# *Does industry-level analysis of trade-related technology spillovers support conclusions obtained at an aggregate level? Evidence for non-G7 countries*

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## *Abstract*

One of the main characteristics of endogenous growth theory is the possibility of international diffusion of technology, which in turn might have a positive impact on economic growth. A review of the literature shows a general agreement about the existence of global positive technology spillovers, but there is no unique or robust conclusion about their magnitude. In this sense, most of the literature focuses on an aggregate level analysis of international technology spillovers, while few exceptions include a disaggregated perspective, all of them concerning the innovation leader countries, and their findings are mixed. This paper contributes to the literature by analyzing, from an industry-level perspective, the international trade-related technology spillovers from the technology leaders (G7 countries) to a group of countries which lie behind them, providing new evidence of the key role of industry-level analysis.

The paper focuses on the trade of intermediate inputs as a channel for international technology spillovers. In a first stage I estimate the technology embodied in the production of technology leader countries following the literature on intersectoral technology flows. Next, I calculate the exports from one industry in a technology leader country to each of the industries of a given trade partner. I estimate these flows using industry-level bilateral trade data and the import Input-Output tables of trade partners. The combination of both estimations results in a measure that captures the technology embodied in bilateral industry trade of intermediate inputs. Finally, I use an extended Cobb-Douglas neoclassical production function to analyze the impact of international trade-related technology spillovers on industries' productivity.

## 1.- Introduction

The modern endogenous growth theory set up the framework for the recent literature concerning the key role of technology as a major driving force of economic growth (Romer, 1986, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). One of the main implications of these models is the possibility of international diffusion of innovations in an open economy setting[1]. The main idea is that innovations developed in one country might be transferred to other economies and have a positive effect over their economic growth. The literature refers to this indirect effect of foreign innovation activity as international technology spillovers and points out several channels through which this might happen including trade of goods, use of patents, alliances between firms or institutions, transnational firm activities and mobility of R&D employees.

Coe and Helpman (1995) were pioneers in analyzing the international diffusion of technology, focusing on the bilateral trade channel. They provide evidence of a positive and significant impact of foreign R&D over domestic productivity for OECD countries and Coe et al (1997) find similar evidence for developing countries at aggregate economy level. This finding has been tested by several authors, who propose alternative approaches related to the measures and econometric techniques used (Keller, 1998; Lichtenberg and van Pottersberghe, 1998; Kao, Chiang and Chen, 1999, Lumenga-Neso et al, 2005). So far, only two papers have undergone industry level

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[1] Authors such as Mansfield (1972), Terleckyj (1974) and Griliches (1979) had formerly made important contributions to the study of technology diffusion and economic growth, but from a domestic perspective.

analysis, both focused mainly on technology leader countries. Keller (1997)[2] concludes that there are significant positive spillovers, but they are mainly domestic and intraindustry, while there is only a small impact coming from foreign R&D. Moreover, Sakurai et al. (1997) study the industry and country differences, finding mixed and heterogeneous results in both dimensions when running country and sector specifications. The review of this literature shows that there is general agreement about the existence of global R&D trade-related spillovers, but there is no unique or robust conclusion about the magnitude, the pattern of that diffusion and how they can be measured in order to be tracked. Moreover their effect on productivity is neither automatic nor costless and the results are sensitive to multiple factors and interactions that must be considered.

Besides the lack of adequate data, one of the explanations for the shortage of conclusive results concerning international R&D spillovers is that they do exist, but they are positive and significant only in some industries, and therefore the results for the aggregate economy might reflect an average impact that gives an incomplete picture of the real influence of spillovers on economic performance. This is actually something that Sakurai et al. (1997) pointed out in their study for 10 OECD countries, but there is no evidence for countries outside that group.

This paper contributes to the literature by analyzing, from an industry level, the patterns of technology diffusion through trade from the technology leaders in terms of R&D expenditure, to a group of countries lying behind them in that sense, at least from an aggregate point of view. Newly available data enables the construction of a more accurate measure of trade-related R&D spillovers and the country sample can shed some light on the patterns of technology transfer to a set of countries that show different

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[2] This refers to a working paper latter published in 2002 with the same title.

situations in terms of innovation activity and economic development and that so far

haven't been studied from an industry perspective. In particular, the aim of the paper is

to provide some empirical evidence about what the industry level can add to the

aggregate economy analysis in terms of trade-related R&D spillovers.

The remainder of the paper is organized as follows. Section two summarizes

some important theoretical considerations. Section three describes the methodology

used to obtain the measure of trade-related R&D spillovers that will be tested in an

extended Cobb-Douglas neoclassical production function to analyze the impact of

international trade-related technology spillovers on industries' productivity. The

empirical implementation is contained in section four, where I will describe the data set

and present the preliminary results, including some conclusions, discussion of the

caveats and suggest some directions for future work.

## 2.- Theoretical considerations

Technological progress is related to the development of innovations, meaning

the process of introduction of new or improved goods in the market, as well as a

reduction in costs through improvements in the production process. This definition of

innovation leads to a distinction between product related innovations and those related

to the production process. In this sense, trade related spillovers defined above will show

mainly product innovations although, in an empirical sense, it is difficult to clearly

delimitate the boundaries due to the interactions between product and process type of innovations.

From another point of view Griliches (1979) introduced an important distinction between rent and knowledge spillovers[3]. Rent spillovers arise because the price of a product doesn't fully adjust for quality improvements, leading to an increase in the price/quality ratio which results in spillovers for the firms that use that product as intermediate input. This is a consequence of two circumstances. Firstly, due to the market structure, innovative firms under competitive pressure are not fully able to increase the price of their products proportionally to the improvements in quality. Secondly, deflator's methodology shows measurement problems to adjust to quality/price ratio changes in consequence of quality improvements. Therefore, these spillovers are related to economic transactions and, in that sense, they can be considered embodied spillovers as they are implicit in the goods traded.

Knowledge spillovers are related to the fact that the knowledge associated to an innovation isn't entirely appropriated by the innovation agents and others can "use" that knowledge without fully paying for it. This can take place through different channels, such as the use of patent information, researchers and skilled labour mobility, scientific publications and so on. Therefore, knowledge spillovers don't necessarily have to be related to economic transactions as is the case of rent spillovers and we can think about them as disembodied spillovers.

Once the concept of spillover has been defined we need to construct an empirical measure of innovation activity and the spillovers related to it. The pioneer works of Terleckyj (1974), Griliches (1980), Mansfield (1980), Scherer (1982) and Griliches and

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[3] Some authors refer to the knowledge spillovers defined by Griliches as pure knowledge spillovers.

Lichtenberg (1984) for US' case introduced the existing two basic approaches to the subject. The first one uses expenditures (or stock) of R&D as a measure of the effort that an agent makes to improve the technology available. This is an input variable and it is related to the investment in developing new technologies but not to the results of that activity and, consequently, it has some drawbacks when used to capture technology spillovers. From the conceptual point of view, not all the R&D efforts become innovations and, thus, we might be overestimating the innovation activity and, moreover, this varies from industry to industry. But there are some other aspects that imply an underestimation; first, R&D expenditures underestimate the technology efforts conducted by small firms where this activity is not isolated in accounts or employee functions. Second, R&D efforts in service sector are still poorly covered by official statistics, although recent efforts have been made to improve the quality of these data. The alternative approach uses an output measure of innovation activity like patents. But patents neither fully capture the innovation activity because, for instance, not all innovations are protected by a patent as this is not always the best option to protect the intellectual property of an innovation. Actually, there are different criteria among countries as to the process and requirements for granting patents. Finally, it should be pointed out that both, R&D expenditures and patents, fail to some extent to entirely capture the economic value of innovations as not all the patents or expenditures have the same value in terms of the innovations.[4]

Even though the theoretical distinction between rent and knowledge spillovers can be depicted, the literature shows some difficulties when trying to empirically identify them, mainly because the variables used to measure R&D spillovers capture both types to some extent. In this sense, R&D expenditures primary reflect embodied

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[4] For a deeper discussion about the use of patents and R&D expenditures as a measure of the innovation efforts see Griliches (1990), Naridi (1993) and Patel and Pavitt (1995).

rent spillovers related to economic transactions, but these transactions can also involve some knowledge spillovers.[5] For instance, if we focus on international trade related spillovers, trade of goods that contain innovations implies an improvement in the technology pool available in the host economy and, therefore, it can involve knowledge spillovers. Concerning patents, their use is closer to the analysis of knowledge spillovers although they can also reflect rent spillovers.

The interindustry dimension of technology spillovers raises the question of to what extent one sector can benefit from innovations developed in the rest of the economy. The empirical literature includes different options to measure how the technology developed in the economy affects one particular industry's technology pool. The baseline equation defines the total technology efforts related to a particular sector "$S_i$" as a weighted sum of the R&D efforts conducted in each sector of the economy (j).

$$S_i = \sum w_{ij} RD_j$$

(1)

The key question is how to define the weight matrix $w_{ij}$. From the point of view of the type of information used, there are two general approaches, related to the use of either interindustry trade or patent information[6]. The former option estimates the relationships using input-output matrices (Terleckyj, 1974), implying that the transfer of technology among sectors is proportional to the intermediate (or capital) goods trade. Therefore, we will be reflecting primary interindustry rent spillovers related to economic transactions. The latter approach, focused on patents information, can derive in different weight matrixes. Scherer (1982) constructs an input-output table that contains the industry of origin of one patent and its user industries. This approach tends

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[5] See Cincera and De la Potterie (2001) for a survey.
[6] See Los and Verspagen (2007) for further detail on this classification.

to stress transaction-based links and, therefore, captures mainly rent spillovers. Verspagen (1997) develops an alternative use of patent information that yields to a patent information input-output table that differs from Scherer's because it can be related to pure knowledge spillovers instead of rent spillovers[7]. Finally, Jaffe (1986) constructs a technological proximity matrix which relates the technological closeness (implying a higher probability of technological spillovers) between two firms or industries based on the coincidence of the classes of their patents. This kind of matrix tries to capture the non-traded knowledge spillovers.

One last aspect to consider is the international perspective of technology spillovers, which brings up the issue of international relationships. Focusing on trade related spillovers, the seminar work of Coe and Helpman (1995) defines the foreign technology advances available in a country as an import-share weighted average of the domestic R&D efforts conducted by trade partners, in a similar equation to the interindustry one (equation 1), but this time referring to countries instead of to firms or industries. Therefore, $S_i$ is the host country R&D received from abroad embodied in goods, $RD_j$ is the R&D efforts in the trade partner and $w_{ij}$ is the weight matrix, which in the case of rent trade related spillovers will contain bilateral import shares ($w_{ij} = M_{ij}/M_i$).

This approach has some disadvantages, quoted by Coe and Helpman themselves[8], related to the ability of $w_{ij}$ to capture the intensity of the R&D embodied in trade relationships. Van Pottelsberghe de la Potterie (1997) suggests an alternative specification for the weighting matrix in an attempt to better reflect the potential embodied technology spillovers related to international trade: $w_{ij} = M_{ij}/Q_i$, where the imports are expressed as a share of output in industry ($Q_i$) instead of total imports ($M_i$).

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[7] See Verspagen (1997) for a comparative analysis between both matrixes.
[8] Coe and Helpman (1995), pp. 863.

In this paper I will follow this approach, which is more appropriate for a sectoral analysis, in an attempt to control the differences in terms of size among sectors.

## 3.- Metodology

The literature focused on estimating technology spillovers is build on the hypothesis that R&D expenditure diffuses proportionately to the intensity of relationships among firms/sectors/countries.

That intensity is usually related to a weighting matrix for which there are several options. In this paper I will use a matrix based on trade of intermediate inputs and thus, I will focus on intermediate inputs trade as a channel for international technology diffusion.

The aim of the methodology is to obtain a measure of total R&D embodied in the production of industry i in country p (technology developer) exported to industry j in country d (technology importer). The measure will be a combination of two dimensions: the particular R&D intensity of production in each trade partner country and the bilateral industry trade intensity between country d and its trade partners. As there is no enough data available to take into account the intersectoral trade in capital goods, the paper will focus in intermediate goods trade.

In a first stage I estimate the technology embodied in production of technology leader countries following the literature about intersectoral technology flows. Next, I calculate exports from one industry in a technology leader country to each of the

industries of a given trade partner. I estimate these flows using industry-level bilateral trade data and import Input-Output tables of trade partners. The combination of both estimations results in a measure which captures the technology embodied in bilateral industry trade of intermediate inputs. Finally, I use an extended Cobb-Douglas neoclassical production function to analyze the impact of international trade-related technology spillovers on industries' productivity.

### ☞ R&D embodied in industry exports of G7 countries (by producer industry)

Concerning the first dimension, we want to have a measure of the technology embodied in production, as exports are part of it. A first approach to the measurement of the R&D embodied in production is to calculate output's R&D intensity, assuming that R&D embodied production is mainly conducted in the own industry.

$$r_j = {R\&D_j} \big/ {x_j} \tag{2}$$

Where $x_j$ refers to industry output. But the literature about technology spillovers recognizes the existence of intersectoral transmission of technology, so if we want to analyze the product-embodied international transfer of technology this should include not only R&D related to industry's efforts but also improvements incorporated through intermediate inputs.

This approach built on the literature about intersectoral R&D flows that uses Input- Output tables to estimate the total content of R&D in one unit of final demand output (in this sense exports are part of this final demand production). It assumes that technology can be transferred through intermediate inputs trade and, thus, the

technology embodied in a final product can include some technology developed by other industries.

Taking into account this possibility there are two alternatives to measure R&D content using as a starting point the square matrix of inter-industry trade of intermediate inputs: input or output coefficients. The choice between them will depend on our assumption concerning the degree of public good that we assign to R&D[9].

In the first case, we assume that the gains that a sector j can obtain from the R&D conducted by suppliers is proportional to their relative importance, in terms of intermediate inputs, in the sector j input structure. Thus, we assume that R&D is a "public good" in the sense that it can benefit several sectors simultaneously. The more important one particular input is in the productive function of one sector, the more it will benefit from the R&D conducted in the supplier sector.

Output coefficients assume that the R&D that one sector can transfer to another is proportional to the output that former sells to the latter. Contrary to the input coefficient, we presume that the benefits of R&D are "industry specific", in the sense that if one sector sells an amount of output to another sector, it implicitly transfers a proportion of its technology to that particular sector.

From another point of view, Input-Output tables, through the inverse matrixes of the direct coefficients mentioned, can take into account not only the first round of technology flows but also include the indirect and induced effects of intersectoral relations. In this respect, we are assuming that the technology embodied in one good is the result of an accumulation process of interindustry trade.

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[9] Wolff E. and Naridi, I. (1993) or Los, B. and Verspagen (2007) include a deeper analysis of the implicit assumptions of both types of direct coefficients.

In this paper I will use input direct and indirect coefficients, focusing in the final content of R&D of a unit produced from the point of view of the user and its production function and trying to avoid overestimating the R&D content due to the reverse effect. Moreover, a priori it is less likely that second and following rounds of indirect transfer of technology will have a significant impact in the final technology content of production in one particular industry[10].

Therefore we can define the total technology content of one unit produced by sector j as the aggregation of the direct ($r_j$) and indirect content ($ir_j$):

$$tir_j = r_j + ir_j \tag{3}$$

The direct content will be the industry R&D effort measured by the R&D intensity defined in equation 2, and the indirect content of technology of production in sector j will be a function of the R&D expenditures in sector i (relative to its output) and the importance in sector j's input structure ($a_{ij}$).

$$r_{ij}^* = \langle r_i \rangle * a_{ij}^* \tag{4}$$

Where $a_{ij}^*$ refers to the coefficients of the technical coefficients matrix A, but where we have set the principal diagonal equal to cero to avoid double counting. If we add up by columns the values for $r_{ij}^*$, we will obtain a measure of the indirect technology contain in each unit produced by sector j.

Indirect R&D spillovers: $ir_j = \sum_i r_{ij}^*$ \hfill (5)

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[10] This approach is used by Wolff and Naridi (1993), who only compute first (direct) and second-round of indirect input coefficients.

The total R&D intensity embodied will be multiply by the value of bilateral industry exports. For a given country "p", total R&D embodied in its exports from industry j to country "d" can be defined as:

$$TRDE_{jpd} = tir_{jp} * EXP_{jpd} \qquad (6)$$

Where $tir_{jp}$ is the value of $tir_{j}$ for a particular country p and $EXP_{jpd}$ are the exports from industry i in country p to country d.

### ☞ Industry imports by trade partner (G7) for non G7 countries

The optimal approach to calculate international industry trade will be to use the trade information contained in bilateral import Input-Output tables (which include the distribution of imports coming from a particular industry and country by industry of use in the importing country), but these tables are not available yet. Thus, I will estimate the distribution of imports of each importing country by user industry by means of the information included in import Input-Output table for each one of these countries. These tables consider only total imports by industry without trade partner disaggregation.

*Estimation of how much does industry "j" in country "c" import from industry "i" of country "p"*

Using the import Input-Output table for a given country "d", I derive a similar matrix that shows the industry of use's share of total imports from each industry of origin:

$$W_{d} = \begin{bmatrix} w_{11d} & .. & w_{1kd} \\ .. & .. & .. \\ w_{j1d} & .. & w_{jkd} \end{bmatrix} \qquad (7)$$

Thus, $W_d$ shows by rows the distribution, by using industry, of imports produced in sector "j" overseas and by columns the imports made by each domestic industry. This matrix has a shortcoming for our purpose as it accounts for the total imports and we need to have information with sectoral breakdown by country (and industry) of origin of imports. We will assume that the distribution of imports by industry of use is common to all trade partners[11]. Note that this doesn't imply that imports come in equal proportion from each trade partner. These differences are captured by industry export statistics taken into account in the calculation of R&D embodied in exports.

The calculated shares ($w_{jpd}$) will be used as weights to distribute the total R&D content of each trade partner exports to country d ($TRDEj_{pd}$), obtaining as a result a matrix for each pair of trade partners (p and d) that shows total R&D embodied in imports with an industry and partner dimension:

$$S_{pd} = \begin{bmatrix} S_{11pd} & .. & S_{1kpd} \\ .. & .. & .. \\ S_{j1pd} & .. & S_{jkpd} \end{bmatrix} \tag{8}$$

Where $S_{jkpd} = w_{jkd} * TRDE_{jpd}$

In this paper I focus on the industry perspective of international technology and, thus, I will add up the measure obtained to show global imported R&D by industry of use (aggregation by columns) for each non G7 country[12]:

$$TRD_{kd} = \sum_j \sum_p S_{jkpd} \tag{9}$$

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[11] This can be in some way interpreted as if there were perfect substitution among the countries of origin of imports.

[12] To obtain $TRD_{kd}$ I have applied a tornqvist index aggregation process.

### ☞ *Framework for the impact analysis: Production functions*

The literature concerning macroeconomic analysis follows two approaches to empirically address the impact of technology over economic performance, using production or cost functions[13]. In this paper I will follow the first option as it is more convenient for the data used.

Therefore I will relate a measure of economic performance (productivity) with the spillover measure previously calculated, besides the classical production factors, in line with the work of Griliches (1979), who introduced the technology spillovers as a source of technological change. Later, Grossman and Helpman (1991) also take into account the role of trade in economic growth, setting the theoretical framework for the seminar empirical work on trade and technology spillovers conducted by Coe and Helpman (1995).

I will use a production function approach based on an extended Cobb-Douglas neoclassical production function:

$$Y_{kdt} = A_{kdt} K_{kdt}^{\alpha_K} L_{kdt}^{\alpha_L} M_{kdt}^{\alpha_M} \tag{10}$$

where k refers to the industry and t to the period of time, Y is the gross output, K the capital input, L the labour input, M intermediate inputs and A the technology component.

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[13] For a discussion on the use of those approaches see eg. Nadiri (1993).

If we divide both sides of the above equation by L and substitute production by value added we can rewrite (10) in the following way[14]:

$$y_{kdt} = A_{kdt}\left(k_{kdt}\right)^{\alpha}$$ (11)

where $y_{kdt}$ is labour productivity, $k_{kdt}$ is the labour-capital intensity and $\alpha$ is the share of capital in rents.

Focusing again in the technology component or total factor productivity, A, we will defined it as $A_{kdt} = \phi e^{\lambda t} R_{kdt}^{\gamma}$, where $e^{\lambda t}$ is an exogenous parameter of technological change and R is a function of the measure obtained for international technology spillovers ($TRD_{kdt}$).

In this respect, we will divide $TRD_{kdt}$ by the industry value added, leading to a measure of the share of foreign embodied knowledge related to the industry total value added[15].

$$trd_{kdt} = \frac{TRD_{kdt}}{GVA_{kdt}}$$ (12)

Taking logarithms we obtain the final specification

$$\ln y_{kdt} = \lambda + \alpha_K \ln k_{kdt} + \gamma \ln trd_{kdt}$$ (13)

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[14] In this equation the standard hypotheses apply and we have homogeneous inputs and outputs, constant returns to scale ($\Sigma\alpha=1$), competitive behaviour and profit maximizing levels of factors of production other than R&D.

[15] The lack of proper rates of obsolescence of R&D capital and of the lag structure relating R&D expenditure to current increases in technological knowledge makes interesting to use alternative measures such as R&D intensity. Griliches (1973) and Terleckyj (1974) reparametrize the standard model, common elasticities one, in terms of a common rate of return across industries. They show equivalence between this concept and the use of the rate of growth of R&D capital, under the assumption of 0% depreciation rate for R&D capital.

# 4.- Empirical implementation

## 4.1.- Definition of variables and data sources

The data set employed in the implementation is obtained mainly from two sources, OECD Databases and Groningen Development Center EU KLEMS Database. In particular, OECD provides figures for R&D expenditure for G7 countries (ANBERD Database), bilateral trade (Bilateral Trade Database) and Input Output tables (Input-Output Database). The structural variables used are derived using STAN Database from OECD and EUKLEMS Database[16]. The monetary variables have been expressed in real terms, where prices used as deflators are chain-price indexes, with reference year 1995. The export data has been deflated using output prices due to the lack of proper industry deflators and Input-Output tables have been used in current terms and refers to 2000 or closer year.

For the employment data I have used the number of employees, as there are not complete data for fulltime equivalent employees or worked hours with the disaggregation used in this paper.

Finally, physical capital stock has been calculated applying the Permanent Inventory Method to Gross Fixed Capital Formation data (deflated by GFCF prices), assuming a depreciation rate of 10%, following the mainstream literature[17].

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[16] The main source of data is EUKLEMS due to the existence of quality corrected prices, although we have used alternatives sources to estimate some blanks.

[17] Verspagen (1996) and Lee (2006) are examples of papers that use the same rate for OECD countries.

The sample of the empirical application is limited by the available data for some

sectors, mainly in terms of R&D expenditure and Gross Fixed Capital Formation, and

consist in nine OECD countries (Austria, Belgium, Denmark, Finland, Ireland, The

Netherlands, Norway, Spain and Sweden), besides the G7 countries used as the source

of technology transfer (Canada, France, Italy, Japan, UK and US), and covers

manufacturing industries at a two digit level[18] over the period 1992-2002.

*Table 1. Description of industry breakdown*

| ISIC code | Description |
|-----------|-------------|
| 15-16 | Food products, beverages and tobacco |
| 17-19 | Textiles, textile products, leather and footwear |
| 20 | Wood and products of wood and cork |
| 21-22 | Pulp, paper, paper products, printing and publishing |
| 24 | Chemicals and chemical products |
| 25 | Rubber and plastics products |
| 26 | Other non-metallic mineral products |
| 27 | Basic metals |
| 28 | Fabricated metal products, except machinery and equipment |
| 29 | Machinery and equipment, n.e.c. |
| 30 | Office, accounting and computing machinery |
| 31 | Electrical machinery and apparatus, nec |
| 32 | Radio, television and communication equipment |
| 33 | Medical, precision and optical instruments |
| 34 | Motor vehicles, trailers and semi-trailers |
| 35 | Other transport equipment |
| 36-37 | Manufacturing nec; recycling |

**4.2.- Preliminary results**

Assuming a linear function of the equation 13 defined and expressing the model

in growth rates, I will estimate a panel data model for the following specification:

$$\Delta \ln y_{dt} = c_d + \beta_1 \Delta \ln k_{dt} + \beta_2 \Delta \ln trd_{dt} + \varepsilon_{dt} \qquad (14)$$

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[18] Due to the lack of data for several countries the application excludes industry 23 (Coke, Refined
Petroleum Products and Nuclear Fuel).

Where $c_d$ is the constant term, $\beta_1$ is the elasticity of labour-capital intensity, $\beta_2$ is the rate of return to the international technology spillovers measure, and $\varepsilon_{dt}$ is the error term.

*Table 2. Estimation results*

| | *Industry* | *Capital Stock per worker* | *Technology transferred by trade* | *$R^2$* |
|---|---|---|---|---|
| 15-16 | Food products, beverages and tobacco | 0,63 (0,10)*** | 0,21 (0,08)*** | 0,48 |
| 17-19 | Textiles, textile products, leather and footwear | 0,36 (0,08)*** | 0,13 (0,08)* | 0,34 |
| 20 | Wood and products of wood and cork | 0,31 (0,09)*** | 0,20 (0,09)** | 0,25 |
| 21-22 | Pulp, paper, paper products, printing and publishing | 0,26 (0,08)*** | 0,26 (0,08)*** | 0,28 |
| 24 | Chemicals and chemical products | 0,27 (0,09)*** | 0,17 (0,08)** | 0,24 |
| 25 | Rubber and plastics products | 0,38 (0,11)*** | 0,21 (0,08)*** | 0,32 |
| 26 | Other non-metallic mineral products | 0,22 (0,08)*** | 0,20 (0,11)* | 0,23 |
| 27 | Basic metals | 0,22 (0,08)*** | 0,28 (0,14)** | 0,19 |
| 28 | Fabricated metal products, except machinery and equipment | 0,19 (0,08)*** | 0,37 (0,10)*** | 0,38 |
| 29 | Machinery and equipment, n.e.c. | 0,37 (0,10)*** | 0,37 (0,10)*** | 0,46 |
| 30 | Office, accounting and computing machinery | 0,24 (0,23) | 1,08 (0,35)*** | 0,12 |
| 31 | Electrical machinery and apparatus, nec | 0,55 (0,13)*** | 0,27 (0,13)** | 0,31 |
| 32 | Radio, television and communication equipment | 0,08 (0,16) | 0,47 (0,16)*** | 0,11 |
| 33 | Medical, precision and optical instruments | 0,31 (0,09)*** | 0,10 (0,09) | 0,18 |
| 34 | Motor vehicles, trailers and semi-trailers | 0,25 (0,08)*** | 0,31 (0,11)*** | 0,28 |
| 35 | Other transport equipment | 0,43 (0,10)*** | 0,05 (0,04) | 0,24 |
| 36-37 | Manufacturing nec; recycling | 0,25 (0,08)*** | 0,31 (0,11)*** | 0,28 |

Notes: t-test statistics reported in parentheses, *, 10% significance level, **5% significance level ***1% significance level

Table 2 reports the results obtained for each industry regression based on correlates panels corrected standard error estimations (PCSEs). I have run Wooldridge test to detect serial correlation, Modified Wald test for group heteroskedasticity and Breush and Pagan test LM of independence for contemporaneous correlation on each industry. Finally, there are several approaches to deal with the endogeneity problem related to the fact that changes in R&D expenditures can be a consequence of economic

growth patterns. I have included a lagged value for the R&D variable to analyze this possibility and the results don't change in sign and significance[19].

The results obtained show that in general terms the measure developed of technology potentially transferred through imports from G7 countries has a positive impact over labour productivity, which results significant in most of the sectors although the explanation power of the regressions is relatively low.

This conclusion is consistent with the literature, where there is a general agreement about the positive correlation between R&D and economic growth, and the average rate of return of direct R&D is on average a 15%. If we calculate the unweighted average of the values for the rate of return obtained in this paper, the result is 29%, almost twice that 15%. Two considerations need to be made, firstly, the unweighted average is not quite representative as there are size differences among industries and, in fact, this is one of the reasons for the need of an industry perspective analysis pointed out at the beginning of the paper. Secondly, the inclusion of the impact related to indirect R&D embodied in production might lead to a higher value for the rate of return, although probably not resulting in such a difference.

In particular the results for sectors 33 and 35 are interesting, as the R&D measure is not significant. They are high technology sectors and therefore one would expect to find a stronger relationship in them. Although these results need a deeper analysis, from an economic perspective, this might reflect the importance of disembodied R&D spillovers versus the rent spillovers considered in this paper.

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[19] Due to the lack of a longer series I haven't been able to test for different lag structures. In this sense, the literature hasn't arrived to a conclusion about the proper lag structure behind the R&D expenditure effect on productivity. Coe and Helpman (1995), Lichtenberg and van Pottelsberghe (1998) and Keller (2002) are examples of the use of one year lag.

Moreover, from the technical point of view one of the possible explanations is the lack of appropriate information to construct a stock measure of R&D, which could affect these sectors in particular. Also the lack quality adjustment of prices for several countries for GFCF industry deflator might cause a higher bias in these sectors.

Therefore, the results confirm the importance of trade as a channel for technology spillovers, even from an industry perspective, although they also remark the differences in its impact industry by industry. The rate of returns vary from 5% (sector 35, other transport equipment) to 100% (sector 35, office, accounting and computing machinery), although these seem to be outliers and if we exclude them, the range goes from 10% to 47%.

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