Mexico, we do not include affiliated data as it is not possible to obtain a sectoral breakdown on a country by country basis.

R&D expenditures statistics refer to the US business R&D expenditures for 1997 in current millions of US dollars as there is not sectoral breakdown for the total national innovation investment. They are taken from the Analytical Business Enterprise Research and Development database (ANBERD) provided by the OECD and we again need to do some adjustment to match the classification used in the data analysis. The results show that a quarter of the R&D done in 1997 was concentrated on the branch resulting from aggregating computer and electronic product manufacturing (sector 11). Only other three sectors obtain values beyond the 10% borderline. They are the manufacture of chemicals and chemicals products (with 12%) and manufacture of other transportation equipment[2] with 11% of the total R&D investment.

The first thing to mention is the important concentration that business R&D expenditures show in US. This fact directly affects the international transfer of technology process and therefore the results obtained for the vector $XUXIN_j$. The

[1] See annex to a complete description of the sectors used in this paper.

[2] It refers to the manufacture of transportation equipment other than motor vehicles, trailers and semi-trailers, which are contemplated in sector 14.

disparity in the sectoral breakdown of the innovation investment determines the embodied technology transferred through exports. This feature is strengthened by the structure obtained for the S-operator that, as we will next see, shows a high percentage of intermediate commodities devoted to the intra-industry consumption.

The interindustry trade structure of intermediate commodities can foster the diffusion of the innovation originated in one industry, reinforcing the direct effects of the innovation expenditures directly embodied in a particular commodity or service. When analysing the interindustry economic transactions it is important not only to focus on the absolute terms of that trade, but also in the proportion it represents in terms of the total output of that industry.

The branches of "other services and "wholesale, retail trade and repairs" are the sectors with the higher volume of interindustry trade, with 2.4 and 1.1 billons dollars. On the contrary, if we consider the proportion of this trade in the total output for a given industry, the ranking obtained is significantly different. Construction, with 90%, and hotels and restaurants, with 80%, are the two sectors that devote the highest proportion of their output to the final demand. These features imply a limited effect of their R&D expenditures over the rest of the economy through interindustry trade. At the bottom of the ranking we find the "wood product manufacturing" industry and the "other non-metallic mineral products" industry. Only 18% of its production is used to satisfy the final demand.

As we already defined in the theoretical framework, the analysis by rows of the S-operator show us how are distributed the efforts in production of a particular industry over each sector of the economy (included the own one). Using the Input-Output data we calculate the current structure of the Sraffa operator, which considers the absolute values of the final demand. This allows us to take into account the relative share of each industry in the total production activity.

From the perspective of the production effort distribution it is important to point out that, with just a few exceptions, most of the production is realized to satisfy the own demand requirements. Table a.4 in annex shows there are just three values outside the principal diagonal of the matrix $<S>$ above 0.2, meaning 20% of one unit output is used by other sectors production systems as intermediate inputs. This is something that must be considered when analysing the results based on this matrix coefficients.

However, it is still interesting to distinguish the industries which production is used mainly for self-consumption, obtaining a high value for the element s_{ij} when i=j. As we can observe in table 1, sectors as construction; motor vehicles, trailers and semi-trailers or hotel and restaurant services, obtain coefficients higher than 0.8. This means that almost all the production is consumed by the own sector, resulting in a small capacity for interindustry technology transfer by means of interindustry trade. Actually, we can just mention three sectors in which the production efforts are incorporated to other industry production processes. It is the case of the food products, beverages and tobacco industry, where 12% of its production is used by the hotel and restaurant services sector. The electricity, gas and water supply services sector and the financial intermediation sector sell 12% and 10% respectively to the "rest of services" sector. Unfortunately, this is an "artificial" sector that concentrates heterogeneous services, something that makes unable for us to extract any interesting conclusion from these economic transactions.

Table 1
Operator Sraffa, current structure. Principal diagonal values

Sector	Descripción	Vslue
19	Construction	0.905
14	Motor vehicles, trailers and semi-trailers industry	0.864
21	Hotels and restaurants	0.813
1	Rest of the economy (agriculture, minery...)	0.748
25	Computer and related activities	0.738
20	Wholesale, retail trade and repairs	0.733
2	Food products, beverages and tobacco	0.732
27	Other services	0.732
13	Medical, precision and optical instruments, watch and clock manufactures	0.716
15	Other transport equipment	0.632
17	Recycling	0.615
11	Computer and electronic product manufacturing	0.551
24	Financial intermediation	0.550
18	Electricity, gas and water	0.538
3	Textiles, textile products, leather and footwear manufacturing	0.522
Source: Own calculations		

The R&D expenditures done by almost every sector have a limited indirect repercussion on US production, and it is mainly based on the absolute amount of investment realized by each sector. This will determine the technology embodied in US exports, which main influence factors are the direct embodied technology and the volume of the exports, as there are few indirect imputations in the economy structure.

Despite intraindustry concentration is one of the main characteristic of intermediate input trade, we can mention some sectors in which the production is spread out, in terms of intermediate consumption, over the rest of the economy in some significant way. There are some sectors where the share of production used by the own sector is less than 50% and most of them are manufacturing industries like wood product manufacturing (22%), rubber and plastic products (22%) or other non-metallic mineral products (20%). The main consumers of these intermediate outputs are construction and "other services" sectors. Hence, in all the cases there is no receptor that accumulates more than 10% of the output of the provider sector.

From the point of view of the consumers (columns analysis) there is also a high degree of concentration. As we have pointed out earlier, the sector "other services" consumes intermediate output coming from different sectors (others than the own one) in bigger proportion than the rest of sectors. Construction is placed in the second position and we can highlight the inputs coming from mineral production sectors (8 and 9) and from wood product manufacturing (sector 4). Finally, the motor vehicles, trailers and semi-trailers industry and the wholesale, retail trade and repair sector, both utilized in a comparative significant proportion intermediate inputs coming from other sectors, although in a lower proportion than construction.

Considering at the same time the S-operator coefficients and the R&D expenditures the first conclusion is the inexistence of a sector both receptor of high amounts of innovation investments and able to disseminate those investments over the rest of the production structure. This is partly because almost half of these expenditures were concentrated in 1997 in three sectors: Computer and electronic product manufacturing, other transport equipment and chemical production. In the first two cases, we observe a high proportion of self-consumption of intermediate commodities, limiting the potential interindustry technology transfer. On the other hand, chemistry production carries out 12% of the R&D investment and shows some sign of being able to diffuse some of those expenditures over the rest of the economy. Nevertheless, it only shows a relative interesting relationship with sector “other services”.

To complete this vision we calculate the s-operator using a unit value matrix for the final demand <y>, discounting the size effect of the final demand over the interindustry trade relations. Thus, we will obtain the constant structure of the S-operator that shows none significant difference comparing to the current one just analysed. So far, the main difference is the lower values that most of the s_{ij} coefficients obtain, which only in four cases outside the principal diagonal go beyond the threshold of 0.1.

Hence, it seems there are some signs that confirm the assumption made about the key role of the R&D expenditures. The innovation investment made in each sector and its volume of exports seems to act as the main factors in the innovation that US can transfer to Mexico by means of international trade of commodities and services, as there no conclusive evidence about the role of indirect imputed R&D expenditures.

The results for the innovation expenditures imputation matrix *XIN*, are a combination of the s-operator elements and the R&D investment made by each industry. Table 2 in the next page shows the current structure of the *XIN*, which at a first glance points out the effect of the relative size of each sector in the values obtained.

We first have to emphasize that the most important imputations of R&D expenditures are concentrated in the intraindustry use of intermediate commodities. Within the calculated matrix there are just three values outside the principal diagonal it worth mentioning as they show amounts beyond 10 billon dollars. We are referring to the following sectors: Computer and electronic product manufacturing, motor vehicles, trailers and semi-trailers industry and other transport equipment. Regarding this, those sectors coincide with the activities with higher gross R&D investment.

After them we find the manufacturing sectors of medical, precision and optical instruments, watches and clocks manufactures and of chemical production, all with values within 5 and 10 billon dollars. Regarding services, the most important in terms of direct imputation of R&D expenditures are computer and related activities and wholesale, retail trade and repairs, both with values around 6 billion dollars. Finally there is little evidence of intersectorial embodied technology transfer as there are few significant values outside the principal diagonal.

Table 2. R&D expenditures imputation matrix: Current structure (mill. US$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	total
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	81	1396	6	1	3	3	13	2	1	6	3	1	2	7	3	2	1	7	13	19	226	6	3	7	3	1	92	1907
3	8	10	279	2	5	1	4	7	1	13	4	2	4	39	6	5	6	2	33	29	8	5	3	5	3	1	49	535
4	15	7	5	83	5	2	5	3	2	9	2	1	4	9	4	6	9	4	111	24	6	9	3	4	2	1	47	383
5	46	92	29	3	533	5	28	10	6	49	19	8	13	44	17	12	10	13	84	228	63	32	33	64	53	8	399	1902
6	97	38	15	6	10	700	74	10	10	44	13	8	10	39	18	8	8	21	151	75	22	88	14	14	8	2	187	1690
7	1128	584	582	51	220	182	7480	370	89	601	343	163	209	828	358	207	131	104	1289	826	297	196	122	165	136	48	2422	19131
8	38	61	52	6	14	5	33	316	5	67	36	15	26	125	34	17	19	9	176	113	39	21	13	14	11	3	174	1439
9	23	19	6	2	8	5	11	3	125	21	6	4	6	49	9	5	4	8	165	33	12	16	5	6	4	4	74	633
10	236	196	90	19	48	26	97	42	27	3642	129	110	122	951	300	62	62	55	1004	399	100	127	68	62	47	14	660	8695
11	422	390	319	56	196	64	393	171	79	1241	21320	580	1634	1915	861	164	145	112	1642	1926	254	283	627	395	1068	65	2380	38703
12	88	81	51	10	25	13	56	26	13	363	241	1115	152	530	149	31	29	41	569	275	52	58	66	36	52	7	379	4507
13	120	96	47	10	38	17	78	23	14	299	149	56	9904	359	304	35	30	39	570	339	80	78	87	73	57	15	917	13835
14	95	114	38	7	15	9	34	15	13	171	33	30	26	13138	72	15	25	23	266	483	55	121	23	30	18	5	328	15201
15	229	204	83	18	46	23	100	46	25	761	140	80	114	900	10623	58	67	69	1109	500	141	370	97	80	52	35	825	16795
16	11	16	7	3	4	1	7	3	2	16	5	3	5	19	7	247	4	3	55	29	11	6	4	6	3	1	67	545
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	9	7	3	1	2	1	4	1	1	7	2	1	1	6	2	1	1	161	10	20	10	3	2	4	2	1	37	300
19	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	236	3	1	1	0	1	0	0	11	261
20	119	154	48	11	32	19	61	19	12	135	83	27	44	202	53	21	23	23	407	5977	114	73	27	38	34	6	387	8150
21	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	2	4	126	2	0	2	1	0	10	155
22	24	25	7	2	6	4	10	3	3	18	6	3	4	23	8	3	3	23	40	38	16	320	6	11	6	1	66	681
23	34	28	10	2	9	3	12	4	3	29	14	5	10	32	13	5	6	11	82	217	36	38	994	73	44	3	298	2017
24	101	39	9	2	7	5	16	4	3	23	14	5	8	30	11	4	4	10	52	100	29	21	10	824	12	1	156	1499
25	87	67	22	4	36	9	32	10	7	71	183	18	40	78	37	11	12	33	135	344	69	123	63	160	6390	11	602	8656
26	239	207	93	14	56	47	258	42	25	238	176	70	113	362	159	35	30	39	253	311	90	73	43	88	50	3409	511	7029
27	55	36	12	2	10	5	18	5	3	31	16	6	12	36	15	5	6	12	93	179	40	33	22	61	28	4	2032	2777
total	3309	3869	1813	314	1331	1150	8826	1134	469	7855	22939	2310	12464	19722	13063	958	637	824	8547	12490	1898	2104	2337	2225	8083	3645	13112	157427

Source: Own calculations

Table 3 shows[3], in the left part, the sectors with the higher total embodied technology investment in their output (both directly and indirectly imputed). Once again we must refer to the computer and electronic product manufacturing (sector 11) and to motor vehicles, trailers and semi-trailers industry (sector 14) as the main receptors of R&D expenditures, including the direct embodied investment, reaching around 20 billion dollars in each case. This is a direct consequence of their gross R&D expenditures, which account for 34% of the global innovation investments.

The industries of medical, precision and optical instruments, watch and clock manufactures and of other transport equipment industries also reach meaningful values, above 20 billion dollars. As it happens with branches 11 and 14, the main reason of these results is the own expenditure in R&D carried out by these industries. In both cases the indirect imputation of innovations investment is around 20% of total embodied innovation. Regarding services, sector 27 of “Other services” and sector wholesale, retail trade and repairs are the only ones that obtain amounts of total imputed innovation expenditures beyond the threshold of 10 billion dollars.

It is clear that computer and electronic product manufacturing is becoming the main agent of the technology transfer process. It is not only the bigger investor in innovation (39 billion dollars in 1997) but it is also the industry that accounts the biggest R&D expenditure deliveries through embodied innovation. Moreover, as we just have mentioned, it is the first receptor of R&D expenditures flows although its s-operator coefficient is 0.55. As we can see in the right part of table 3, when we subtract the own investment imputations, the value of innovation expenditures indirectly imputed to its output reaches just 1.6 billion dollars. Therefore, even with a low rate of interindustry investment, given the magnitude of that investment, this sector arises as the first receptor of R&D embodied expenditures.

Concerning its capacity to transfer innovation investment, it can be considered the first source of indirect embodied technology in sectors 17 (recycling) and 19 (construction). In fact, its innovation deliveries go beyond one billion dollar in seven industries, and can be estimated to be around 2 billion dollars for three sectors: wholesale, retail trade and repairs, motor vehicles, trailers and semi-trailers industry and other services.

Motor vehicles, trailers and semi-trailers industry constitutes the second industry in terms of total R&D imputed in its output (almost 20 billion dollars). However, this value is directly related to the high amount of intraindustry investment it carries out. If we compare the left and right parts of table 3, we can see the small percentage of indirectly imputed R&D, less than 33%. However, in absolute terms, it is the third sector in R&D embodied in intermediate inputs coming from other sectors with 6.6 billion dollars.

The main receptor of indirect embodied innovation flows is “other services” sector (27), that receives 11 billion dollars of imputed innovation expenditures from other sectors. Actually, that is the main source of innovation in this sector, where just 13% of the R&D imputed to its output comes from its own investment in innovation. Moreover, its gross R&D expenditures account for only 1.8% of total business

[3] See table a2 in annex for the detailed results.

investment but it is at the top of both total and interindustry R&D embodied innovation receptors ranking.

Table 3
Main receptors of R&D expenditures
(Imputation matrix, current structure. Mill. US$)

Sector	R&D received
11	22939
14	19722
27	13112
15	13063
20	12490
13	12464
7	8826
19	8547
25	8083
10	7855
2	3869
26	3645
1	3309
Source: Own calculations	

Sector	R&D imputed substracting intraindustry investment
27	11079
19	8311
14	6583
20	6513
10	4213
1	3309
13	2560
2	2473
15	2440
22	1784
21	1772
25	1693
11	1619
Source: Own calculations	

Construction is the second sector in terms of indirect R&D imputed to its production although we are now below 10 billion dollars investments. Furthermore, 97% of this commodity embodied innovation comes from the intermediate inputs purchased to other sectors, as we have mentioned earlier in the analysis.

The chemistry manufacturing industry undertakes 12% of the gross R&D investment (almost 20 billion dollars), just below computer and electronic product manufacturing. However, its output has a relative low total imputed innovation as it is shown in table 3 (8.8 billion dollars). This is due to a combination of a low s-operator coefficient (0.4) and few indirect embodied technology flows. Actually it just receives 1.3 billion dollars from other sectors, 15% of the total embodied R&D of its final output.

The rest of its R&D expenditures are disseminated along the rest of productive systems. Despite not being significantly related to any particular sector, given the high absolute amount of its innovation investment it is, together with sector 11, one of the main sources of intersectorial technology transfers. Its principal receptors are sectors 19 and 27, receiving 2 and 1 billion dollars respectively.

After analysing the global R&D embodied in the total production, we have calculated the innovation expenditure embodied in one monetary unit of output and the innovation embodied in the US exports to Mexico.

Table 4
R&D expenditures embodied in US exports to Mexico.

Sector	Unit embodied R&D*	Exports (mill.US$)	R&D embodied in US exports (mill. US$)
1	0.002	3938	8.6
2	0.008	2482	19.2
3	0.009	4756	40.5
4	0.003	571	1.6
5	0.004	2168	9.1
6	0.011	1006	11.1
7	0.023	5494	128.8
8	0.006	3953	25.7
9	0.003	1708	5.1
10	0.010	13119	136.4
11	0.088	9843	866.8
12	0.011	8048	92.2
13	0.103	1900	194.8
14	0.057	6007	341.4
15	0.070	1761	123.2
16	0.011	1222	13.0
17	0.009	496	4.2
18	0.003	9	0.0
19	0.012	20	0.2
20	0.008	36	0.3
21	0.005	9	0.0
22	0.004	3355	14.3
23	0.006	477	3.0
24	0.002	239	0.4
25	0.032	41	1.3
26	0.058	105	6.0
27	0.003	6235	20.4
Total		79000	2067.7

* Embodied R&D expenditures per dollar produced.
Source: United States International Trade Commission, Bureau of Economic Analysis and own calculations.

The unit embodied R&D expenditure shows a different picture from the outcome when calculating the imputed innovation to the total production. Medical, precision and optical instruments, watch and clock manufactures (sector 13) have the higher proportion of R&D expenditures per dollar produced, although we are talking of a small proportion of 10%.

If we compare the performance of the service sectors in the R&D imputed in global output (table 3) and the values obtained for the embodied innovation expenditures per dollar produced (table 4), we can observe the low proportion of innovation per unit produced (1%) comparing to the significant values estimated when referring to the total production. Actually, only research and development related services (sector 26) appears among the sectors which production has more that 5% of innovation expenditures content. The rest of the "technology intensive" sectors are manufacturing industries like sector 13.

In any case the proportion of R&D expenditures embodied in one monetary unit is relatively low, only five sectors show values above 5% (sectors 11,13,14, 15 and 26) and they are the same ones that have shown the higher embodied R&D expenditures for the total production with the exception of sector 13.

The third column of table 4 contents the calculations for the R&D expenditures embodied, directly and indirectly, in the US exports to Mexico. This country received in 1997 two billion dollars of R&D investment flows embodied in commodities and services. Most of these innovation expenditures are related to the trade of computer and electronic manufacturing products (sector 11). This sector has transferred 867 million dollars to the Mexican economy through international trade, 42% of the total exported innovation. This volume of transfers is due to the high amount of gross investment carried out by this sector and to the magnitude of its exports (9.8 billion dollars). Furthermore, it is mostly direct embodied innovation as the indirect imputed R&D expenditures are not significant.

Motor vehicles, trailers and semi-trailers industry exports are in the second place, with an imputed innovation expenditure of 341 million dollars. Thus, it supposes less than half of the flows related to the sector 11, something that gives us an idea of the concentration in the embodied technology transfer. As in sector 11 they are essentially related to intraindustry innovation investment, something already observed formerly in the analysis of total R&D embodied investment.

The study of the imputation matrix and the vector $XUXIN_j$ of innovation transfers shows that there is a common group of sectors that head the R&D gross investment and also have a relative significant capacity for transferring those innovation expenditures to other economies.

An example of those sectors is the computer and electronic product manufacturing industry. It concentrates 25% of the gross innovation expenditures carried out by the business sector and we have estimated that this leads to a total R&D expenditures embodied of 23 billion dollars. Moreover, the unit innovation investment imputed is 9% for each dollar produced, the second highest one, and the sectoral exportations reach almost 10 billion dollars. Therefore, as we have mentioned, the R&D innovation investment imputed to US exports in this sector is 867 million dollars, 47% of total.

Chemical products manufacturing industry (sector 7) accomplished an investment of 19 billion dollars in 1997 reaching embodied innovation expenditures in its exports of 129 million dollars. Therefore, although contributes in a significant way to the transfer of technology, it does not show a high potential to act as a channel for international dissemination of innovation. Above this sector we find the contribution of basic metals and fabricated metal products industry (sector 10). This is due to the considerable value of its exports (129 million dollars) as the unit R&D imputation is only 1%.

Manufactures of medical, precision and optical instruments, watches and clocks (sector 13) constitutes an interesting sector as it is a relative small industry in terms of output, but with a relative high investment in innovation (14 billion dollars). This explains the fact that it is the sector that heads the unit R&D expenditure, with a 10% of each dollar produced. Therefore, although it exports only 1.9 billion dollars, it is the third sector in terms of R&D expenditures embodied in the exports to Mexico.

Finally, we focus on the transport manufacturing industry, composed by sectors 14 and 15. They have carried out similar innovation expenditures in 1997 but their R&D embodied in exports differ significantly. Whereas motor vehicles, trailers and semi-trailers industry delivers 341 million dollars embodied in its exports, the amounts decreases to 195 for the rest of transport equipment manufactures (sector 15). The difference is related mainly to the export values, while sector 14 exports are about 6 billion dollars, sector 15 ones are below 2 billion dollars.

4.- Concluding remarks.

The commercial relations between US and Mexico have increasingly became stronger, specially after the signature of the NAFTA agreement in 1992. This trade agreement fostered trade volume, intra-firm transactions, capital investments and other channels of international technology transfer. Concerning the trade relations, both mexican imports and exports have experienced a significant growth from nineties. Actually, since 1995 trade balance shows positive and increasing values. In fact, while mexican exports have gone from 30.1 billion dollars in 1990 to 138.1 billion in 2003, import have gone from 28.3 to 97.5 billion dollars.

The R&D statistics clearly show the differences existing among these countries in innovation activities and the funds devoted to the generation of new ideas. While US carried out an total R&D investment[4] of 212.7 billion dollars in 1997, meaning 2.6% of its GDP, Mexico only reached 2.5 billion, 0.3% of its GDP. They also differ in the financing source. Whereas most of US innovation investment in 1997 was financed by the business sector, government-financed investment is still the main source of innovation development in Mexico (71% of the total funds).

US picture of innovation expenditures distribution confirms the assumption made in the theoretical framework. Innovation supplier industries are part of the manufacturing industry, they receive relatively few embodied technology inflows and mainly uses its own technology to improve its productivity. Computer and electronic product manufacturing industry (sector 11) is a clear example of this hypothesis and it is the main channel for a potential technology transfer, both at a national level and for the mexican case analysed.

When analysing the results we may keep in mind the limitations that business expenditures in R&D may have as a measure for innovation efforts and the proportion

[4] Gross domestic expenditures on R&D in current PPP dollars.

embodied in the production. The innovation investment carried out in most of the sectors has a total impact over exports based on the gross sectoral R&D expenditures and the extent of its exports. The results show the limited effect of indirect embodied technology in terms of international diffusion of innovation, at least in our empirical application.

In conclusion, the estimated international innovation transfers through trade show how the flows delivered by US using this particular channel almost equal the total amount of mexican R&D expenditures for 1997. Concerning this we should stress that we have used US business R&D expenditures and therefore there is a subestimation of the total innovation effort. Moreover, multinational activities could not be fully introduced in the trade statistics used and in this case it implies a significant source of subestimation.

In a future work it would be interesting to perform a simultaneous analysis of both economies R&D expenditures imputation matrices. This would allow us to try to trace down the path of US embodied innovation diffusion across the mexican productive system. It would be also important to include in the trade statistics the intra-firm trade accomplished by multinationals through some sort of imputation as there is no useful sectoral breakdown.

5.- References

- Dietzenbacher, Erik and Los, Bart (2002) "Externalities of R&D Expenditures". Economic Systems Research. Vol. 14. number 4. Dic2002,

- Griliches, Z (1979) Issues in assessing the contribution of research and development to productivity growth, Bell Journal of econometrics, 10, pp 92-116.

- Grossman, G.M., Helpman, E. (1991). "Innovation and Growth in the Global Economy". MIT Press, Cambridge, MA.

- Hermann Schnabl "The subsystem - MFA: A qualitative meted for analysing National Innovation Systems – The case of Germany". Economic Systems Research, vol 7, Nº4, 1995, 383-396.

- Mohnen, P.; Bernstein, J. (1998) "International R&D spillovers between U.S. and Japanese R&D intensive sectors". Journal of international economics 44 (1998) 315-338

- Mohnen, Pierre (1997). "Introduction: Input-Output analysis of interindustry R&D spillovers". Economic System Research, June 1997. Vol. 9. Issue 1, 3-8

- OECD (1988). "Science and technology policy outlook, 1988". París.

- OECD (1992). "Technology and the economy. The key relationships". París.

- OECD (1998). “Science, technology and industry outlook, 1998”. París.

- Romer, P. (1990) “Endogenous technological Change” Journal of Political Economy, nº 98, Octubre 1990 71-102

- Van Pottelsberghe de la Potterie, B (1997) “Issues assessing the Effect of Interindustry R&D Spillovers”. Economic System Research, June 1997, vol. 9, Nº 4, 331-356

APPENDIX

Table a.1. Industry classification.

Sector	Description
1	Rest of the economy (agriculture, mining...).
2	Food products, beverages and tobacco.
3	Textiles, textile products, leather, footwear.
4	Wood product manufacturing.
5	Manufacture of paper and paper products and publishing, printing and reproduction of recorded media.
6	Coke, refined petrol production and nuclear fuel.
7	Chemical products.
8	Rubber and plastic products.
9	Other non-metallic mineral products.
10	Basic metals (Iron, steel and non ferrous metals). Manufactured metal products, except machinery and equipment. Machinery and equipment, nec.
11	Computer and electronic products.
12	Electrical machinery and apparatus, nec.
13	Medical, precision and optical instruments, watch and clock manufactures
14	Motor vehicles, trailers and semi-trailers.
15	Other transport equipment.
16	Manufacturing nec.
17	Recycling.
18	Electricity, gas and water.
19	Construction
20	Wholesale, retail trade and repairs.
21	Hotels y restaurants.
22	Transport and storage (except from post and telecommunications)
23	Post and telecommunications.
24	Financial intermediation.
25	Computer and related activities
26	Research and development related activities
27	Other service activities

Table a.2. R&D expenditures imputed to the sectoral output

	Current structure			Constant structure		
	Received R&D	R&D imputed (subtracting intraindustry investment)		Received R&D	R&D imputed (subtracting intraindustry investment)	
	mill. US$	*mill. US$*	% over total R&D received	*mill. US$*	*mill. US$*	% over total R&D received
1	3309	3309	100.0	548	548	100.0
2	3869	2473	63.9	2786	1395	50.1
3	1813	1533	84.6	3071	2697	87.8
4	314	231	73.6	2134	1846	86.5
5	1331	798	60.0	2905	1777	61.2
6	1150	450	39.2	3082	1754	56.9
7	8826	1346	15.3	10914	1723	15.8
8	1134	818	72.2	4351	3476	79.9
9	469	344	73.4	2333	1908	81.8
10	7855	4213	53.6	5734	2570	44.8
11	22939	1619	7.1	27295	2323	8.5
12	2310	1195	51.7	6570	3922	59.7
13	12464	2560	20.5	16303	4302	26.4
14	19722	6583	33.4	17013	3989	23.4
15	13063	2440	18.7	16395	3372	20.6
16	958	711	74.2	3201	2754	86.0
17	637	637	100.0	2236	2235	100.0
18	824	663	80.4	940	746	79.3
19	8547	8311	97.2	2446	2227	91.1
20	12490	6513	52.1	3581	953	26.6
21	1898	1772	93.4	1277	1154	90.3
22	2104	1784	84.8	1825	1506	82.5
23	2337	1343	57.5	2698	1342	49.8
24	2225	1400	62.9	1036	464	44.8
25	8083	1693	20.9	8315	1431	17.2
26	3645	236	6.5	7163	1257	17.6
27	13112	11079	84.5	1275	725	56.8
Total	157427	66056	42.0	157427	54395	34.6

Source: Own calculations

Table a.3
(mill. US$)

	Exports	R&D expenditures	Total output
1	3,938	0	1,522,235
2	2,482	1,907	500,619
3	4,756	535	212,816
4	571	383	113,828
5	2,168	1,902	317,139
6	1,006	1,690	104,333
7	5,494	19,131	376,508
8	3,953	1,439	174,607
9	1,708	634	156,481
10	13,119	8,695	755,726
11	9,843	38,703	260,482
12	8,048	4,507	201,610
13	1,900	13,835	121,590
14	6,007	15,202	347,000
15	1,761	16,796	186,774
16	1,222	545	89,995
17	496	1	74,942
18	9	300	282,088
19	20	261	687,007
20	36	8,150	1,609,028
21	9	155	385,068
22	3,355	681	494,607
23	477	2,017	366,793
24	239	1,499	1,201,783
25	41	8,656	251,219
26	105	7,029	63,340
27	6,235	2,777	4,005,257
Total	79,000	157,427	14,862,876

Source: USITC, BEA, OECD

Table a.4 Sraffa operator: Current structure

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	total
1	0.75	0.07	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.03	0.75
2	0.04	0.73	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.05	0.04
3	0.02	0.02	0.52	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.00	0.01	0.07	0.01	0.01	0.01	0.00	0.06	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.09	0.02
4	0.04	0.02	0.01	0.22	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.01	0.02	0.01	0.01	0.02	0.01	0.29	0.06	0.02	0.02	0.01	0.01	0.01	0.00	0.12	0.04
5	0.02	0.05	0.02	0.00	0.28	0.00	0.01	0.01	0.00	0.03	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.04	0.12	0.03	0.02	0.02	0.03	0.03	0.00	0.21	0.02
6	0.06	0.02	0.01	0.00	0.01	0.41	0.04	0.01	0.01	0.03	0.01	0.00	0.01	0.02	0.01	0.00	0.01	0.01	0.09	0.04	0.01	0.05	0.01	0.01	0.00	0.00	0.11	0.06
7	0.06	0.03	0.03	0.00	0.01	0.01	0.39	0.02	0.00	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01	0.01	0.07	0.04	0.02	0.01	0.01	0.01	0.01	0.00	0.13	0.06
8	0.03	0.04	0.04	0.00	0.01	0.00	0.02	0.22	0.00	0.05	0.03	0.01	0.02	0.09	0.02	0.01	0.01	0.01	0.12	0.08	0.03	0.01	0.01	0.01	0.01	0.00	0.12	0.03
9	0.04	0.03	0.01	0.00	0.01	0.01	0.02	0.00	0.20	0.03	0.01	0.01	0.01	0.08	0.01	0.01	0.01	0.01	0.26	0.05	0.02	0.03	0.01	0.01	0.01	0.01	0.12	0.04
10	0.03	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.42	0.01	0.01	0.01	0.11	0.03	0.01	0.01	0.01	0.12	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.08	0.03
11	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.55	0.01	0.04	0.05	0.02	0.00	0.00	0.00	0.04	0.05	0.01	0.01	0.02	0.01	0.03	0.00	0.06	0.01
12	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.08	0.05	0.25	0.03	0.12	0.03	0.01	0.01	0.01	0.13	0.06	0.01	0.01	0.01	0.01	0.01	0.00	0.08	0.02
13	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.72	0.03	0.02	0.00	0.00	0.00	0.04	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.07	0.01
14	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.01
15	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.01	0.00	0.01	0.05	0.63	0.00	0.00	0.00	0.07	0.03	0.01	0.02	0.01	0.00	0.00	0.00	0.05	0.01
16	0.02	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.03	0.01	0.00	0.01	0.04	0.01	0.45	0.01	0.01	0.10	0.05	0.02	0.01	0.01	0.01	0.01	0.00	0.12	0.02
17	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.05	0.01	0.00	0.61	0.00	0.08	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.08	0.01
18	0.03	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.54	0.03	0.07	0.03	0.01	0.01	0.01	0.01	0.00	0.12	0.03
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
20	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.05	0.73	0.01	0.01	0.00	0.00	0.00	0.00	0.05	0.01
21	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.81	0.01	0.00	0.01	0.01	0.00	0.06	0.01
22	0.04	0.04	0.01	0.00	0.01	0.01	0.02	0.00	0.00	0.03	0.01	0.00	0.01	0.03	0.01	0.00	0.00	0.03	0.06	0.06	0.02	0.47	0.01	0.02	0.01	0.00	0.10	0.04
23	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.04	0.11	0.02	0.02	0.49	0.04	0.02	0.00	0.15	0.02
24	0.07	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.03	0.07	0.02	0.01	0.01	0.55	0.01	0.00	0.10	0.07
25	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.01	0.01	0.02	0.74	0.00	0.07	0.01
26	0.03	0.03	0.01	0.00	0.01	0.01	0.04	0.01	0.00	0.03	0.03	0.01	0.02	0.05	0.02	0.00	0.00	0.01	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.48	0.07	0.03
27	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.03	0.06	0.01	0.01	0.01	0.02	0.01	0.00	0.73	0.02
total	0.75	0.07	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.03	0.75

Source: Own calculations

Table a.6. R&D expenditures imputation matrix. Current structure (mill. US$).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	total
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	81	1396	6	1	3	3	13	2	1	6	3	1	2	7	3	2	1	7	13	19	226	6	3	7	3	1	92	1907
3	8	10	279	2	5	1	4	7	1	13	4	2	4	39	6	5	6	2	33	29	8	5	3	5	3	1	49	535
4	15	7	5	83	5	2	5	3	2	9	2	1	4	9	4	6	9	4	111	24	6	9	3	4	2	1	47	383
5	46	92	29	3	533	5	28	10	6	49	19	8	13	44	17	12	10	13	84	228	63	32	33	64	53	8	399	1902
6	97	38	15	6	10	700	74	10	10	44	13	8	10	39	18	8	8	21	151	75	22	88	14	14	8	2	187	1690
7	1128	584	582	51	220	182	7480	370	89	601	343	163	209	828	358	207	131	104	1289	826	297	196	122	165	136	48	2422	19131
8	38	61	52	6	14	5	33	316	5	67	36	15	26	125	34	17	19	9	176	113	39	21	13	14	11	3	174	1439
9	23	19	6	2	8	5	11	3	125	21	6	4	6	49	9	5	4	8	165	33	12	16	5	6	4	4	74	633
10	236	196	90	19	48	26	97	42	27	3642	129	110	122	951	300	62	62	55	1004	399	100	127	68	62	47	14	660	8695
11	422	390	319	56	196	64	393	171	79	1241	21320	580	1634	1915	861	164	145	112	1642	1926	254	283	627	395	1068	65	2380	38703
12	88	81	51	10	25	13	56	26	13	363	241	1115	152	530	149	31	29	41	569	275	52	58	66	36	52	7	379	4507
13	120	96	47	10	38	17	78	23	14	299	149	56	9904	359	304	35	30	39	570	339	80	78	87	73	57	15	917	13835
14	95	114	38	7	15	9	34	15	13	171	33	30	26	13138	72	15	25	23	266	483	55	121	23	30	18	5	328	15201
15	229	204	83	18	46	23	100	46	25	761	140	80	114	900	10623	58	67	69	1109	500	141	370	97	80	52	35	825	16795
16	11	16	7	3	4	1	7	3	2	16	5	3	5	19	7	247	4	3	55	29	11	6	4	6	3	1	67	545
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	9	7	3	1	2	1	4	1	1	7	2	1	1	6	2	1	1	161	10	20	10	3	2	4	2	1	37	300
19	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	236	3	1	1	0	1	0	0	11	261
20	119	154	48	11	32	19	61	19	12	135	83	27	44	202	53	21	23	23	407	5977	114	73	27	38	34	6	387	8150
21	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	2	4	126	2	0	2	1	0	10	155
22	24	25	7	2	6	4	10	3	3	18	6	3	4	23	8	3	3	23	40	38	16	320	6	11	6	1	66	681
23	34	28	10	2	9	3	12	4	3	29	14	5	10	32	13	5	6	11	82	217	36	38	994	73	44	3	298	2017
24	101	39	9	2	7	5	16	4	3	23	14	5	8	30	11	4	4	10	52	100	29	21	10	824	12	1	156	1499
25	87	67	22	4	36	9	32	10	7	71	183	18	40	78	37	11	12	33	135	344	69	123	63	160	6390	11	602	8656
26	239	207	93	14	56	47	258	42	25	238	176	70	113	362	159	35	30	39	253	311	90	73	43	88	50	3409	511	7029
27	55	36	12	2	10	5	18	5	3	31	16	6	12	36	15	5	6	12	93	179	40	33	22	61	28	4	2032	2777
total	3309	3869	1813	314	1331	1150	8826	1134	469	7855	22939	2310	12464	19722	13063	958	637	824	8547	12490	1898	2104	2337	2225	8083	3645	13112	157427

Source: Own calculations