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ABSTRACT

A Note on The Drivers of R&D Intensity*

The objective of this paper is to evaluate the extent to which technological specialization influences the observed R&D intensity of countries. The econometric analysis performed on a cross-country cross-industry panel dataset (21 industrial sectors, 18 countries, from 2001 to 2004) suggests that accounting for the technological specialisation of countries substantially affect the traditional country ranking. The exceptions are Sweden, The United States, France and Japan, which have an 'above-than-average' R&D intensity in most industries, as compared to the 14 other countries. The high level of R&D intensity of South Korea and Finland, for instance, is essentially due to their specialisation in R&D-intensive industries, and not to a macroeconomic environment particularly favourable to R&D.

JEL Classification: E22, O31 and O57
Keywords: high-tech industries, Lisbon agenda, R&D intensity and science and technology policies

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*The views expressed in this paper are purely those of the authors and may not in any circumstances be regarded as stating an official position of the U.L.B. or Bruegel. This paper presents updated results with more recent data and more countries than in its previous version, which included only 10 countries, from 1991 to 2002. In this version the analysis concerns 18 countries and data is available until 2004.

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1. The R&D component of the Lisbon Agenda

According to its 2006 *Innovation Scoreboard*, the European Union (EU) suffers from a worrying large innovation gap as compared to the USA and Japan.[2] This is worrying because innovation is increasingly perceived as being at the root of sustainable economic growth and employment creation (Griliches, 1979; Adams, 1990). It is even more worrying in the context of the *Lisbon Agenda*, endorsed in 2000, as the key reaction of European policy makers to relatively poor economic performances. The Lisbon objective stated that the EU had to become by 2010 "*the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment*". Amongst the areas covered by this agenda, the realisation of a knowledge society included: "*increasing Europe's attractiveness for researchers and scientists, making research and development (R&D) a top priority...*"[3]

Two years after its creation, the 'Barcelona' European Council reviewed progress towards the Lisbon agenda. It was then agreed that, at the EU-wide level, R&D expenses should reach 3% of GDP by 2010 and that the business sector should secure two-thirds of total R&D expenses. This agenda was set at a time where relative R&D expenses were much higher in the USA and Japan (respectively 2.7% and 3% of GDP in 2000) than in the EU (about 1.9% for the EU15).

Since then, the European Commission has regularly published 'expert reports' or EC official report on the drivers of R&D intensity (*e.g.*, report of the CEC, 2004, on "*tax cooperation in an enlarged European Union"*; or the OECD report, 2003, on tax incentives). Most of these reports essentially produce cross-country macroeconomic analyses of the effectiveness of science and technology (S&T) policies. As the 'best in class' are Finland, Sweden, Denmark and Germany, not to mention Japan and the US, most evaluations focus on these countries' designs of specific policy tools aiming at stimulating business R&D. These tools include for instance direct subsidies (or government-funded business R&D), fiscal incentives, and public research outlays (see e.g., Guellec and van Pottelsberghe, 2001). Industrial policies, or policies aiming at the development of specific industrial sectors, were – and still are - much less fashionable.

The objective of this paper is to test to what extent the degree of technological specialization drives business R&D intensity. The methodology consists in a panel data analysis of the R&D intensity of 21 industrial sectors in 18 countries over the period 2001-2004 (a longer time

[2] See The Financial Times, 13th of January 2006, "EU is 50 years behind the US for innovation".
[3] See "Facing the Challenge: The Lisbon Strategy for Growth and Employment", Report from the High Level Group chaired by Wim Kok, November 2004.

span leads to very similar results). The idea is to measure the extent to which R&D intensity is driven by industry and country specificities.

The paper is structure as follows. The next section illustrates the 'Lisbon failure', and puts forward that the major reason underlying the poor R&D performances of the EU, as compared with the US and Japan, is probably due to low expected returns to R&D and a relatively small specialization in high-tech industries. Section 3 presents the quantitative analysis aiming at explaining cross-industry and cross-country variations in R&D intensity. Section 4 concludes.

The results show that industrial specialization is a very important driver of R&D intensity across countries. Countries with an above-than-average business R&D intensity in most industries are the USA, Japan, France and Sweden. Taking in to account their strong specialization in information and communication technologies, countries like Finland or South Korea actually perform like (or even worse) the average country. Sweden is the "best in class" and would deserve a particular attention.

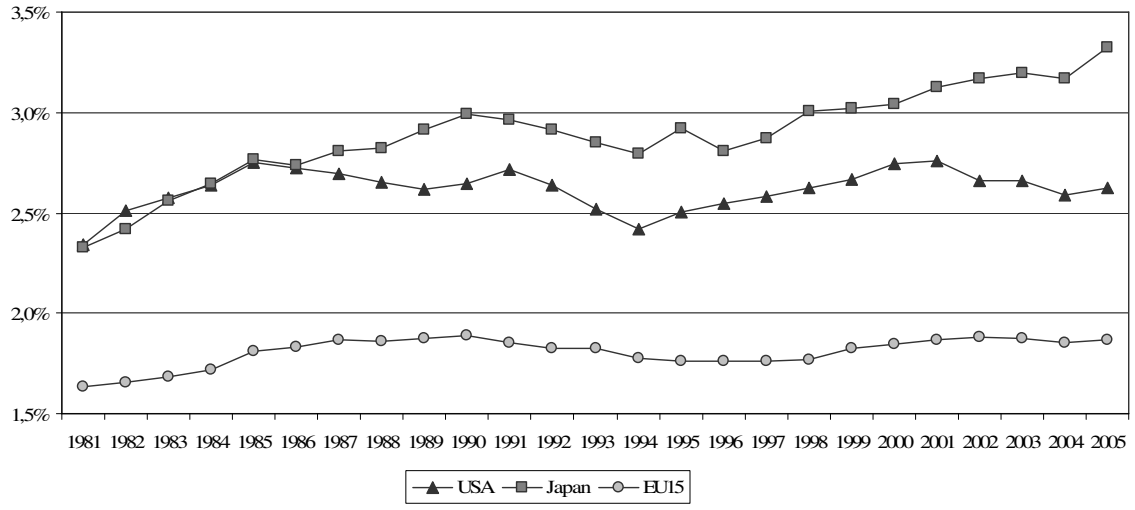
2. Interpretation(s) of the Lisbon agenda

The failure to reach the Lisbon target is illustrated by both by statistical evidence and the head of the EU: "*In contrast to the success of the single market and the Euro, the Lisbon agenda has not brought about a reform spree. Although it has contributed to initiating a discussion on subjects traditionally considered the domain of national governments, five years down the line the reform record is still largely disappointing*."[4] Figure 1 clearly shows two striking differences between the EU on the one hand and Japan and the US on the other hand. First, the R&D intensity has always been significantly lower in the EU than in Japan or the US. Second, over the past 10 years (starting in the mid 90s), the gap between the EU 15 and Japan or the US has substantially increased. In 2005, Japan and the USA, with R&D intensities of 3.3% and 2.6% respectively, are far ahead from the EU-15' R&D intensity of 1.9%.

There is however a strong heterogeneity within the EU-15 area (cf. figure 2). While three Scandinavian countries pull the European average upwards, Mediterranean countries like Italy, Spain and Greece have a rather low performance. If the focus is put on the evolution of relative efforts in research activities, important differences appear as well. The strongest increase in R&D intensity has primarily occurred in the Nordic countries and Austria (with a minimum increase of 1%). For the majority of countries, however, the R&D intensity only slightly increased. For the United Kingdom and, to lower extent, the Netherlands and France, the R&D intensity has actually decreased between 1991 than in 2005.

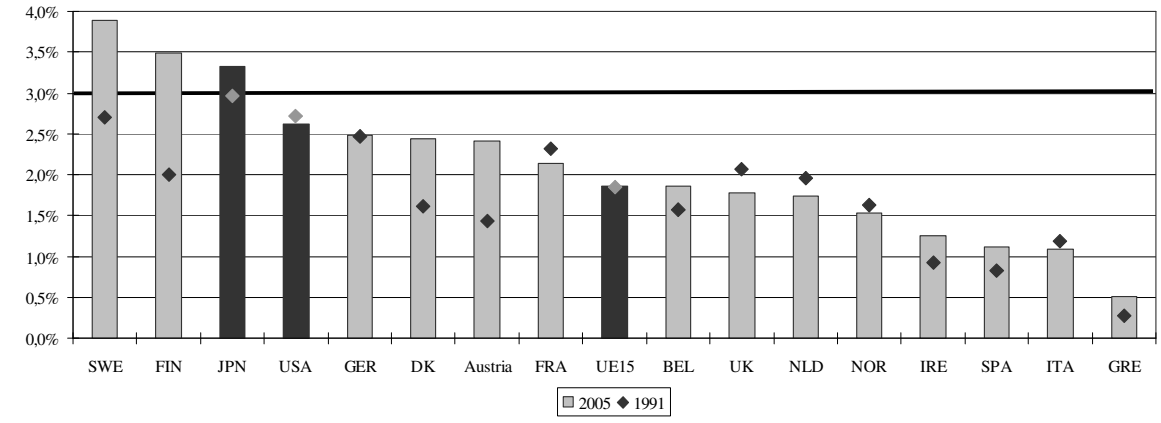
[4] José Manuel Barroso, *Achieving Lisbon,* Global Agenda Magazine, Edition 2005.

Figure 1 Evolution of the R&D intensity (DIRD/GDP) in Japan, in the USA and in Europe, 1981-2005



Source: OECD, MSTI (2007)

Figure 2 R&D Intensity (DIRD/GDP) across the EU countries, the USA and Japan, 1991 and 2005



Source: OECD, MSTI (2007)

One can interpret the Lisbon agenda – becoming the most competitive knowledge-based economy in the world - as follows: the "*effective" rate of return* to R&D must increase. Indeed, achieving more competitiveness requires a higher level of productivity, through an accelerated rate of technical change. At a given level of R&D expenses, an improved level of competitiveness can therefore be reached through a higher return to R&D expenses. The

second part of the Lisbon Objective, which states that R&D expenses should reach 3% of GDP, means that the amount of R&D expenses must increase. This suggests that the "*expected" rate of return* to R&D must increase, as it would logically induce a higher propensity to invest in R&D.

In other words, the Lisbon agenda can be interpreted as the will to improve both the "*expected*" and the "*effective*" rate of return to R&D. This can be achieved through three main channels:

- Lower costs of performing R&D

Science and technology (S&T) policies essentially aim at reducing the cost of doing R&D (and hence improve its expected return). The empirical literature on the determinants of business R&D generally confirms the effectiveness of R&D tax credits and R&D subsidies. The two types of financial support stimulate business funded R&D (see for instance, Reinthaler and Wolff (2002, 2004); Falk (2004) and Guellec and van Pottelsberghe (2003, 2004) who provide empirical evidence on the effectiveness of government financial support to business R&D).

- A larger homogeneous market for new technologies

This second driver implicitly assumes a positive relationship between the size of a country and its R&D intensity (see Guellec (1999) for conceptual support and anecdotic evidence and Desmet and Parente (2006) for theoretical and empirical evidence). The size of a country is indeed an indicator that helps to predict, at least partly, the relative effort in R&D. The USA and Japan, for instance, are by far the largest homogenous market amongst the OECD countries, and both have relatively high R&D expenses. Within Europe, the largest country, Germany, has a relatively high R&D intensity of more than 2.5%. However, some small countries also have a very high R&D intensity, suggesting that size is not the only driver of R&D expenditure. Sweden, Finland and Denmark all have a high R&D intensity, despite their relatively small size. Another factor has therefore to be accounted for.

- A specialization in R&D intensive industries

This latter factor obviously plays a role when analysing countries like Finland or Luxembourg. The high R&D intensity of the former country is most probably due to its strong specialization in information and communication technologies, especially mobile communication technologies, which require large R&D outlays. Luxembourg is well known for its specialisation in the banking and finance industry, which is far from being intensive in R&D.

In a nutshell, three main factors may drive the observed R&D intensity of countries: S&T policies, market size and technological specialization. The first two factors have an important impact on both the effective and expected rate of return to R&D. As far as market size is concerned, one could wonder why Europe, by far a larger market than the USA or Japan, is not associated with a higher R&D intensity. The main reason is probably related to the fact that the European market is still far from being integrated, or at least not sufficiently integrated. Several clues witness an insufficient level of integration of the European market for goods and services. The market for good or for services is not yet homogeneous, there is a lack of harmonised tax scheme, there is a lack of labour mobility (especially across borders) and there is a lack of a European market for technology, mainly due to the fact that once granted, a European patent must be validated, translated and managed at the country level, inducing high levels of complexity, not to mention heavy costs (cf. van Pottelsberghe and François, 2008).

3. Quantitative evidence

This section investigates empirically whether business R&D intensity is driven more by country-specific or sector-specific factors. The idea is to test whether the variation in national R&D intensities (total R&D expenditures/GDP) across the OECD countries is more due to national differences – *i.e.*, national innovation system, national Science & Technology policies -, and/or to different degree of specialisation in R&D intensive industries – *i.e.*, does the specialisation of Finland in mobile communication explain its good macro-economic R&D intensity? Or is the high R&D intensity of Finland more the result of efficient S&T policies and particularly good 'national' framework conditions (such as education, entrepreneurial culture, the corporate income tax rate, labour mobility…).

In order to test which of the two hypotheses prevails - the 'national factor' or the 'specialization factor' – we rely on a panel database composed of 21 industrial sectors in 18 countries for the years 2000 to 2004. The control variables are time dummies, country-specific dummies and/or industry-specific dummies. The former take into account the 'national factor' whereas the latter account for the 'specialization factor'. The 21 industries are indexed by i (= 1,…,21); the 18 countries are indexed by j (= 1,…,18), and the 5 years by t (=1,..., 5), which makes 5,735 observations. *RI, J*, *I* and *T* are respectively the business R&D intensity, or total R&D expenses divided by value added, country- industry- and time-specific vectors of dummy variables. R&D outlays are from the OECD ANBERD database and from OECD (2006a, b, c, d), and the information on value added comes from the OECD STAN database. β_i and β_j are the vectors of parameters to be estimated. The results are presented in Table 1.

$$RI_{i,jt} = \beta_j J + \varphi_t T \qquad (1)$$

$$RI_{i,jt} = \beta_j J + \alpha_i I + \varphi_t T \qquad (2$$

Equation 1 investigates the extent to which country specificities explains the variance in R&D intensity (cf. column 1). All the country dummies have a significant impact on R&D intensity. The adjusted R-squared suggests that national differences explain about 32% of the variation in R&D intensity across the studied countries and sectors. The countries that are associated with the highest impact are Sweden (0.11) and the USA (0.11), France (0.11), Norway (0.09) and Japan (0.09). Interestingly, Finland is in an intermediate position, with a 0.08 impact, whereas it is the second highest level of R&D intensity in Figure 2. This difference is explained by the fact that the Finish industrial sectors are on average less intensive in R&D than in the other countries of the panel. A substantial specialization in a few high-tech (R&D intensive) industries is probably the major factor underlying the high macroeconomic level of R&D intensity in Finland.

The second regression measures the simultaneous effects of national and industry-specific factors, which explain 69% of the variance in R&D intensity, more than twice higher than the variance explained by country dummies (Table 1, column 2). Taking into account the industry effect reduces the estimated impact of most country dummies, but the relative ranking remains broadly similar to the one presented in column 1. Sweden, France and the USA have the highest 'median' R&D intensity across industries.

It could be argued that the US and Japanese economies should be compared with a large geographical area, like Europe, instead of a multitude of smaller European countries. This approach is presented in column 3 of table 1. It appears that the median R&D intensity of European manufacturing sectors is about twice smaller than in Japan or the USA (the results concern the period 1998-2002, due to data availability).

Technological specialization being accounted for, one could logically wonder whether cross country differences are significant or not. A simple way to test the relative differences across countries is to add an intercept amongst the explanatory variables and drop one of the country dummies. All country-related impact would therefore be relative to the 'dropped' economy. The results - relative to Germany -, are presented in table 2. The countries that seem to invest in R&D "above than average" in a majority of industries are Sweden, France, the USA and and, to a lesser extent, Japan. Several other countries have R&D intensities across industries that are similar to the German ones, including Belgium, the United Kingdom and The Netherlands. The Finish and South Korean industries are also in this group, which was unexpected, as these two economies have very high R&D intensities.

Table 1 Quantitative results: R&D intensity with country and industry dummies.

Dependent variable is RIt							
Regression #		*1*		*2*			*3*
Japan	0,094***	(15,95)	0,075***	(12,98)	*Japan*	0,061***	(6,04)
Korea	0,041***	(5,23)	0,022***	(3,3)	*USA*	0,070***	(6,96)
Finland	0,079***	(13,5)	0,058***	(10)	*Europe*	0,032***	(2,97)
Norway	0,090***	(14,63)	0,066***	(11,28)			
Sweden	0,111***	(18,73)	0,091***	(15,68)			
Denmark	0,063***	(10,39)	0,042***	(7,15)			
Italy	0,043***	(6,57)	0,024***	(3,97)			
Spain	0,029***	(5,14)	0,011*	(1,87)			
USA	0,109***	(17,91)	0,086***	(14,65)			
Germany	0,081***	(12,42)	0,062***	(10,26)			
France	0,106***	(17,98)	0,087***	(15,04)			
Australia	0,025***	(3,53)	0,035***	(5,56)			
Belgium	0,061***	(9,46)	0,053***	(8,82)			
Czech Republic	0,022***	(2,99)	0.008	(1,25)			
Irland	0,032***	(5,07)	0.005	(0,86)			
Nederlands	0,074***	(12,65)	0,058***	(10,1)			
United Kingdom	0,075***	(12,07)	0,053***	(8,93)			
Canada	0,071***	(12,11)	0,056***	(9,64)			
Reference sector			Machinery & Equipment, N.E.C.			Machinery & Equipment, N.E.C.	
2001	0.005	(0,76)	0.002	(0,62)	*1998*	0.000	(0,01)
2002	0.006	(1,07)	0.004	(1,11)	*1999*	0.001	(0,09)
2003	0.006	(1,08)	0.004	(1,01)	*2000*	0.002	(0,23)
2004	0.003	(0,35)	0.001	(0,16)	*2001*	0.010	(1,15)
					2002	0,016*	(1,81)
Constant		No		No			No
Sector dummies		No		Yes			Yes
Number of obs		5735		5735			863
F(22, 5713)		123.46	F(42, 5693)	310.86	F(28, 835)		153.52
Prob > F		0		0			0
Adj R-squared		0.3196		0.6941			0.8319
Root MSE		0.11037		0.074			0.06424

For these two countries it seems that their observed performance at the country level would be due to a very strong specialization in an R&D intensive sector (ICT), but not to a particularly high propensity to invest in R&D. South Korean industries are even significantly less R&D intensive than German ones. This is also the case for Irish, Spanish or Australian industries. The relatively good performance of the US and Japan may be explained by their market size, by far the largest homogeneous markets. Sweden deserves a particular attention, as its R&D intensity outperforms all other countries in most manufacturing sectors.

In other words, the international differences in total R&D intensity observed in Figure 2 should be taken with caution. The business component of this R&D intensity is actually mainly driven by the degree of specialization in R&D intensive industries and not by a country-specific environment particularly favourable to R&D expenses, except for a few countries. The other major component of the total R&D intensity of a country, the public research performed by universities and public labs, is in turn, essentially country specific.

Table 2 Empirical results, testing for differences across countries.

Dependent variable is RIt					
Regression #		*4*			*5*
Sweden	0,029***	(4,89)	*USA*	0,038***	(6,18)
USA	0,023***	(3,95)	*Japan*	0,029***	(4,65)
France	0,025***	(4,20)			
Japan	0,013**	(2,16)			
Norway	0,004	(0,70)			
Finland	-0,005	(-0,81)			
United Kingdom	-0,010	(-1,59)			
Nederlands	-0,004	(-0,72)			
Canada	-0,007	(-1,13)			
Belgium	-0,009	(-1,50)			
Denmark	-0,021**	(-3,49)			
Italy	-0,038***	(-6,25)			
Korea	-0,040***	(-6,00)			
Irland	-0,057***	(-9,50)			
Spain	-0,052***	(-8,96)			
Australia	-0,027***	(-4,21)			
Czech Republic	-0,054***	(-8,30)			
Reference country	Germany			Europe-15	
Reference sector	Machinery & Equipment, N.E.C.			Machinery & Equipment, N.E.C.	
2001	0,002	(0,62)	*1998*	0,000	(0,01)
2002	0,004	(1,11)	*1999*	0,001	(0,09)
2003	0,004	(1,01)	*2000*	0,002	(0,23)
2004	0,001	(0,16)	*2001*	0,010	(1,15)
			2002	0,016	(1,81)
Constant	0,062***	(10,26)		0,032***	(2,97)
Sector dummies		Yes			Yes
Number of obs		5735			863
F(21, 5713)	F(41, 5693)	191,13	F(27, 835)		86,33
Prob > F		0			0
Adj R-squared		0,5762			0,7277
Root MSE		0,074			0,06424

Ici supprimer la colonne 4 stp et renommer les deux autres 4 et 5 (au lieu de 5 et 6)

4. Concluding remarks

The objective of this short paper was to test the extent to which technological specialization influence the observed R&D intensity at the macroeconomic level, and hence the country rankings that are highly fashionable nowadays. The motivations were essentially driven by the idea that some countries may wrongly be considered as particularly intensive (or non intensive) in research activities. For instance, Sweden, Finland and Japan are highly

specialized in high-tech industries, and have a high R&D intensity. One could therefore wonder whether they actually invest more than other countries, taking into account their specialization.

In order to test for the role of the technological specialization a quantitative analysis was performed with a panel dataset composed of 21 industrial sectors in 18 countries over the period 2000 to 2004. The econometric results clearly confirm that the driver of business R&D intensity is strongly influenced by technological specialization. When it is accounted for, the countries which keep a particular high (significantly above than average) R&D intensity are Sweden, the USA, France and, to a lower extent, Japan. Finland and South Korea, on the other hand, have actually a relatively low R&D intensity when their industrial structure is accounted for.

The well known international 'rankings' of R&D intensity should therefore be taken with a degree of caution. The business component of R&D intensity is actually mainly driven by the degree of technological specialization and not by a country-specific environment particularly favourable to R&D expenses, except for Sweden, France, the USA and Japan.

It is worth noticing that these results essentially concern business R&D expenditures, and not the total R&D activities of countries, which are also composed of the public research activities performed by universities and public labs, which are, in turn, essentially country-specific, and may ultimately lead to new specializations in R&D intensive industries.[5] Further research is needed to explain why the Swedish, American, French or Japanese manufacturing industries have a propensity to invest in R&D that is substantially higher than in other countries.

[5] Cf. for instance van pottelsberghe (2008)'s Policy Brief on the issue and some explanatory factors.

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