**Growth, R&D expenditure and spillover effects. An input-output approach.**

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# 1. Introduction.

 There is a certain consensus in economic literature about the factors that have influenced in historical differences in growth rates observed between developed and developing countries. This can be seen in papers such as Szirmai (2013), who highlights the role of industrialization as engine of growth in developing countries, or Hanushek (2013), with a focus on human capital. However, it is less clear what elements have marked different paths of growth in developed economies in recent decades, being these differences more visible during the recent economic crisis.

 R&D expenditure seems to be key for explain economic growth in developed countries. Some papers have tried to analyse the effect of R&D expenditure realized in a particular sector over others. In that way we can mention papers such as Tsai, K-H et al. (2004), Bernstein, J. I (1998) or Berdnt, E.R. (1995); which work with sectors such as manufacturing sector or high-tech industry. However here we take as reference Ten Raa, T et al. (2000), that gives an alternative way to calculate spillover effects of R&D expenditure and its effect over total factor productivity and Antonelli, C (2015) that captures the role of knowledge externalities over productivity making use of input-output tables of 15 countries. So, the main objective of this paper is to analyze inside a multiregional frame the R&D expenditure embodied in production and sales of each country and how and when this R&D embodied has effect over their economies, using econometric tools. In order to do that, we use MRIO-WIOD (World input-output database) to make our empirical study and we obtain R&D expenditure information from OECD databases.

 In that way in the first section we explain the methodology used, based on input-output models, to calculate the R&D embodied both in production and sales, as this analyses has not made yet in these two perspectives. To do it, we have only to define demand matrix in two different forms, as we will explain with more detailed. In the following section we make a briefly analyses of data relative to R&D expenditure to continue showing the main results obtained from the empirical application. Then, in section 4, following the idea that spillover effects have effect in productivity, and, so on in economic growth, with some retard we wanted to make an econometric regression that would reflect the evolution follow for the effect of this R&D expenditure embodied. In other words, we want to capture the temporal gap of R&D effect over economic growth, being something not studied until now. We will finish giving some conclusions.

**2. Methodology.**

 As we have said before, we are going to work inside multiregional frame, as we are going to use WIOD tables. WIOD tables are multiregional input-output tables that are formed b 40 countries plus rest of world (obtained as a residual) and 35 sectors by each country, as Timmer, M.P. (2012) explains with more detailed. The implicit model we are going to use is input-output model, being its basic equation;

**x**= **Ax** + **y** (1)

where **x** is outputs vector, **A** is the technical coefficients matrix and **y** is the vector of final demand. We can transform expression (1) into expression (2) as follows;

**x**= (**I**-**A**)-1**y** (2)

being (**I**-**A**)-1 Leontief inverse, whose each column reflect the output increments of sector i if there would be a unitary increment of production of sector j.

 As we have said before we are going to work inside MRIO-WIOD frame, behind which the model implicit is the explained. So a basic way to calculate the R&D embodied would be as follows:

**S**=**R** (**I**-**A**)-1**Y** (3)

where **S** would be the resulting matrix and **R** would be R&D expenditure matrix. However, in that way, we are missing information, and it is needed to transform **R** into a diagonal matrix, represented by**.** This diagonal matrix is created through the formation of diagonal matrices by parts, as in the example:

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **COUNTRY 1** | **COUNTRY 2** |
| **COUNTRY 1** | *Sector 1* | 2  | 0 |
| *Sector 2* | 3 | 0 |
| **COUNTRY 2** | *Sector 1* | 0 | 1 |
| *Sector 2* | 0 | 7 |

In this case we will make a diagonal matrix for each colored area. In that way, we would obtain a matrix such as the following:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | **COUNTRY 1** | **COUNTRY 2** |
|  |  |  | *Sector 1* | *Sector 2* | *Sector 1* | *Sector 2* |
| **COUNTRY 1** | *Sector 1* | 2 | 0 | 0 | 0 |
| *Sector 2* | 0 | 3 | 0 | 0 |
| **COUNTRY 2** | *Sector 1* | 0 | 0 | 1 | 0 |
| *Sector 2* | 0 | 0 | 0 | 7 |

It is obvious that to make calculus we have to adapt R&D expenditure to WIOD tables. In this step we have had some problems to harmonize both databases, so to solve problems we have had to eliminate countries and to aggregate sectors. In this form, we will work with 17 sectors and 25 countries in 1995, 1996 and 1997, 28 countries in 2005 and 2009 and 27 countries in the rest of the years.

 Coming back to expression (3) we have to note that in multiregional frame **Y** is a not square matrix having a column by each country. So, we can transform this demand matrix in two ways, giving each one different interpretation to results obtained. The first way we can transform demand is making diagonals matrices by parts as we have made with R&D data. In that way we take into account imports of each country as their own demand. So it will be a production perspective, as we can see in the followings expressions:

** ** (4)

The matrix expression of this equation for 2x2 model would be:

|  |  |  |  |
| --- | --- | --- | --- |
| $$r\_{1}^{1}$$ | 0 | 0 | 0 |
| 0 | $$r\_{2}^{1}$$ | 0 | 0 |
|  0 | 0 | $$r\_{1}^{2}$$ | 0 |
| 0 | 0 | 0 | $$r\_{2}^{2}$$ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| $$α\_{1,1}^{1,1}$$ | $$α\_{1,2}^{1,1}$$ | $$α\_{1,1}^{1,2}$$ | $$α\_{1,2}^{1,2}$$ | $$y\_{1}^{1,1}$$ | 0 | $$y\_{1}^{1,2}$$ | 0 |
| $$α\_{2,1}^{1,1}$$ | $$α\_{2,2}^{1,1}$$ | $$α\_{2,1}^{1,2}$$ | $$α\_{2,2}^{1,2}$$ | 0 | $$y\_{2}^{1,1}$$ | 0 | $$y\_{2}^{1,2}$$ |
| $$α\_{1,1}^{2,1}$$ | $$α\_{1,2}^{2,1}$$ | $$α\_{1,1}^{2,2}$$ | $$α\_{1,2}^{2,2}$$ | $$y\_{1}^{2,1}$$ | 0 | $$y\_{1}^{2,2}$$ | 0 |
| $$α\_{2,1}^{2,1}$$ | $$α\_{2,2}^{2,1}$$ | $$α\_{2,1}^{2,2}$$ | $$α\_{2,1}^{2,2}$$ | 0 | $$y\_{2}^{2,1}$$ | 0 | $$y\_{2}^{2,2}$$ |

The resulting matrix **S*X*** would be:

|  |  |  |  |
| --- | --- | --- | --- |
| $$r\_{1}^{1}\left(\sum\_{r=1}^{2}α\_{1,1}^{1,r}y\_{1}^{r,1}\right)$$ | $$r\_{1}^{1}\left(\sum\_{r=1}^{2}α\_{1,2}^{1,r}y\_{2}^{r,1}\right)$$ | $$r\_{1}^{1}\left(\sum\_{r=1}^{2}α\_{1,1}^{1,r}y\_{1}^{r,2}\right)$$ | $$r\_{1}^{1}\left(\sum\_{r=1}^{2}α\_{1,2}^{1,r}y\_{2}^{r,2}\right)$$ |
| $$r\_{2}^{1}\left(\sum\_{r=1}^{2}α\_{2,1}^{1,r}y\_{1}^{r,1}\right)$$ | $$r\_{2}^{1}\left(\sum\_{r=1}^{2}α\_{2,1}^{1,r}y\_{2}^{r,1}\right)$$ | $$r\_{2}^{1}\left(\sum\_{r=1}^{2}α\_{2,1}^{1,r}y\_{1}^{r,2}\right)$$ | $$r\_{2}^{1}\left(\sum\_{r=1}^{2}α\_{2,1}^{1,r}y\_{2}^{r,2}\right)$$ |
| $$r\_{1}^{2}\left(\sum\_{r=1}^{2}α\_{1,1}^{2,r}y\_{1}^{r,1}\right)$$ | $$r\_{1}^{2}\left(\sum\_{r=1}^{2}α\_{1,1}^{2,r}y\_{2}^{r,1}\right)$$ | $$r\_{1}^{2}\left(\sum\_{r=1}^{2}α\_{1,1}^{2,r}y\_{1}^{r,2}\right)$$ | $$r\_{1}^{2}\left(\sum\_{r=1}^{2}α\_{1,1}^{2,r}y\_{2}^{r,2}\right)$$ |
| $$r\_{2}^{2}\left(\sum\_{r=1}^{2}α\_{2,1}^{2,r}y\_{1}^{r,1}\right)$$ | $$r\_{2}^{2}\left(\sum\_{r=1}^{2}α\_{2,2}^{2,r}y\_{2}^{r,1}\right)$$ | $$r\_{2}^{2}\left(\sum\_{r=1}^{2}α\_{2,1}^{2,r}y\_{1}^{r,2}\right)$$ | $$r\_{2}^{2}\left(\sum\_{r=1}^{2}α\_{2,2}^{2,r}y\_{2}^{r,2}\right)$$ |

 We can interpret the first column of matrix **S** as the R&D integrated in the production of good 1 and consumed in country 1, the second column as the R&D integrated in the production of good 2 and consumed in country 1, the third column as the R&D integrated in the production of good 1 and consumed in country 2 and the fourth column in the production of good 2 and consumed in country 2.

 The other way to transform demand matrix is creating a diagonal matrix for each column and making the sum of resulting diagonal matrices. As a difference with previous perspective, each column of matrix **S**S indicates de R&D embodied in sales of good i with independence of demand’s origin. This can be seen better if we reproduce with detailed the matrix expression of expression (5) for 2x2 model:

**** (5)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| $$r\_{1}^{1}$$ | 0 | 0 | 0 | $$α\_{1,1}^{1,1}$$ | $$α\_{1,2}^{1,1}$$ | $$α\_{1,1}^{1,2}$$ | $$α\_{1,2}^{1,2}$$ |
| 0 | $$r\_{2}^{1}$$ | 0 | 0  | $$α\_{2,1}^{1,1}$$ | $$α\_{2,2}^{1,1}$$ | $$α\_{2,1}^{1,2}$$ | $$α\_{2,2}^{1,2}$$ |
|  0 | 0 | $$r\_{1}^{2}$$ | 0 | $$α\_{1,1}^{2,1}$$ | $$α\_{1,2}^{2,1}$$ | $$α\_{1,1}^{2,2}$$ | $$α\_{1,2}^{2,2}$$ |
| 0 | 0 | 0 | $$r\_{2}^{2}$$ | $$α\_{2,1}^{2,1}$$ | $$α\_{2,2}^{2,1}$$ | $$α\_{2,1}^{2,2}$$ | $$α\_{2,1}^{2,2}$$ |

|  |  |  |  |
| --- | --- | --- | --- |
| $$y\_{1}^{1,1}+y\_{1}^{1,2}$$ | 0 | 0 | 0 |
| 0 | $$y\_{2}^{1,1}+y\_{2}^{1,2}$$ | 0 | 0 |
| 0 | 0 | $$y\_{1}^{2,1}+y\_{1}^{2,2}$$ | 0 |
| 0 | 0 | 0 | $$y\_{2}^{2,1}+y\_{2}^{2,2}$$ |

The resulting matrix **S**S would be the following;

|  |  |  |  |
| --- | --- | --- | --- |
| $$r\_{1}^{1}α\_{1,1}^{1,1}\left(\sum\_{s=1}^{2}y\_{1}^{1,s}\right)$$ | $$r\_{1}^{1}α\_{1,2}^{1,1}\left(\sum\_{s=1}^{2}y\_{2}^{1,s}\right)$$ | $$r\_{1}^{1}α\_{1,1}^{1,2}\left(\sum\_{s=1}^{2}y\_{1}^{2,s}\right)$$ | $$r\_{1}^{1}α\_{1,2}^{1,2}\left(\sum\_{s=1}^{2}y\_{2}^{2,s}\right)$$ |
| $$r\_{2}^{1}α\_{2,1}^{1,1}\left(\sum\_{s=1}^{2}y\_{1}^{1,s}\right)$$ | $$r\_{2}^{1}α\_{2,2}^{1,1}\left(\sum\_{s=1}^{2}y\_{2}^{1,s}\right)$$ | $$r\_{2}^{1}α\_{2,1}^{1,2}\left(\sum\_{s=1}^{2}y\_{1}^{2,s}\right)$$ | $$r\_{2}^{1}α\_{2,2}^{1,2}\left(\sum\_{s=1}^{2}y\_{2}^{2,s}\right)$$ |
| $$r\_{1}^{2}α\_{1,1}^{2,1}\left(\sum\_{s=1}^{2}y\_{1}^{1,s}\right)$$ | $$r\_{1}^{2}α\_{1,2}^{2,1}\left(\sum\_{s=1}^{2}y\_{2}^{1,s}\right)$$ | $$r\_{1}^{2}α\_{1,1}^{2,2}\left(\sum\_{s=1}^{2}y\_{1}^{2,s}\right)$$ | $$r\_{1}^{2}α\_{1,2}^{2,2}\left(\sum\_{s=1}^{2}y\_{2}^{2,s}\right)$$ |
| $$r\_{2}^{2}α\_{2,1}^{2,1}\left(\sum\_{s=1}^{2}y\_{1}^{1,s}\right)$$ | $$r\_{2}^{2}α\_{2,1}^{2,1}\left(\sum\_{s=1}^{2}y\_{2}^{1,s}\right)$$ | $$r\_{2}^{2}α\_{2,1}^{2,2}\left(\sum\_{s=1}^{2}y\_{1}^{2,s}\right)$$ | $$r\_{2}^{2}α\_{2,2}^{2,2}\left(\sum\_{s=1}^{2}y\_{2}^{2,s}\right)$$ |

 Column 1 would be reflecting the R&D integrated in demand of good 1 of country 1, column 2 the R&D integrated in demand of good 2 of country 1 and so on successively.

 To sum up, we have seen two different forms to obtain the R&D “embodied”; the first one is going to be called invested perspective whereas the second one will be called embodied perspective. The main difference between both perspectives is that the first one has a production perspective while the second one is focus on final destinations or consumptions. In the following section we are going to show the main results associated to both perspectives, focusing both on differences and similarities.

# 3. Data and main results.

 In this section first we are going to make a briefly analysis of data used to make the empirical application, in order to have some clear ideas about R&D behavior at global terms. Then we will explain the main results obtained, centering the study in both perspectives production and sales.

3.1. Data

As we have said before, R&D data is obtained from OECD data base, particularly from Structural Analysis databases and we use the file related to R&D expenditure in industry ([www.oecd.org](http://www.oecd.org), Structural Analysis (STAN) Databases). However, this database lacks of data for some countries such as Malta or Luxembourg and the disaggregation by sectors is not the same for all countries (this is the case of China or Denmark). These problems create some difficulties that we have to deal with when we match R&D data and WIOD magnitudes[[1]](#footnote-1).

 Observing the R&D expenditure data we can say that four countries stand out; USA, Japan, Germany and China at the end of the period studied. Besides, there is a positive tendency along the period, despite the beginning of the recent crisis and the evolution followed by gross fixed capital. The effect of the crisis it is possible to see better if we observe rates of growth of R&D expenditure. In 2008 and, specially, in 2009 this rate is negative for most countries. For instance, in Japan the rate of growth of R&D expenditure was 3.5% in 2007 and in 2009 was -11%.

 More interesting is the results related to weights of R&D expenditure respect to output and value added. In countries such as Germany, Finland, Denmark, Japan or USA the weight respect to output is near to 1% of total output and in the last years is, even, higher. It is remarkable the case of Spain where it is observed low percentages that achieves 0.40% in the last year, as is the case of Italy, Netherlands or China since 2008. These differences are important because they may distinguish between innovator and followers countries. Besides, we have to mention the evolution follow by these weights. In most countries the percentage of R&D expenditure respect output has a significant growth until 2001, approximately. Since this year this figure decline, particularly in Germany, Finland, Japan and Denmark; where the R&D expenditure is the highest, as we can see in graph 1. Perhaps, these results could have been signals of the crisis that would have started in 2007.

 The evolution followed by the percentage of R&D expenditure respect to value added has (see graph 2) similar behavior as the percentage respect to output, although it is possible to observe some differences. First, the countries where we find the highest percentage are Finland, Japan, Denmark, Germany, USA and Korea. Besides, in the case of value added, the R&D expenditure realized by these countries represents over 2% in the last four years. However, in countries such as Spain, Italy or Hungary this percentage is around 0.8%, being some of the lowest values we can observe. The evolution followed by the percentage of R&D expenditure respect to value added is similar as the percentage respect to output in the six countries we focus on. In the cases of Finland and Germany it is possible to observe a decline around 2000-2001, approximately. The same negative tendency it is possible to observe in Denmark in the years we have data for. By contrast, in the cases of USA, Japan and Korea it is possible to observe a positive tendency with the beginning of the crisis, although in Japan we can see more oscillations than in the other countries. As we have said before, perhaps these evolutions could be indicating signals of crisis some years before the start of the current crisis.

**Graph 1:** percentage of R&D expenditure respect to output.

Germany

Japan





**Graph 2:** percentage of R&D expenditure respect to value added.





 It is also interesting what it is the distribution of R&D expenditure between sectors. This can be seen in table 1. In general, R&D expenditure is located in sectors of high and medium-high equipment such as Chemicals and Chemicals products, Machinery and equipment or Electrical and optical equipment; although high technology services gain positions along the years in some countries such as UK, Spain and USA. For instance, as can be seen in table 6, in 1995 in Spain R&D expenditure realized in high technology services represented 10% whereas in 2011 represented over 22%. In USA the change is more visible, in 1995 R&D expenditure in high technology services represented over 20% and in 2011 this percentage had incremented 20 percentage points, being around 40% in that year. Despite that, countries, in general, have centered their R&D investment in less sectors along the period studied and R&D expenditure, in the last years, is usually located in sectors related to equipment sectors or to chemical product; while at the beginning R&D expenditure was more distributed between sectors.

**Table 1:** distribution of R&D expenditure between


 So with this brief comment about the data we are gping to use, we are able to continue with our analysis and show the main results obtained associated to R&D embodied both in countries production and countries sales.

3.2. Invested and Embodied R&D: main results.

 First we have to start explaining the evolution followed by total flow of R&D expenditure and what percentage represents the proportion associated to external sector in the case of both perspectives. This can be seen in graph 3.

**Graph 3:** total flow and external flow since invested and embodied perspective.[[2]](#footnote-2)

 We can observe that total flow follows an increasing path, despite the insignificant decreases observed in 2005 and 2009. If we focus our attention on the volume of external flow it is possible to see the same evolution (growing) both at production and sales perspective. However, the volume of external flow of R&D expenditure distributed between countries is higher in the case of invested perspective than in embodied perspective. This can be better seen in graph 4 where we show the percentage that this external flow represents over total flow.

**Graph 4:** percentage of external flow over total production since invested and embodied side.

As we have said previously, the evolution followed by the percentage of external flow respect total flow in both cases is really similar. However, the percentage that represent in each situation is different being a difference of 10 percent points along all the period, higher since production side than sales side. This perhaps is indicating that the R&D invested is more distributed between countries than R&D embodied.

Until now we have made a global analysis, now we have to focus our attention on countries and the proportion of R&D invested and embodied. In general, as we can see in table 2, the countries that achieves the most important role are USA, Japan and Germany, both analyzing R&D invested and R&D embodied. Between the three countries, the R&D, both, embodied and invested represent near 70% of total R&D flow. This percentage seems to be lower when we introduce China (we only have data for the last four years). At this moment Japan R&D embodied and invested tend to decrease; for example, R&D embodied was 26% in 1995 and 8% in 2011, whereas China R&D embodied represented near 15% in 2011. Other countries where we can observe significant levels of R&D embodied and invested are France and UK that achieves percentages respect total flow near 5% and 4% respectively in 1995. In 2011 the scenery change and France and UK achieve lower values, while Italy gets a percentage over 6% respect total flow. Really, one tendency that seems to be observe is an increase in the number of ‘characters’ since the beginning until the end of the period, although USA keeps its R&D embodied and invested stable around 40% of total flow. This can be explained for the magnitude of different variables in this country, such as production, trade… Because of that it is also important to take perspective and think in the reasons that let to get this value. As we have been able to see, there are no differences until now between both perspectives. To observe these differences we have to focus in the proportion that this R&D embodied or invested corresponds to external production or external demand. This can be seen in table 3.

**Table 2:** distribution of R&D embodied by countries.

|  |  |
| --- | --- |
| **R&D invested** | **R&D embodied**  |
|  | **1995** |  | **2009** |  | **1995** |  | **2011** |
|  | **Absolute values** | **%** |  | **Absolute values** | **%** |  | **Absolute values** | **%** |  | **Absolute values** | **%** |
| **AUS** | 3938.19 | 1.63 | **AUS** | 15617.33 | 2.71 | **AUS** | 3481.86 | 1.44 | **AUS** | 12841.31 | 2.23 |
| **BEL** | 2052.94 | 0.85 | **AUT** | 4976.27 | 0.86 | **BEL** | 2026.34 | 0.84 | **AUT** | 4751.25 | 0.83 |
| **CAN** | 6950.65 | 2.87 | **BEL** | 3706.09 | 0.64 | **CAN** | 6423.98 | 2.65 | **BEL** | 4068.25 | 0.71 |
| **CZE** | 458.77 | 0.19 | **CAN** | 21858.65 | 3.80 | **CZE** | 384.71 | 0.16 | **CAN** | 15346.89 | 2.66 |
| **DEU** | 20343.62 | 8.41 | **CHN** | 81951.57 | 14.23 | **DEU** | 22662.93 | 9.37 | **CHN** | 86782.56 | 15.07 |
| **ESP** | 2910.33 | 1.20 | **CZE** | 2105.01 | 0.37 | **ESP** | 2264.22 | 0.94 | **CZE** | 2194.42 | 0.38 |
| **FIN** | 1039.13 | 0.43 | **DEU** | 36408.32 | 6.32 | **FIN** | 1122.69 | 0.46 | **DEU** | 43866.39 | 7.62 |
| **FRA** | 12301.58 | 5.08 | **DNK** | 3301.88 | 0.57 | **FRA** | 12966.22 | 5.36 | **DNK** | 4031.75 | 0.70 |
| **GBR** | 11005.84 | 4.55 | **ESP** | 11540.58 | 2.00 | **GBR** | 10885.72 | 4.50 | **ESP** | 10514.66 | 1.83 |
| **GRC** | 578.46 | 0.24 | **EST** | 131.20 | 0.02 | **GRC** | 376.07 | 0.16 | **EST** | 205.22 | 0.04 |
| **HUN** | 202.29 | 0.08 | **FIN** | 964.77 | 0.17 | **HUN** | 106.29 | 0.04 | **FIN** | 435.82 | 0.08 |
| **IRL** | 406.17 | 0.17 | **FRA** | 12812.25 | 2.22 | **IRL** | 329.00 | 0.14 | **FRA** | 6502.48 | 1.13 |
| **ITA** | 6412.41 | 2.65 | **GBR** | 19362.02 | 3.36 | **ITA** | 5904.40 | 2.44 | **GBR** | 19632.62 | 3.41 |
| **JPN** | 59713.69 | 24.68 | **HUN** | 1348.23 | 0.23 | **JPN** | 64547.34 | 26.67 | **HUN** | 1223.63 | 0.21 |
| **KOR** | 5409.17 | 2.24 | **ITA** | 30004.68 | 5.21 | **KOR** | 4853.28 | 2.01 | **ITA** | 35561.96 | 6.18 |
| **MEX** | 2921.79 | 1.21 | **JPN** | 51225.58 | 8.89 | **MEX** | 3149.05 | 1.30 | **JPN** | 51231.49 | 8.90 |
| **NLD** | 2181.16 | 0.90 | **KOR** | 6367.45 | 1.11 | **NLD** | 1322.64 | 0.55 | **KOR** | 5149.41 | 0.89 |
| **POL** | 455.27 | 0.19 | **MEX** | 12540.85 | 2.18 | **POL** | 310.68 | 0.13 | **MEX** | 12041.90 | 2.09 |
| **PRT** | 476.93 | 0.20 | **NLD** | 3949.38 | 0.69 | **PRT** | 230.58 | 0.10 | **NLD** | 2343.07 | 0.41 |
| **ROM** | 103.00 | 0.04 | **POL** | 3317.12 | 0.58 | **ROM** | 61.71 | 0.03 | **POL** | 2231.49 | 0.39 |
| **RUS** | 769.41 | 0.32 | **PRT** | 2669.84 | 0.46 | **RUS** | 309.19 | 0.13 | **PRT** | 2254.27 | 0.39 |
| **SVK** | 126.21 | 0.05 | **ROM** | 1239.17 | 0.22 | **SVK** | 87.35 | 0.04 | **ROM** | 798.69 | 0.14 |
| **SVN** | 149.31 | 0.06 | **SVK** | 588.82 | 0.10 | **SVN** | 99.64 | 0.04 | **SVK** | 454.94 | 0.08 |
| **TUR** | 618.45 | 0.26 | **SVN** | 526.73 | 0.09 | **TUR** | 351.83 | 0.15 | **SVN** | 576.37 | 0.10 |
| **USA** | 100447.91 | 41.51 | **TUR** | 4146.59 | 0.72 | **USA** | 97737.98 | 40.39 | **TUR** | 2662.33 | 0.46 |
|  |  |  | **TWN** | 3314.27 | 0.58 |  |  |  | **TWN** | 3652.67 | 0.63 |
|  |  |  | **USA** | 239928.76 | 41.66 |  |  |  | **USA** | 244544.62 | 42.46 |

**Table 3:** proportion of external R&D embodied by countries.

|  |  |
| --- | --- |
| **Invested perspective**  | **Embodied perspective** |
| **1995** | **2011** | **1995** | **2011** |
|  | **Absolute values** | **% External flow** | **% Total flow countries** |  | **Absolute values** | **% External flow** | **% Total flow countries** |  | **Absolute values** | **% External flow** | **% Total flow countries** |  | **Absolute values** | **% External flow** | **% Total flow countries** |
| **AUS** | 1133.39 | 2.09 | 28.78 | **AUS** | 4945.25 | 2.13 | 31.67 | **AUS** | 568.48 | 1.89 | 16.33 | **AUS** | 1818.11 | 1.08 | 14.16 |
| **BEL** | 1526.64 | 2.82 | 74.36 | **AUT** | 2647.33 | 1.14 | 53.20 | **BEL** | 1023.83 | 3.41 | 50.53 | **AUT** | 1246.74 | 0.74 | 26.24 |
| **CAN** | 3940.17 | 7.28 | 56.69 | **BEL** | 2711.47 | 1.17 | 73.16 | **CAN** | 2463.29 | 8.19 | 38.35 | **BEL** | 1720.47 | 1.02 | 42.29 |
| **CZE** | 302.66 | 0.56 | 65.97 | **CAN** | 14476.27 | 6.22 | 66.23 | **CZE** | 158.71 | 0.53 | 41.25 | **CAN** | 6900.45 | 4.10 | 44.96 |
| **DEU** | 5608.14 | 10.36 | 27.57 | **CHN** | 22804.58 | 9.81 | 27.83 | **DEU** | 2505.95 | 8.34 | 11.06 | **CHN** | 16736.81 | 9.94 | 19.29 |
| **ESP** | 2068.67 | 3.82 | 71.08 | **CZE** | 1482.80 | 0.64 | 70.44 | **ESP** | 1255.55 | 4.18 | 55.45 | **CZE** | 1108.64 | 0.66 | 50.52 |
| **FIN** | 368.31 | 0.68 | 35.44 | **DEU** | 15099.32 | 6.49 | 41.47 | **FIN** | 201.83 | 0.67 | 17.98 | **DEU** | 7631.34 | 4.53 | 17.40 |
| **FRA** | 4196.01 | 7.75 | 34.11 | **DNK** | 1101.08 | 0.47 | 33.35 | **FRA** | 2372.57 | 7.89 | 18.30 | **DNK** | 730.72 | 0.43 | 18.12 |
| **GBR** | 4296.20 | 7.94 | 39.04 | **ESP** | 5749.06 | 2.47 | 49.82 | **GBR** | 2239.89 | 7.45 | 20.58 | **ESP** | 3044.12 | 1.81 | 28.95 |
| **GRC** | 421.32 | 0.78 | 72.83 | **EST** | 69.13 | 0.03 | 52.69 | **GRC** | 210.75 | 0.70 | 56.04 | **EST** | 67.92 | 0.04 | 33.10 |
| **HUN** | 202.29 | 0.37 | 100.00 | **FIN** | 964.77 | 0.41 | 100.00 | **HUN** | 106.29 | 0.35 | 100.00 | **FIN** | 435.82 | 0.26 | 100.00 |
| **IRL** | 406.17 | 0.75 | 100.00 | **FRA** | 12812.25 | 5.51 | 100.00 | **IRL** | 329.00 | 1.09 | 100.00 | **FRA** | 6502.48 | 3.86 | 100.00 |
| **ITA** | 3118.47 | 5.76 | 48.63 | **GBR** | 10509.12 | 4.52 | 54.28 | **ITA** | 1644.70 | 5.47 | 27.86 | **GBR** | 5092.21 | 3.02 | 25.94 |
| **JPN** | 3422.53 | 6.32 | 5.73 | **HUN** | 1075.39 | 0.46 | 79.76 | **JPN** | 1659.98 | 5.52 | 2.57 | **HUN** | 745.10 | 0.44 | 60.89 |
| **KOR** | 2488.56 | 4.60 | 46.01 | **ITA** | 22173.13 | 9.53 | 73.90 | **KOR** | 1526.17 | 5.08 | 31.45 | **ITA** | 25244.35 | 14.99 | 70.99 |
| **MEX** | 2916.30 | 5.39 | 99.81 | **JPN** | 50610.55 | 21.76 | 98.80 | **MEX** | 3145.70 | 10.47 | 99.89 | **JPN** | 50839.52 | 30.19 | 99.23 |
| **NLD** | 2178.04 | 4.02 | 99.86 | **KOR** | 6329.25 | 2.72 | 99.40 | **NLD** | 1320.82 | 4.39 | 99.86 | **KOR** | 5118.72 | 3.04 | 99.40 |
| **POL** | 455.13 | 0.84 | 99.97 | **MEX** | 12529.82 | 5.39 | 99.91 | **POL** | 310.60 | 1.03 | 99.97 | **MEX** | 12035.53 | 7.15 | 99.95 |
| **PRT** | 476.93 | 0.88 | 100.00 | **NLD** | 3949.38 | 1.70 | 100.00 | **PRT** | 230.58 | 0.77 | 100.00 | **NLD** | 2343.07 | 1.39 | 100.00 |
| **ROM** | 100.06 | 0.18 | 97.15 | **POL** | 3017.02 | 1.30 | 90.95 | **ROM** | 58.42 | 0.19 | 94.67 | **POL** | 1789.94 | 1.06 | 80.21 |
| **RUS** | 707.28 | 1.31 | 91.93 | **PRT** | 1283.38 | 0.55 | 48.07 | **RUS** | 243.52 | 0.81 | 78.76 | **PRT** | 512.42 | 0.30 | 22.73 |
| **SVK** | 92.91 | 0.17 | 73.61 | **ROM** | 1065.62 | 0.46 | 85.99 | **SVK** | 45.82 | 0.15 | 52.45 | **ROM** | 576.73 | 0.34 | 72.21 |
| **SVN** | 130.62 | 0.24 | 87.48 | **SVK** | 554.56 | 0.24 | 94.18 | **SVN** | 62.75 | 0.21 | 62.98 | **SVK** | 388.99 | 0.23 | 85.50 |
| **TUR** | 618.45 | 1.14 | 100.00 | **SVN** | 322.86 | 0.14 | 61.29 | **TUR** | 351.83 | 1.17 | 100.00 | **SVN** | 161.83 | 0.10 | 28.08 |
| **USA** | 12938.40 | 23.91 | 12.88 | **TUR** | 2793.79 | 1.20 | 67.38 | **USA** | 6021.47 | 20.03 | 6.16 | **TUR** | 1084.64 | 0.64 | 40.74 |
|  | 54113.65 |  |  | **TWN** | 2259.62 | 0.97 | 68.18 |  | 30058.50 |  |  | **TWN** | 1214.16 | 0.72 | 33.24 |
|  |  |  |  | **USA** | 29227.42 | 12.57 | 12.18 |  |  |  |  | **USA** | 13315.39 | 7.91 | 5.44 |
|  |  |  |  |  | 232564.18 |  |  |  |  |  |  |  | 168406.23 |  |  |

 In table 3 we show two ways of reflect the proportion of R&D embodied and invested that corresponds to external production or to external demand. The first column of each year reflect the absolute value and then we show two percentages; one respect total external flow and other respect total R&D embodied or invested of each country. If we focus our attention first in percentage respect total external flow and in the case of invested perspective, we can say that Japan, USA and Germany have again the highest values. However, by contrast as happened with total R&D invested, external flow is more distributed between countries. In that way, in 1995, countries such as Canada, France, UK, Italy and Mexico achieves values around 7% (Canada, France and UK) and 5% (Italy and Mexico). This changes a little in 2011, when France and UK decrease their proportion of R&D invested in external production and China emerges with values near 10%. However, if we pay attention in the second percentage the results seem to be different. In countries such as Ireland, Hungary, Mexico, Netherlands, Poland, Portugal and Rumania, both in 1995 and 2011, near the 100% of total R&D invested is coming from external production. What reasons can explain this fact? First, some of these are countries of small size with high level of opening of their production. Second, other countries are developing the structure of their economies. And third, we have to take into account the case of Mexico, where trade with USA is really important. Why is this no reflected in percentage respect external flow? Surely, because in absolute values the magnitude is low in comparison with other countries that their levels of production, trade, population, R&D expenditure,… are really high as could be the case of USA or Germany. In both cases, the percentage of external R&D invested respect total external flow represents around 12% and 10% in 2011, while the percentage that represents respect their own total R&D invested is really low in relative terms; 12% in USA and 27% in Germany.

 Similar situation it is possible to observe in the case of R&D embodied perspective but with some differences. Again, focusing in the percentage of external R&D embodied in sales USA, Germany and Japan get high values. However, is really significant the percentages achieve for Mexico and Canada at the beginning of the period, probably due to the relationships with USA. This results changes in 2011, being Japan, Italy and China the countries that achieves the most relevant percentages; around 30% in Japan, 14% in Italy and 10% in China. If we pay attention on the percentage of external R&D embodied respect total R&D embodied on each country, the same countries as in the invested perspective appears, in 1995, with percentages near 100%. However, in the case of embodied perspective, in 2011, the scenery changes, being Finland, France, Japan, Korea, Mexico and Netherlands the countries that get values around 100%. The case of Mexico it is characteristic because of their relations with USA. In the other cases, we can think in its level of opening and the features of its domestic demand. Again, the countries where we see the highest percentages respect their own R&D embodied no corresponds to the countries that makes the highest contribution to external flow. What reasons can we find? Perhaps, as we have commented previously, because, in relative terms, the magnitudes are not as significant as for the country itself.

 To complete the image we have to focus on sectorial behavior. In table 4 we show the absolute value and the percentage of each sector of total and external R&D embodied, both, in production and in sales. We can observe a common pattern at both perspectives. The sectors that it is found higher levels of R&D embodied is in Rest of services (RS), Transport equipment and Electrical and optical equipment, both in 1995 and 2011, total and external. However, we have to stress the case of Construction sector. When we analyze external R&D embodied in sales, in 1995 it represents 10.8 and in 2011 represents around 12%, being one of the key sectors in terms of R&D embodied in sales, although Transport equipment and Rest of services achieve higher percentages. These results seems to be coherent with the analysis of the data we have used, as a great part of R&D expenditure realized by countries is done in high-tech industry sectors or in Rest of services.

 So, we can conclude the section saying that USA, Germany and Japan, together with China at the end of the period, have an important role in terms of R&D. However, there are other countries that also reflect significant results, as could be the cases of Mexico and Canada and their relationships with USA, or Netherlands, France and UK, showing it relevance inside the European Union. We are sure that this R&D, both, embodied and invested, should have some effect in the economies and their developing. About this we are going to discuss in next section.

**Table 4:** R&D embodied in production and sales by sectors.

|  |  |  |
| --- | --- | --- |
|  | **Invested perspective** | **Embodied perspective** |
|  | **Total R&D**  | **External R&D**  | **Total R&D**  | **External R&D**  |
|  | **1995** | **2011** | **1995** | **2011** | **1995** | **2011** | **1995** | **2011** |
|  | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** | **Absolute value** | **%** |
| **Primary sector** | 1590.59 | 0.66 | 4916.72 | 0.85 | 583.72 | 1.08 | 2121.89 | 0.91 | 1591.16 | 0.66 | 4916.71 | 0.85 | 509.54 | 1.70 | 1920.48 | 1.14 |
| **Energy sector** | 2636.24 | 1.09 | 7655.50 | 1.33 | 374.16 | 0.70 | 2457.09 | 1.06 | 2636.02 | 1.09 | 7655.50 | 1.33 | 360.52 | 1.21 | 2404.87 | 1.43 |
| **Food, Beverages and Tobacco** | 9743.78 | 4.03 | 23350.42 | 4.05 | 2344.02 | 4.36 | 10167.35 | 4.37 | 9745.75 | 4.03 | 23350.45 | 4.05 | 1781.50 | 5.96 | 8554.21 | 5.08 |
| **Leather, Textiles and Textile Products** | 3503.78 | 1.45 | 8779.77 | 1.52 | 1130.91 | 2.10 | 5855.98 | 2.52 | 3504.22 | 1.45 | 8779.47 | 1.52 | 842.68 | 2.82 | 3957.37 | 2.35 |
| **Wood, Pulp, Paper, Paper , Printing and Publishing** | 2370.10 | 0.98 | 4126.97 | 0.72 | 525.00 | 0.98 | 1338.36 | 0.58 | 2370.69 | 0.98 | 4126.97 | 0.72 | 434.29 | 1.45 | 1134.73 | 0.67 |
| **Coke, Refined Petroleum and Nuclear Fuel** | 1772.84 | 0.73 | 3645.62 | 0.63 | 366.98 | 0.68 | 1996.72 | 0.86 | 1773.01 | 0.73 | 3645.62 | 0.63 | 259.85 | 0.87 | 1709.97 | 1.02 |
| **Chemicals and Chemical Products** | 16674.48 | 6.90 | 43395.57 | 7.54 | 4163.06 | 7.74 | 18537.07 | 7.97 | 16700.14 | 6.91 | 43395.40 | 7.54 | 1654.70 | 5.53 | 6927.91 | 4.11 |
| **Rubber and Plastics** | 1676.43 | 0.69 | 3479.81 | 0.60 | 474.11 | 0.88 | 1808.43 | 0.78 | 1676.98 | 0.69 | 3479.79 | 0.60 | 360.03 | 1.20 | 1317.27 | 0.78 |
| **Other Non-Metallic Mineral** | 403.09 | 0.17 | 853.49 | 0.15 | 109.21 | 0.20 | 415.04 | 0.18 | 402.80 | 0.17 | 853.48 | 0.15 | 77.04 | 0.26 | 345.24 | 0.21 |
| **Basic Metals and Fabricated Metal** | 2315.42 | 0.96 | 4436.61 | 0.77 | 532.87 | 0.99 | 2434.56 | 1.05 | 2314.76 | 0.96 | 4436.55 | 0.77 | 383.10 | 1.28 | 2005.80 | 1.19 |
| **Machinery, Nec** | 15479.40 | 6.41 | 42605.07 | 7.40 | 4289.56 | 7.97 | 22430.66 | 9.64 | 15512.56 | 6.42 | 42605.19 | 7.40 | 1260.80 | 4.22 | 13576.86 | 8.06 |
| **Electrical and Optical Equipment** | 28887.89 | 11.96 | 62271.26 | 10.81 | 7817.32 | 14.5 | 29572.40 | 12.72 | 28911.68 | 11.97 | 62270.99 | 10.8 | 2252.98 | 7.54 | 13347.03 | 7.93 |
| **Transport Equipment** | 56070.88 | 23.22 | 83560.36 | 14.51 | 16436.51 | 30.5 | 43345.17 | 18.6 | 56093.49 | 23.22 | 83558.20 | 14.5 | 5821.40 | 19.4 | 24895.68 | 14.78 |
| **Manufacturing, Nec; Recycling** | 3461.82 | 1.43 | 12837.33 | 2.23 | 876.56 | 1.63 | 5659.80 | 2.43 | 3453.91 | 1.43 | 12837.47 | 2.23 | 466.04 | 1.56 | 3636.94 | 2.16 |
| **Construction** | 19140.54 | 7.93 | 56332.86 | 9.78 | 3247.27 | 6.03 | 21252.58 | 9.14 | 19140.18 | 7.92 | 56332.86 | 9.78 | 3243.52 | 10.8 | 21173.53 | 12.57 |
| **HTS** | 14509.86 | 6.01 | 62924.45 | 10.93 | 1133.47 | 2.11 | 12973.02 | 5.58 | 14508.65 | 6.00 | 62924.36 | 10.9 | 936.01 | 3.13 | 11860.71 | 7.04 |
| **RS** | 61276.78 | 25.37 | 150731.61 | 26.17 | 9406.25 | 17.4 | 50198.06 | 21.5 | 61274.98 | 25.36 | 150731.45 | 26.1 | 9255.77 | 30.9 | 49637.62 | 29.47 |

# 4. How evolve R&D expenditure effects?

 It is clear that direct and indirect R&D expenditure has a positive effect over productivity and, so, over economic growth. However, in our opinion this effect is not immediate. It has to pass some time until these effects are visible in the economy. We think that we can study this evolution through the use of econometric tools. This is what we are going to see in the following lines, discuss what kind of econometric regression is better to represent the evolution of R&D expenditure effect. Then we will demonstrate with our data that effectively, this regression is the appropriate. This section is still in process, we hope to obtain some preliminary results in the following days, in that way in the conference we will be able to advance some of our ideas an results in relation with this issue.

# 5. Conclusions.

 This paper is form by two parts. In the first one we discuss about two different ways to obtain the “spillovers” of R&D investment, depending in the way that demand matrix is calculated. The first way is creating diagonal matrices by parts; this is what we call invested perspective. The second one it is going to be called embodied perspective; basically it consists in the creation of diagonal matrices by each column and then make the sum of these matrices.

 The main difference between both perspectives seems to be that the volume of external flow of R&D expenditure distributed between countries is higher in the case of invested perspective than in embodied perspective. However, it is possible to observe a common pattern, where the main countries involved are USA, Germany and Japan, together with China at the end of the period, although other countries also have a significant role. This is the case of Canada and Mexico, most probably due to NAFTA agreements that make their relation with USA really strong. Other relevant countries seem to be Netherlands, France or UK, being this a signal of the role play by them in European Union. Respect to sectors we can say that it is also possible to observe a common pattern at both perspectives. The sectors that it is found higher levels of R&D embodied is in Rest of services (RS), Transport equipment and Electrical and optical equipment, which seems to be coherent with the intensity of R&D investment.

 Finally, it is clear that this R&D has some effect over productivity and, so on, over economic growth. However, we ask ourselves whether this effect has an immediate effect or it is necessary some years until the effect is visible in the economic. This work is still in process, trying different econometric regressions, so in the conference we will advance some preliminary results that we hope to obtain in the following days.

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1. The countries we will work with will be the following; Germany, Australia, Austria (since 1998), Canada, China (since 2008), Korea, Denmark (since 2009), Spain, Estonia (since 2005), Finland, France, Greece (until 2007), Hungary, Ireland (until 2005), Italy, Japan, Mexico, Netherlands, Poland, Belgium, Portugal, Czech Republic, Romania, Russia, Slovakia, Slovenia, Taiwan, Turkey, UK and USA. [↑](#footnote-ref-1)
2. Total flow of R&D must be the same since production as sales side. [↑](#footnote-ref-2)