R&D and Productivity:
The US/EU Productivity Gap before and after the Crisis

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ABSTRACT

European companies have been experiencing lower productivity records in comparison with their main competitors, US firms. Most of the explanations provided by the literature are directly or indirectly related to a technological disadvantage of the EU with respect to US.

In order to test the relationship among R&D and productivity, we rely on updated longitudinal firm-level data. In particular, we use data from the IRI EU Industrial R&D Scoreboard on the global top R&D spenders collected from 2004 until 2012 (approx. 1,000 companies).

Consistent with previous literature, we find robust evidence of a significant impact of R&D on productivity. However, on the whole sample, the R&D coefficients for the US firms turn out to be significantly higher: US firms not only tend to have a higher propensity to invest in R&D than EU firms, but they also show a higher capacity to translate R&D investment into productivity gains.

Moreover, in order to test the role of different industrial structures in the US and the EU, we also differentiate the analysis by macro-sectors, according to their technological level.

According to our results, the transatlantic efficiency divide in translating R&D investments into productivity gains emerges as particularly obvious in the high-tech industries and detectable but less significant in the medium-tech sectors. On the contrary, in the low-tech sectors it seems that European firms are more efficient than US companies even if this difference turns out to be not statistically significant.

Given the key role of high-tech and emerging sectors in fostering productivity and the overall economic growth, this evidence can be considered particularly worrying in terms of the overall perspectives of the European economy.

Furthermore, our results show that the EU companies have been more affected by the economic crisis in their capacity to translate R&D investments into productivity: indeed, the US/EU efficiency gap in linking R&D and productivity has worsened as a consequence of the global economic crisis. This is a hot issue for the EU policy makers.

Key words: R&D; productivity; economic crisis; US; EU.

JEL codes: O33

1. Introduction

During the last decades, there has been a widening productivity gap between European countries and the United States. Indeed, OECD macroeconomic data (OECD Productivity Database) report for the year 2014 that the labor productivity (measured as GDP per hour worked) in EU-28 was $49.9, meanwhile it was $67.4 in the US. Moreover, while productivity trends were broadly stable between the 1980s and the first half of the 1990s, both in the Europe and the US, a substantial change has been observed since the second half of the 1990s: indeed - as measured by Broadberry and O'Mahony (2004) and van Ark et al. (2008) - the slowdown in productivity growth in Europe with respect to the US has worsened the long-run transatlantic productivity gap.

In the last few years, from the 2008 onwards – the slow-recovery period after the economic crisis - the productivity growth rate has followed less monotone paths. Nevertheless, the last available OECD data still report an annual growth rate (2014 *vs*. 2013) of 0.5% for US against 0.3% for European Union (28 countries) suggesting that a gap in the productivity growth rate is still present (OECD Productivity Database).

Which are the main causes of the transatlantic productivity gap? The literature has pointed out to different possible reasons probably jointly contributing to determine this result, ranging from the different level of flexibility in labor markets (Gomez-Salvador *et al.,* 2006); the quality of human capital (Gu *et al*., 2002); the better North-American managerial practices (Bloom *et al*., 2005). However, not surprisingly, the bulk of the analyses have focused on the differentials in the introduction and diffusion of the new technologies between the two side of the Atlantic (Oliner and Sichel, 2000; Daveri, 2002; Wilson, 2009).

In order to measure the size of innovation and to analyze how it affects productivity, R&D expenditures are generally considered a good proxy of technological investment both at the aggregate and the microeconomic level. Indeed, the persistent gap in R&D investments between European countries and US might contribute explaining the slowdown of European catching-up in productivity (Rogers, 2010). Considering the EU-28, the BERD/GDP[1] ratio was 1.11% in 2002, it has remained almost constant until 2008 (1.14%), while slightly increasing in the following years up to 1.24% in 2012; meanwhile, the US R&D intensity was 1.77% in 2002, reached 1.97% in 2008, slowed down in the following years to get back to 1.95% in 2012 (the latest available value - Science Technology and Industry Outlook , 2014).

Indeed, recently, European policy makers made explicit that it is necessary to augment R&D investments and sustain knowledge diffusion to foster productivity and, therefore, to support the

[1] BERD = Business Enterprise Expenditure on R&D.

recovery of growth and jobs in a 'knowledge-based' EU economy (European Commission 2010a and 2010b).

However, turning our attention to the microeconomic foundations of the aggregate trends briefly discussed above, it may be that the overall European productivity delay can be explained not only by a lower level of R&D investment but also by a lower capacity to translate R&D investment into productivity gains (see Ortega-Argilés *et al*., 2014). In a sense, European companies might be still affected by a sort of modern Solow's (1987) paradox, *i.e.* by a difficulty to translate their own investments in R&D into increases in productivity.

In more detail, many scholars argue that the European delay is mainly due to the so-called *structural composition effect*. This sectoral composition effect arises because the R&D-intensive manufacturing and R&D-intensive service sectors are under-represented in the European economy in comparison with the US (European Commission, 2007a; Mathieu and van Pottelsberghe de la Potterie, 2008; Lindmark *et al.*, 2010; Ortega-Argilés and Brandsma, 2010).

Nevertheless, a second effect might be at play (the so-called *intrinsic effect*): namely, a structural difficulty of European firms in achieving productivity gains. In other words, EU firms within each industrial sector might show a lower capacity and ability to translate inputs into gains in productivity than their US counterparts (Erken and van Es, 2007; Ortega-Argilés *et al*., 2010, 2011). Moreover, the sectoral and intrinsic effects might have different dynamics depending on the different phases of the business cycle.

This paper is pursuing the aim of shedding additional light on the relationship between R&D investments and productivity in Europe and the US. We propose an empirical analysis based on a unique longitudinal database comprising comparable samples of European and US companies for a total of 1,112 firms. Together with aggregate comparisons, we will also split our analysis by macro-sectors (high-, medium-, low-tech), in order to better investigate the nature and source of the transatlantic productivity gap. Moreover, the time-period available (2004-2012) also allows us to investigate the R&D-productivity dynamics before and after the recent worldwide economic crisis.

The rest of the paper is organized as follows. Section 2 discusses the previous microeconometric evidence on the subject. Section 3 outlines how the dataset was constructed and presents the empirical methodology used to pursue the analysis. Section 4 discusses results, while the final section concludes and puts forward some policy implications.

2. Previous evidence

Back in 1979, Zvi Griliches started a prosperous empirical literature devoted to investigate the relationship between R&D and productivity. On the whole, this microeconometric literature has provided robust evidence of a positive and significant impact of R&D on productivity at firm-level, with an elasticity ranging from 0.05 to 0.25.

Indeed, the consensus about the existence of a positive and significant impact of R&D on productivity remains strong across almost all studies and methodologies, even if comparable data in more countries are not common and results might be subject to discussion (Hall and Mairesse, 1995; Janz *et al.*, 2004; Klette and Kortum, 2004; Loof and Heshmati, 2006; Heshmati and Kim, 2011; Ortega-Argiles *et al.*, 2011).

However, when considering the structural dimension of an economic system, its industrial composition might affect the overall aggregate result since technological opportunities and appropriability conditions are so different across sectors (see Freeman 1982; Winter 1984; Malerba 2004), that may involve substantial differences in the specific sectoral R&D-productivity links. Indeed, previous sectoral studies (mainly on manufacturing industries) clearly suggest a greater impact of R&D investment on productivity in the high-tech sectors rather than in the low-tech ones.

For instance, Griliches and Mairesse (1982) and Cuneo and Mairesse (1983), who proposed two companion studies on French and US firms, found that the impact of R&D on productivity for scientific firms (elasticity equal to 0.20) was significantly greater than for non-scientific firms (0.10). By the same token, Verspagen (1995) carried out a multi-country study involving 9 countries, singling out three macro industries: high-tech, medium-tech and low-tech, according to the OECD classification (Hatzichronoglou 1997). The major finding of his study was that the impact of R&D was significant and positive only in high-tech sectors. Los and Verspagen (2000) found - for a sample of US manufacturing firms - that the average elasticity of the R&D investment to company productivity was 0.014; however, when they run the same analysis for the high-tech sectors only, the elasticity increased to 0.1.

A recent study by Ortega-Argilés *et al.* (2010), looking at the top 577 EU R&D investors, concluded that the coefficient of this impact increases monotonically when moving from the low-tech over the medium-high to the high-tech sectors, ranging from a minimum of 0.03/0.05 to a maximum of 0.14/0.17.

Moving closer to the topic investigated in this study, Ortega-Argilés *et al.* (2014 and 2015) analyze the transatlantic productivity gap providing evidences of differences among industries. Estimates are based on a longitudinal database covering the period 1990-2008 and comprising 1,809

US and EU companies for a total of 16,079 observations. Robust evidence of a significant impact of R&D on productivity are provided; however, even using different estimation techniques, the R&D coefficients for the US firms always turn out to be significantly higher. To see to what extent these transatlantic differences in the R&D-productivity relationship may be related to the different sectoral structures in the US and the EU, the analysis is differentiated by sectors. The result is that both in manufacturing, services and high-tech manufacturing sectors US firms are more able to translate their R&D investments into productivity increases. However, previous literature suggests that more complex and radical product innovation generally relies on formal R&D, while process innovation is much more related to embodied technical change achieved by investment in new machinery and equipment (see Conte and Vivarelli 2005; Parisi *et al*., 2006). Consistently with this framework, another result from Ortega-Argilés *et al*. (2014 and 2015) is that in traditional low-tech sectors - which focus on process innovation - productivity gains turn out to be more related to capital accumulation rather than to R&D expenditures.

Building on this microeconomic literature focusing on the relationship between R&D and productivity, our empirical study uses more updated microdata and analyzes a critical time span including pre- and post- world crisis sub-periods.

3. Data and methodology

3.1The data

Previous literature has been partly limited by the extreme difficulty to obtain reliable and comparable micro datasets across countries. The microdata used in this study were provided by the JRC–IPTS (Joint Research Centre-Institute for Prospective Technological Studies, Sevilla) of the European Commission[2]. The dataset is mainly based on the EU Industrial R&D Scoreboard and aggregates information on top R&D spenders worldwide from 2004 until 2012. In particular, the EU Industrial R&D Investment Scoreboard provides economic and financial data of the top corporate R&D investors from the EU and from abroad. It uses data extracted directly from each company's Annual Report (data are consolidated at group level, *i.e.* including all the subsidiaries). Additional balance sheet information from the Bureau Van Dijk's ORBIS database for the same period is also considered.

2 This panel dataset was previously used in the JRC 'European Innovative Companies and Global Value Chains: The Productivity Impact of Heterogeneous Strategies' research project.

Overall, the data is organized as a panel of over 2,000 companies worldwide over the years 2004-2012. The data refers primarily to general firm figures, among them employment, capital expenditures, and R&D.

In order to focus on EU vs. US, we excluded companies belonging to different geographical areas. However, the number of years available for each company depends upon the company's history; therefore, the data source is unbalanced in nature and comprises 1,355 companies (732 European firms and 623 US firms). Nevertheless, the outliers have been dropped following the Grubbs test - as discussed in Section 3.2 - and we ended up with 1,112 companies (504 European firms and 608 US firms) and 8,763 observations.

Table 1 reports the distribution of the retained firms and observations across countries, showing a dominant role of Germany and United Kingdom in Europe, but letting the other European countries to be adequately represented in the sample.

<INSERT TABLE 1>

3.2 The econometric specification and descriptive statistics

Following Hall and Mairesse (1995), we test an augmented production function, obtainable from a standard Cobb-Douglas function in three inputs: knowledge capital, physical capital and labour (equation (1)):

$$(1) \qquad \ln\left(\frac{VA}{E}\right)_{i,t} = \alpha + \beta \ln\left(\frac{K}{E}\right)_{i,t} + \gamma \ln\left(\frac{C}{E}\right)_{i,t} + \vartheta \ln(E)_{i,t} + \varepsilon_{i,t}$$

with $i = 1,\dots, 1{,}112$; $t = 2004,\dots, 2012$; ln = natural logarithm.

Our ideal proxy for productivity is labour productivity (Value Added, VA, over total Employment, E), while our pivotal impact variables are the R&D stock (K) per employee and the physical capital stock (C) per employee[3]. Taking per capita values permits both standardisation of

[3] All the monetary variables are expressed in Euro after applying appropriate exchange rates for companies based in non-Euro countries (i.e. Denmark, Hungary, Sweden, United Kingdom, United States) and in cases of firms whose financial data where expressed in sterlings or dollars even if located in Euro-area.

our data and elimination of possible company's size effects (see, for example, Crépon *et al*., 1998, p.123). In this framework, total employment (E) is a kind of control variable: if θ turns out to be greater than zero, it indicates increasing returns.

In particular, K/E (R&D stock per employee) captures that portion of technological change which is related to the cumulated R&D investments, C/E (physical capital stock per employee) is the result of the accumulated investment, implementing different vintages of technologies. So, this variable might encompasses the so-called embodied technological change, possibly affecting productivity growth.

Considering more in detail our dataset, unfortunately the Value Added variable has a huge number of missing values due to accounting procedures adopted in the US. In order to maintain a reasonable number of observations, we decided to use Net Sales (NS)[4] instead of Value Added to construct the productivity variable. Over the available 3,866 observations the pairwise correlation coefficient between Value Added and Net Sales turn out to be 0.88. This high correlation makes us confident in using Net Sales/Employment as a proper proxy for labor productivity.

Given the crucial role assumed by the R&D variable in this study, it is worthwhile to discuss in detail what is intended by R&D in our database, since R&D measurement might follow different accounting practices in different countries over the world. The R&D investment included in the Scoreboard is the cash investment which is funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. Therefore R&D is quite restrictive and is homogeneous across all the considered countries and refers to the genuine flow of current additional resources.

As it is common in this type of literature (see Hulten, 1990; Jorgenson, 1990; Hall and Mairesse, 1995; Parisi *et al*., 2006), stock indicators rather than flows are considered as impact variables; indeed, productivity is affected by the accumulated stocks of R&D and physical capital and not only by current or lagged flows.

Moreover, dealing with stocks - rather than flows - has two additional advantages: on the one hand, since stocks incorporate the accumulated investments in the past, the risks of endogeneity are minimised; on the other hand, there is no need to deal with the complex (sometimes arbitrary) choice of the appropriate lag structure for the flows.

In our paper, R&D stock (K) is computed using a perpetual inventory method (PIM) approach according to the following formula (equation (2)):

[4] Net Sales variable follows the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures and associates.

$$(2)\quad K_t = \frac{K_{t-1}}{(1+\delta)} + R\&D_t$$

Where R&D = R&D expenditures; δ = depreciation rate (0.15)

The physical capital stock (C) was instead provided in the dataset as a public information from balance sheets[5].

In order to have data not affected by outliers, we undertook an outlier detection procedure using the Grubbs (1969) test over NS/E, K/E and C/E. After the outlier detection process, 243 companies were dropped. More in detail, 138 observations for the NS/E variable, 313 for the K/E variable and 294 observations for the C/E variable were deleted.

Specification (1) was estimated through different estimation techniques. Firstly, pooled ordinary least squared (POLS) regressions were run to provide preliminary evidence. Although very basic, these POLS regressions were controlled for heteroskedasticity (we used the Eicker/Huber/White sandwich estimator to compute robust standard errors) and for a complete set of country (17 European countries + US), time (9 years), sector (29 ICB 3-digit code[6]) dummies.

Secondly, fixed effect (FE) regressions were performed in order to take into account firm specific unobservable characteristics such as managerial capabilities. The advantage of the FE estimates is that different firms are not pooled together but taken into account individually. The disadvantage is that country and sector dummies are dropped for computational reasons, since they are encompassed by the individual dummies.[7]

Table 2 reports the means and standard deviations of the four relevant variables in specification (1). As we are also interested in singling out sectoral differences in the R&D/productivity relationship, we split our panel - following the aggregation proposed in Ortega-Argilés *et al.* (2011) - into three subgroups: high-tech, medium-tech and low-tech sectors. Furthermore, we also consider the descriptive statistics in the pre and post-world crisis sub-periods.

As can be seen, our sample comprises very large and established corporations, with an average employment of more than 20,000 employees. On average, US companies are characterized

[5] We also computed the physical capital stock starting from the investment flows using the same PIM procedure adopted in the case of the R&D stock. Nevertheless, due to a large number of missing values, we opted for the already available capital stock variable. Overall, the pairwise correlation coefficient between the physical capital stock from balance sheets and the physical capital stock computed with the PIM is 0.72 (over the available 7,056 observations), which supports our choice.

6 The Industry Classification Benchmark (ICB) is a definitive system categorizing over 70,000 companies and 75,000 securities worldwide, enabling the comparison of companies across four levels of classification and national boundaries. The ICB system is supported by the ICB Database, an unrivalled data source for global sector analysis, which is maintained by FTSE International Limited (http://www.icbenchmark.com/).

[7] Random effect (RE) regressions were also run and tested against the FE specification through the Hausman test. According to the outcomes of the test, in all the following investigated cases the FE estimates turned out to be preferable to the RE ones (results available from the authors upon request).

by a larger knowledge stock per employees with respect to EU companies (+60 %); moreover, US companies are more productive (NS/E) than EU firms, although being smaller on average. This very preliminary evidence is not in contrast with a view that relates the transatlantic R&D gap to the productivity gap, although other determinants – such as scale economies – may play a role. Only the econometric analysis (see next section) will allow us to properly investigate this issue.

Considering the sectoral taxonomy, not surprisingly, average values suggest that the productivity per employees decreases monotonically from high to low-tech sectors together with the knowledge capital per employee, meanwhile the physical capital per employee increases, suggesting a larger endowment of embodied technologies in the low-tech sectors.

Turning our attention to the pre and post-crisis subsamples, the statistical evidence suggests that in the post-crisis period top R&D companies have reacted largely investing in knowledge capital, providing gains in productivity terms.

< INSERT TABLE 2 >

4. Econometric analysis

4.1 Main results

Table 3 provides – in the first panel - the overall econometric results concerning the whole sample of 1,112 companies (8,763 observations). We find robust evidence of a positive and significant impact of the R&D stock on productivity with an elasticity ranging from 0.148 to 0.178, according to the different adopted estimation techniques (POLS vs. FE). The obtained estimates are within the bounds set by previous empirical studies (0.05/0.25; see Section 2).

As far as physical capital is concerned, we assess a positive and significant impact ranging from 0.112 (FE) to 0.236 (POLS); capital formation - embodying vintages of new technologies - emerges as a still important driver of productivity growth.

< INSERT TABLE 3 >

Turning our attention to the comparison between US and EU, the same model is run separately in US companies and European firms (608 vs. 504 companies). As can be seen in the second and third panel of Table 3, the results fully confirm the previous results from the literature. Although uniformly positive and statistically significant, the R&D coefficients for the US firms turn out to be consistently larger than the corresponding coefficients for the European firms. Indeed, the two estimation techniques consistently provide European elasticities equal to about 30% of their US counterparts. Focusing on the more reliable fixed-effects (FE) specification, the US/EU gap is clearly statistically significant, as reported in the last column of Table 2 where a t-test measures if the FE coefficients referred to the two areas are significantly different. We interpret these unambiguous results as a clear evidence of the better ability of US firms to translate R&D investments into productivity gains and as a signal of the persistence of a structural gap that European firms and European policy have to deal with.

As far as the productivity impact of the physical capital is concerned, POLS and FE estimates tell us a different story: they both show that EU reveals a relative (and barely significant) advantage in productivity from investing in physical capital. The elasticities for US are almost equal to 70% of the EU counterparts. This evidence suggests that in the 2004-2012 time span, European companies have mainly relied on physical capital in order to foster their levels of productivity.

As a further step, we split our sample in three sub-samples - high-tech, medium-tech and low-tech industries - to analyze the R&D-productivity relationship in each of them. As already discussed in Section 2, previous literature suggests that a greater impact of R&D investment on productivity is expected in the high-tech sectors rather than in the low-tech ones. Therefore, even in our data it may well be the case that the US advantage in terms of R&D impact is totally due to a sectoral composition effects (structural effect), since high-tech sectors are over-represented in the US. In contrast, if an intrinsic effect is present, the US advantage should be evident across all sectors of the economy.

< INSERT TABLES 4, 5 AND 6 >

Table 4 displays the US/EU comparison with regard to the high-tech industries. As expected comparing Table 4 with Table 3 - high-tech companies turn out to be able to have the largest productivity gains from investments in R&D. However, the European delay is fully confirmed: as it was the case for the whole economy, in the high-tech sectors the US coefficients in the FE specification are larger than their European counterparts (0.333. vs 0.128). Moreover, focusing on the FE estimates, the R&D gap turns out to be statistically significant at the 99% level of confidence (t-test in the last column). Differently, the capital gap in favor of the European firms does not pass the significance threshold. This evidence suggests that the US advantage in translating knowledge into productivity gains is particularly obvious in the high-tech industries. Moreover - in these sectors - the European companies do not show a better ability of their American counterparts to obtain productivity gains from physical capital. Given the key role of high-tech and emerging sectors in fostering productivity and the overall economic growth, this evidence can be considered particularly worrying in terms of the overall perspectives of the European economy.

In Table 5, results for the companies in the medium-tech sectors are presented. The picture is similar but paler than in the high-tech case. Overall – first panel Table 5 – the elasticity for knowledge capital ranges from 0.060 to 0.111 and European companies show (in the FE) a value of 0.087 which is below the 50% of their US counterparts; however, this differential is only barely significant. On the other hand, European companies seem to better transform investment in physical capital into productivity gains, but the t-test does not support a statistical significance of the difference among the relative coefficients.

On the whole, the transatlantic productivity divide can be explained not only by a lower level of knowledge investment (as obvious in Table 2), but also by a lower capacity to translate R&D into productivity gains by EU firms: this seems to be clear in aggregate, particularly evident in the high-tech industries and detectable but less significant in the medium-tech sectors.

In the low-tech case – instead - the evidence is more mixed. In Table 6, the impact of the R&D stock on productivity is overall positive and significant, but - not surprisingly - its magnitude is lower than in the two previous cases (the elasticity ranges from 0.049 to 0.086). Contrary to the previous cases, it seems that European firms are more efficient than US companies in translating R&D investments into productivity gains (0.095 vs. 0.065), however, the t-test does not confirm that this difference is statistically significant. Moreover, European low-tech firms turn out to be more able than US ones to transform investment in physical capital into productivity gains and in this case the difference turns out to be statistically significant (at 95%). These joint results might suggest a sort of efficiency advantage of European companies, limited to the low-tech sectors. Whether this outcome may be considered positive for the EU economic perspectives is a matter of policy debate.

In order to check if the previous evidence is confirmed over the economic cycle, we re-run the previous estimates (POLS and FE), splitting the time-period in two: the pre crisis sub-period from 2004 to 2008, and the post crisis sub-period, from 2009-2012. As can be seen in the next

Tables 7 and 8 our data allow us to have adequate and comparable sub-samples to be used for this evaluation exercise[8].

Results - comparing the evidence from the FE in the first panel of the two tables – reveal that in the post-crisis period the top-R&D spenders have been affected by a lower capacity to translate investment in R&D into productivity gains (0.158 *vs* 0.243); while showing a slightly better performance in terms of productivity from physical capital (0.089 *vs* 0.070).

Focusing on the comparison between EU and US, in the pre-crisis period the evidence of the US companies outperforming the EU companies in terms of productivity gains from knowledge capital is confirmed (the t-test supports at 5% significant the difference among the two coefficients). This result is still obvious in the post-crisis period, even if for both US and EU the magnitude of the elasticity lowers (from 0.294 to 0.199 for the US and from 0.194 to 0.093 for the EU). However, the EU companies have been more affected than their US counterparts from the economic crisis in their capacity to translate R&D investments into productivity (-52% *vs* -32%). Therefore, the US/EU efficiency gap in linking R&D and productivity has worsened as a consequence of the global economic crisis. This is also a hot issue for the EU policy makers.

< INSERT TABLES 7 AND 8 >

5. Conclusions and Policy Implications

In this paper we test the hypothesis that the transatlantic productivity gap may be due not only to a lower level of corporate R&D expenditures by European firms, but also to a possible lower capacity to translate corporate R&D expenditures into productivity gains.

Consistent with previous literature, on aggregate we find robust evidence of a positive and significant impact of the R&D stock on productivity. However, the R&D coefficients for the US firms turn out to be consistently and significantly larger than the corresponding coefficients for the European firms: indeed, European elasticities equal to about 30% of their US counterparts. We interpret this unambiguous outcome as a clear evidence of the better ability of US firms in translating R&D investments into productivity gains and as a signal of a structural gap that European firms and European policy have to deal with.

[8] On the contrary, running estimates that jointly apply the time splitting and the sectoral splitting is prevented by the scarce number of observations in each of the six subsamples.

To see to what extent the transatlantic differences may be related to the different sectoral structures in the US and the EU (the US economy being disproportionally characterized by high-tech industries), we have differentiated the US/EU comparative empirical exercise by macro-sectors, according to their technological level.

On the whole, the transatlantic productivity divide has turned out to be particularly obvious in the high-tech industries and detectable but less significant in the medium-tech sectors. Contrary to the previous cases, it seems that European firms are more efficient than US companies in translating R&D investments into productivity gains even if this difference turned out to be not statistically significant. These joint results might suggest a sort of weak efficiency advantage of European companies limited to the low-tech sectors and an obvious and significant advantage of US companies in the high-tech industries.

Given the key role of high-tech and emerging sectors in fostering productivity and the overall economic growth, this evidence can be considered particularly worrying in terms of the overall perspectives of the European economy.

Furthermore, our results show that the EU companies have been more affected by the economic crisis in their capacity to translate R&D investments into productivity: indeed, the US/EU efficiency gap in linking R&D and productivity has worsened as a consequence of the global economic crisis. This is also a hot issue for the EU policy makers.

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Table 1: Distribution of firms and observations across countries

COUNTRY	FIRMS	OBSERVATIONS
AUSTRIA	19	165
BELGIUM	18	140
DENMARK	22	176
FINLAND	31	272
FRANCE	79	642
GERMANY	113	990
GREECE	1	8
HUNGARY	1	9
IRELAND	10	82
ITALY	19	109
LUXEMBOURG	3	15
MALTA	1	8
SLOVENIA	1	9
SPAIN	10	88
SWEDEN	47	360
THE NETHERLANDS	29	235
UNITED KINGDOM	100	791
EUROPEAN UNION	***504***	***4,099***
US	***608***	***4,664***
TOTAL	***1,112***	***8,763***

Table 2: Descriptive statistics

Sample (N. of observations)	*NS/E*		*K/E*		*C/E*		*E*	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Whole sample (8,763)	252.18	199.20	66.98	85.98	130.94	120.08	21,371.09	50,965.21
US (4,664)	261.72	191.50	81.31	92.35	133.29	113.60	16,973.35	40,843.24
EU (4,099)	241.32	207.10	50.68	74.86	128.27	127.01	26,375.02	60,070.24
High-tech (5,583)	248.21	184.22	82.75	88.49	122.02	108.57	17,069.86	43,928.71
Medium-tech (2,128)	239.32	162.44	49.75	85.15	139.75	129.11	25,809.50	58,220.26
Low-tech (1,052)	229.26	307.46	18.20	32.72	160.46	149.73	35,219.81	64,926.75
Whole sample *2004-2008* (4,949)	244.23	192.36	53.31	77.13	122.96	116.25	20,455.02	48,766.52
US (2,652)	253.54	194.05	64.51	82.16	124.51	107.84	16,333.93	38,902.62
EU (2,297)	233.49	189.88	40.39	68.65	121.17	125.26	25,213.03	57,753.02
Whole sample *2009-2012* (3,814)	262.49	207.30	84.72	93.34	141.30	124.12	22,559.77	53,667.32
US (2,012)	272.51	187.59	103.46	100.06	144.86	119.81	17,816.15	43,263.81
EU (1,802)	251.29	226.83	63.80	80.23	137.32	128.69	27,856.20	62,885.47

Table 3: Dependent variable: log(Net Sales/Employees)

	WHOLE SAMPLE		UNITED STATES		EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.148*** (0.007)	0.178*** (0.013)	0.234*** (0.010)	0.267*** (0.019)	0.083*** (0.012)	0.094*** (0.018)	6.55*** (0.000)
Log(Physical stock per employee)	0.236*** (0.009)	0.112*** (0.007)	0.174*** (0.011)	0.099*** (0.009)	0.293*** (0.015)	0.129*** (0.012)	-1.89* (0.060)
Log(Employees)	0.027*** (0.005)	-0.143*** (0.012)	0.031*** (0.006)	-0.082*** (0.016)	0.032*** (0.007)	-0.223*** (0.019)	5.59*** (0.000)
Constant	3.773*** (0.170)	5.507*** (0.118)	5.872*** (0.095)	4.813*** (0.162)	3.437*** (0.165)	6.294*** (0.181)	6.08*** (0.000)
Wald time-dummies (p-value)	5.2*** (0.000)	21.8*** (0.000)	6.5*** (0.000)	15.3*** (0.000)	2.3** (0.017)	11.9*** (0.000)	
Wald country-dummies (p-value)	13.5*** (0.000)	-	-	-	10.8*** (0.000)	-	
Wald sectoral-dummies (p-value)	41.9*** (0.000)	-	198.3*** (0.000)	-	22.3*** (0.000)	-	
R^2 (overall)	0.35		0.38		0.38		
R^2 (within)		0.20		0.22		0.19	
Obs.	8,763		4,664		4,099		
N. of firms	1,112		608		504		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).

Table 4: Dependent variable: log(Net Sales/Employees) – HIGH-TECH

	HIGH-TECH WHOLE SAMPLE		HIGH-TECH UNITED STATES		HIGH-TECH EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.229*** (0.010)	0.255*** (0.016)	0.277*** (0.011)	0.333*** (0.019)	0.154*** (0.020)	0.128*** (0.026)	6.06*** (0.000)
Log(Physical stock per employee)	0.181*** (0.009)	0.082*** (0.007)	0.153*** (0.012)	0.088*** (0.009)	0.219*** (0.017)	0.062*** (0.015)	-1.52 (0.129)
Log(Employees)	0.015*** (0.005)	-0.142*** (0.014)	0.019** (0.008)	-0.096*** (0.017)	0.018** (0.008)	-0.243*** (0.024)	4.83*** (0.000)
Constant	4.298*** (0.916)	5.316*** (0.139)	3.914*** (0.098)	4.734*** (0.172)	3.988*** (0.130)	6.466*** (0.239)	-5.86*** (0.000)
Wald time-dummies (p-value)	11.5*** (0.000)	23.6*** (0.000)	12.2*** (0.000)	20.1*** (0.000)	2.5*** (0.000)	7.7*** (0.000)	
Wald country-dummies (p-value)	24.7*** (0.000)	-	-	-	21.7*** (0.000)	-	
Wald sectoral-dummies (p-value)	100.5*** (0.000)	-	99.3*** (0.000)	-	31.0*** (0.000)	-	
R^2 (overall) **R^2 (within)**	0.39	0.24	0.41	0.22	0.37	0.22	
Obs.	5,583		3,414		2,169		
N. of firms	703		441		262		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).

Table 5: Dependent variable: log(Net Sales/Employees) – MEDIUM-TECH

	MEDIUM-TECH WHOLE SAMPLE		MEDIUM-TECH UNITED STATES		MEDIUM-TECH EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.060*** (0.016)	0.111*** (0.032)	0.136*** (0.030)	0.188*** (0.062)	0.050** (0.023)	0.087** (0.037)	1.65* (0.102)
Log(Physical stock per employee)	0.328*** (0.027)	0.198*** (0.020)	0.210*** (0.032)	0.160*** (0.032)	0.422*** (0.039)	0.213*** (0.026)	-1.28 (0.201)
Log(Employees)	0.026* (0.013)	-0.079*** (0.032)	0.016 (0.018)	0.022 (0.053)	0.053*** (0.018)	-0.157*** (0.040)	2.69*** (0.000)
Constant	3.403*** (0.178)	4.740*** (0.312)	3.964*** (0.402)	3.849*** (0.527)	2.535*** (0.328)	5.412*** (0.393)	-2.37** (0.018)
Wald time-dummies (p-value)	1.2 (0.321)	2.8*** (0.002)	1.3 (0.260)	20.1*** (0.000)	0.62 (0.762)	2.7*** (0.005)	
Wald country-dummies (p-value)	4.8*** (0.000)	-	-	-	3.7*** (0.000)	-	
Wald sectoral-dummies (p-value)	16.9*** (0.000)	-	27.5*** (0.000)	-	11.1*** (0.000)	-	
R^2 (overall) R^2 (within)	0.39	0.15	0.38	0.20	0.43	0.14	
Obs.	2,128		855		1,273		
N. of firms	281		120		161		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).

Table 6: Dependent variable: log(Net Sales/Employees) – LOW-TECH

	LOW-TECH WHOLE SAMPLE		LOW-TECH UNITED STATES		LOW-TECH EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.049*** (0.014)	0.086*** (0.019)	0.053*** (0.017)	0.065* (0.036)	0.045** (0.023)	0.095*** (0.023)	-0.69 (0.490)
Log(Physical stock per employee)	0.333*** (0.010)	0.173*** (0.021)	0.330*** (0.030)	0.130*** (0.031)	0.334*** (0.039)	0.229*** (0.032)	-2.20** (0.028)
Log(Employees)	-0.030*** (0.016)	-0.161*** (0.026)	0.010 (0.013)	-0.111** (0.045)	-0.095*** (0.018)	-0.202*** (0.031)	1.61 (0.108)
Constant	3.847*** (0.164)	5.906*** (0.275)	5.501*** (0.168)	5.598*** (0.465)	5.136*** (0.239)	6.152*** (0.347)	-0.95 (0.342)
Wald time-dummies (p-value)	3.4*** (0.000)	15.6*** (0.002)	1.5 (0.161)	5.1*** (0.000)	2.8*** (0.000)	11.3*** (0.000)	
Wald country-dummies (p-value)	8.2*** (0.000)	-	-	-	7.8*** (0.000)	-	
Wald sectoral-dummies (p-value)	46.8*** (0.000)	-	27.5*** (0.000)	-	36.6*** (0.000)	-	
R^2 (overall)	0.60		0.59		0.43		
R^2 (within)		0.40		0.37		0.44	
Obs.	1,052		395		657		
N. of firms	128		47		81		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).

Table 7: Dependent variable: log(Net Sales/Employees) – 2004-2008

	WHOLE SAMPLE		UNITED STATES		EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.143*** (0.010)	0.243*** (0.022)	0.224*** (0.014)	0.294*** (0.032)	0.074** (0.023)	0.194*** (0.030)	2.20** (0.028)
Log(Physical stock per employee)	0.216*** (0.012)	0.070*** (0.011)	0.161*** (0.016)	0.087*** (0.012)	0.265*** (0.039)	0.034* (0.018)	2.31** (0.021)
Log(Employees)	0.036*** (0.007)	-0.136*** (0.020)	0.046*** (0.009)	-0.133*** (0.029)	0.036*** (0.018)	-0.131*** (0.031)	-0.04 (0.960)
Constant	3.565*** (0.126)	5.465*** (0.206)	3.647*** (0.169)	5.186*** (0.292)	3.235*** (0.238)	5.720*** (0.298)	-1.27 (0.201)
Wald time-dummies (p-value)	0.6 (0.665)	1.5 (0.195)	2.7** (0.028)	8.8*** (0.000)	0.5 (0.750)	1.5 (0.195)	
Wald country-dummies (p-value)	11.2*** (0.000)	-	-	-	8.5*** (0.000)	-	
Wald sectoral-dummies (p-value)	26.5*** (0.000)	-	27.5*** (0.000)	-	17.0*** (0.000)	-	
R^2 (overall) R^2 (within)	0.33	0.18	0.59	0.22	0.43	0.16	
Obs.	4,949		2,652		2,297		
N. of firms	1,090		588		502		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).

Table 8: Dependent variable: log(Net Sales/Employees) – 2009-2012

	WHOLE SAMPLE		UNITED STATES		EUROPE		
	POLS	FE	POLS	FE	POLS	FE	T-test on US vs. EU coefficient differences
Log(R&D stock per employee)	0.164*** (0.011)	0.158*** (0.026)	0.261*** (0.011)	0.199*** (0.034)	0.096** (0.018)	0.093** (0.041)	1.98** (0.049)
Log(Physical stock per employee)	0.258*** (0.013)	0.089*** (0.010)	0.191*** (0.012)	0.105*** (0.013)	0.323*** (0.024)	0.058*** (0.018)	2.09** (0.037)
Log(Employees)	0.006 (0.007)	-0.248*** (0.027)	0.002 (0.008)	-0.319*** (0.034)	0.020* (0.011)	-0.264*** (0.045)	-0.98 (0.327)
Constant	2.868*** (0.095)	6.979*** (0.316)	2.699*** (0.105)	6.895*** (0.403)	3.605*** (0.265)	7.092*** (0.520)	-0.29 (0.771)
Wald time-dummies (p-value)	5.8*** (0.665)	57.7*** (0.000)	3.2** (0.022)	37.7*** (0.000)	4.2*** (0.005)	23.7*** (0.000)	
Wald country-dummies (p-value)	11.9*** (0.000)	-	-	-	7.9*** (0.000)	-	
Wald sectoral-dummies (p-value)	19.8*** (0.000)	-	35.8*** (0.000)	-	12.0*** (0.000)	-	
R^2 (overall)	0.42		0.49		0.43		
R^2 (within)		0.26		0.20		0.20	
Obs.	3,814		2,012		1,802		
N. of firms	1,024		555		469		

Notes: - (Robust in POLS) standard errors in brackets; * significance at 10%, ** 5%, *** 1 %.
- For time-dummies, country-dummies and sectoral-dummies, Wald tests of joint significance are reported.
- The outcomes of the t-tests on the significance of the differences between the US and the EU (FE coefficients) are reported in the last column (p-values in brackets).