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CENTRO STUDI LUCA D'AGLIANO
DEVELOPMENT STUDIES WORKING PAPERS

N. 345

November 2012

R&D Offshoring and the Productivity Growth of European Regions

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R&D Offshoring and the Productivity Growth of European Regions

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Abstract

The recent increase in R&D offshoring have raised fears that knowledge and competitiveness in advanced countries may be at risk of 'hollowing out'. At the same time, economic research has stressed that this process is also likely to allow some reverse technology transfer and foster growth at home. This paper addresses this issue by investigating the extent to which R&D offshoring is associated with productivity dynamics of European regions. We find that offshoring regions have higher productivity growth, but this positive effect fades down with the number of investment projects carried out abroad. A large and positive correlation emerge between the extent of R&D offshoring and the home region productivity growth, supporting the idea that carrying out R&D abroad strengthen European competitiveness.

JEL classification: C23, F23, O47, O52, R11

Keywords: R&D Offshoring, Regional Productivity, Foreign Investments, Europe,

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1. Introduction

Research and Development (R&D), together with other core business activities, is usually centralized at the firms' headquarters in the home country (Patel and Pavitt, 1991; Narula, 2002; Belderbos, Leten, and Suzuki, 2010), but the last decades have documented an increase in the internationalization of R&D and inventive activities (Guellec and van Pottelsberghe de la Potterie, 2001; Picci, 2010). This was at first mainly motivated by the need to better exploit existing home-based advantages (i.e. by adapting existing products to foreign markets needs), while more recently the need to source complementary assets, talents and competences abroad has also became an important motive.[1] This offshoring of R&D activities[2] is related to the emerging phenomenon of Global Innovation Networks (GINs) (Ernst, 2002, 2011; Chaminade, 2009; Borras, 2013).

The trend towards locating R&D activities abroad have raised concerns that the knowledge base of advanced countries may be 'hollowed out', worsening their relative international competitiveness.[3] At the same time, economic research have highlighted the potential benefits of offshoring R&D in terms of reverse technology transfer and increased competitiveness at home. However, while there are works investigating the impact of R&D offshoring both on the innovative and productive performance at the level of the firm, evidence of the overall impact of this phenomenon on the home economy is still scarce and inconclusive. This lack of evidence is particularly unfortunate from the policy perspective, since to inform policy intervention it is essential to evaluate not only the firm-level effects, but also how they interact at a more aggregate level.

This work contributes to filling this gap by assessing to what extent the pro-

[1] See for example, Cantwell (1995); Kuemmerle (1999); Patel and Vega (1999); von Zedtwitz and Gassmann (2002); Le Bas and Sierra (2002); Narula and Zanfei (2005); Manning, Massini, and Lewin (2008); Dunning and Lundan (2009); Ambos and Ambos (2011).

[2] [R&D] Offshoring is defined as the location or transfer of [R&D] activities abroad. It can be done internally by moving services from a parent company to its foreign affiliates —sometimes referred to as 'captive' or 'in-house' offshoring—, or to third (unrelated) parties —referred to as international outsourcing— (UNCTAD, 2006). The empirical analysis carried out in this work will refer to 'captive' R&D offshoring only.

[3] See, for example, Lieberman (2004) for the US, and Kirkegaard (2005) or Pro Inno Europe (2007) for Europe.

ductivity growth of 262 regions in Europe is associated with offshoring of R&D activities by domestic multinational enterprises (MNEs) based in the same regions.[4] The focus on regional productivity allows us to capture not only the direct effect of R&D offshoring on firms' competitiveness, but also the effect through the growth in size of offshoring firms (i.e. through market shares reallocation) and the indirect effect via increase/decrease in local firms' productivity and propensity to enter/exit the market ('spillover' effect).[5] The relationship between R&D offshoring and regional productivity is particularly relevant in the European Union (EU) where regional competitiveness and social and economic cohesion have been crucial concerns for policy makers.[6]

In order to investigate to what extent offshoring of R&D is associated with regional productivity growth, we gather data on international investment projects, that we use to build unique measures of outward investments in R&D at the regional level for the countries of the European Union. We then estimate regressions of productivity growth as a function of the lagged number of international R&D investments, controlling for a measure of incoming multinational activity, as well as other regional characteristics and country fixed effects. We find that offshoring regions have higher productivity growth and a positive correlation emerges between the extent of R&D offshoring and the home region productivity growth.

The contribution of this work is threefold. First, to the best of our knowledge, it is the first large sample empirical investigation into the role of R&D offshoring on home region performance, and, thus, it brings some first general evidence of how the internationalization of innovative processes in a wide sam-

[4] NUTS is an acronym for Nomenclature of Units for Territorial Statistics which indicates a hierarchical classification of administrative areas used by the European statistical office (Eurostat). NUTS levels (1-3) indicate different degrees of aggregation.

[5] Unfortunately, due to the lack of disaggregated data we cannot evaluate the relative contribution of these different channels, but we can measure the overall net effect on the aggregate productivity.

[6] As documented by Fiaschi, Lavezzi, and Parenti (2009), 35% of the EU budget for the period 2007-2013 has been allocated to promote social and economic cohesion among the regions of its member states.

ple of developed (European) regions is related to their competitiveness. Second, given the availability of measures of outgoing and incoming international investments, we are able to look at the effect of R&D offshoring taking into account the extent to which each region is also attracting incoming multinational activity, thus overcoming another major gap in the literature, which have mainly looked either at the outward or at the inward internationalisation separately. Third, combining the information on the sector and destination country in which the R&D offshoring has taken place, we are able to uncover interesting insights on the possible mechanisms through which R&D offshoring affects productivity at home.

The rest of the paper is organized as follows: Section 2 presents the theoretical and empirical background of this paper; Section 3 provides details on the characteristics of the data and focuses on how the main variables of interest have been measured and built; Section 4 illustrates the econometric specification and results. Section 5 concludes the paper.

2. R&D offshoring and regional productivity growth: theoretical and empirical framework

The increasing propensity towards geographical fragmentation of firm activities, especially of high-value added tasks, raises concerns on the impact that offshoring activities may have on competitiveness and employment at home. Despite a widespread fear, especially among policy makers, that offshoring may cause loss of jobs and 'hollowing-out' of local competences (Lieberman, 2004), economic research has not reached a consensus (Bardhan, 2006). As a matter of fact, several studies find a positive relationship between the internationalization of high-value added activities and the degree of innovation and productivity at home.[7]

[7]For example, Criscuolo, Narula, and Verspagen (2005) and Criscuolo (2009), using data on patent citations, show the existence of a reverse technology transfer to European firms, whereas Piscitello and Santangelo (2010) and D'Agostino, Laursen, and Santangelo (2012) support the hypothesis that the patenting activity of OECD countries and regions benefitted from offshored R&D activities in emerging economies (BRICKST). Using firm-level data,

Our study relates to the above empirical works, and tries to assess the relationship between R&D offshoring of EU firms and the productivity growth of their home region. But why (and how) does offshoring of R&D affect regional productivity? As noted (among others) by Bartelsman and Doms (2000), aggregate productivity dynamics can be decomposed into changes in productivity at the level of the firm (the within-component of productivity growth) and reallocation of resources across incumbents and through entry and exit (the between-component). In this perspective, our theory should explain both the effect of R&D offshoring on individual firms' productivity, and on their relative size and probability to entry/exit. This makes very difficult to make clear-cut predictions, and even harder to test the precise underlying mechanisms, especially given the lack of micro data on individual firm productivity and size within each region. Nonetheless, it is important to lay out the various channels through which R&D offshoring may contribute to the home regions' productivity growth, before assessing its net effect by means of an econometric exercise.

The economics and management literature on R&D offshoring has mainly focused on the effects at the level of the firm (i.e., the within-component), highlighting the positive role that R&D offshoring may have on firms' productivity through different channels. On the one hand, R&D labs abroad are needed to be able to quickly and effectively adapt products to the need and specificities of new markets. [8] On the other hand, the need for enhancing innovation capability leads firms to engage in competence-creating activities (Cantwell and Mudambi, 2005) and interaction with different and geographically dispersed actors (Hitt, Hoskisson, and Kim, 1997; Narula and Zanfei, 2005). Moreover, R&D offshoring is necessary to gain access to strategic complementary assets (Teece, 1986), as well as highly qualified and/or lower cost R&D personnel (Manning, Massini,

from the Spanish Technological Innovation Panel, Nieto and Rodriguez (2011) find a positive relationship between offshoring and innovation, with a greater effect on product than process innovations and through captive offshoring than offshore outsourcing.

[8] Eventually, innovation developed for the local markets may be decontextualized, becoming part of the knowledge base of the multinational firms, subsequently exploited elsewhere (Zanfei, 2000).

and Lewin, 2008; Chung and Yeaple, 2008; Puga and Trefler, 2010).

However, R&D offshoring is not a sufficient condition for the increase of knowledge and productivity at home. First, offshored labs need to be able to extract knowledge from foreign locations, thus it may need time and investments to establish relationships with actors in the host innovation system (Narula and Michel, 2009). Second, the firm must be able to manage reverse knowledge transfers (from the offshored labs back to the headquarters and the rest of the company), which may require the adoption of sophisticated mechanisms for the dissemination and integration of both explicit and tacit knowledge (Gupta and Govindarajan, 2000). On this regard, the large-scale offshoring of knowledge-intensive activities tends to be accompanied by an increasing specialization within the firm, which may reduce the ability to orchestrate the entire value chain, exacerbating the risk of 'hollowing out' the competencies of the offshoring firm. For example, as the firm becomes more reliant on its independent suppliers, it may not be able to keep pace with the evolving design and engineering technologies (Kotabe, 1998; Kotabe and Mudambi, 2009). More generally, Contractor, Kumar, Kundu, and Pedersen (2010) posit that the benefits from disaggregation, reconfiguration, and dispersion of the firm increase with corporate restructuring but at a diminishing rate, as the overall costs of managing greater complexity, disaggregation, dispersion, relocation, and coordination may however escalate more quickly after a certain point. Consistent with this theoretical prior, Grimpe and Kaiser (2010), in a panel of innovating firms in Germany, find evidence of an inverted U-shaped relationship between R&D outsourcing and innovation performance.

One less explored channel through which R&D offshoring affects the aggregate productivity of the home region is through the reallocation of market shares (i.e. the between-component). In fact, offshoring, by allowing firms to sell more into foreign markets (thanks to a quick adaptation of their products), will also increase the need for services and activities concentrated in the home territory (Grossman and Rossi-Hansberg, 2008; Barba Navaretti, Castellani, and Disdier, 2010). Provided that offshoring firms are relatively more productive than the purely domestic ones (Helpman, Melitz, and Yeaple, 2004), regional productivity would increase because offshoring firms increase their market share.

Finally, R&D offshoring may also have indirect effects on the productivity, size and entry/exit of other firms in the home region, in a fashion which is similar to the spillover effects which have been analysed at length with reference to foreign-owned firms in host economies (Castellani and Zanfei, 2006). By opening R&D labs abroad, multinational firms may close down activities in the home country, thus disrupting linkages with local firms and institutions. This shrinks the activities of local firms, which may ultimately be forced to exit. Alternatively, if R&D offshoring enables some reverse knowledge transfer, domestic counterparts may also benefit of some positive externalities, via labor mobility, imitation or inter-firm linkages. Borras and Haakonsson (2013) submit that firms engaging in GINs characterized by knowledge-augmenting strategies have a positive 'mobilization effect' on the national innovation system in terms of expanding the size, the types of organization, the content of the collaboration, the concurrent internationalization and the degree of formalization in the innovation networks within the national system.

In sum, R&D offshoring affects the home region productivity through a variety of channels, and only some of them are observable at the level of the individual firm: an aggregate perspective allows to evaluate the net effect of such different transmission channels. Moreover, most of these effects are likely to be relatively confined in space and, thus, the regional level would more appropriate than the country level to capture them.[9]

Thus, this paper is a first attempt to provide a robust empirical evidence to the broad question of whether R&D offshoring is ultimately positively or negatively associated with the growth prospects of EU regions.

[9]First, the smaller the units of observation, the easier it would be to appreciate the direct effects, which may be more diluted in more aggregate data. Second, indirect effects may be enhanced by the geographic proximity, which can be important for transmitting knowledge as face-to-face communication (Audretsch and Feldman, 2004). Third, in the presence of transport costs, vertical linkages (which foster pecuniary and knowledge externalities) occur between closely-located suppliers and customers (Venables, 1996).

Our work is related with the emergence of GINs. In particular, in terms of the three attributes of GINs laid out by Borras (2013) (geographic scope, degree of innovativeness and networking), the concept of R&D offshoring (as opposed to international R&D outsourcing) refers mainly to internal networking strategies, but without any limitation in geographic scope. More precisely, in this paper we will explore R&D investments within the boundaries of MNCs, either within Europe and towards other advanced and emerging economies, and we will assess to what extent expanding the internal R&D network of MNCs affects productivity growth at the home. In this exercise we will implicitly assume that there may be positive or negative effects both within the MNCs and to other home firms and institutions which may be part of some local external network of the MNC, but we will not be able to identify the extent of such external linkages. As for the degree of innovativeness, our data will not allow to assess with certaintly whether R&D offshoring is aimed to 'new to the world' or 'new to the industry' innovation, but a causal inspection of our data suggests that it is more likely that they identify competence-creating than competence-exploiting strategies.[10]

3. Data and variables

3.1. Data sources

We exploit an original database, which has been compiled recovering data from different sources. Data refer to European regions, at the NUTS 2 level: this level of analysis has been chosen for three main reasons. First, it is suitable for taking into account the within-country heterogeneity (in terms of labor productivity, R&D investments abroad and the other observed and unobserved characteristics); second, it allows for comparable units across different countries;

[10]The international business literature on the internationalization of innovative activities have distinguished among those aimed at exploiting existing competences/knowledge possessed by the MNC (and mainly developed at home) and those aimed at augmenting/creating the knowledge/competence pool of the firm (Kuemmerle, 1999; Cantwell and Mudambi, 2005; Narula and Zanfei, 2005).

third, more information is available on regional characteristics at this level of disaggregation.[11]

3.2. Labor Productivity

The dependent variable is labor productivity, which has been computed as the ratio of the regional gross valued added (at basic prices in millions of euro), obtained from from the *EU Regional Database* by Eurostat[12], to employment (thousands of employees) in the region, whose data come from the *European Regional Database* by Cambridge Econometrics (release 2006). Value added has been deflated using nationwide indexes, available in the *Growth and Productivity Accounts* database developed by EU KLEMS[13] (releases 2008 and 2009). The last year for which information on value added are available in the Regio database is 2006.

Figure 1 provides a graphical representations of the variables measuring the labor productivity in levels and growth rates at the NUTS 2 level. Labor productivity levels are clearly higher in the core regions of the EU-15, they decline in Southern European regions and reach minimum values in the regions of EU-12 countries. As for the growth rates, in most countries, we observe a rather specific-to-the-country pattern of growth, i.e. regions belonging to the same country display similar growth rates: these rates are higher for regions belonging to EU-12 countries, lower for France and even lower for Italy and Spain. Nonetheless, in Germany and UK, productivity growth displays a remarkable within-country variability. In order to account for possible biases stemming from these country patterns in productivity growth, country dummies are introduced in our estimated equation.

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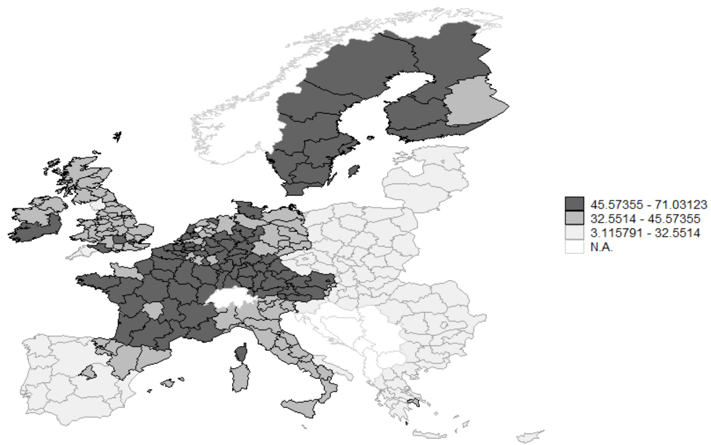
[11] See Table A.4 in the Appendix for the detailed list of regions, that have been considered in the econometric analysis.

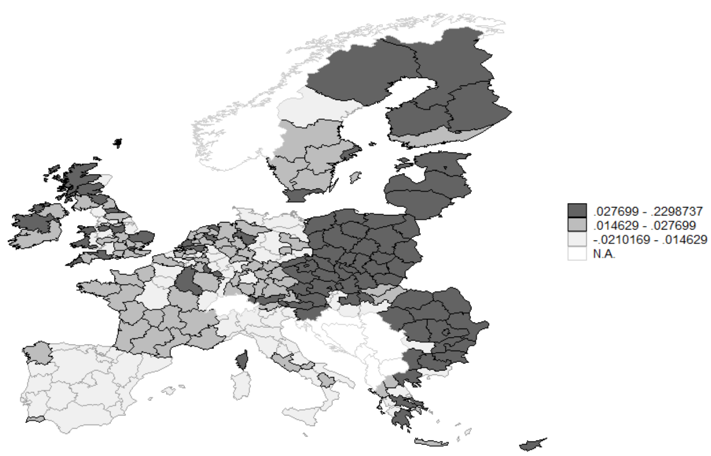
[12] See the Eurostat web page `http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/`.

[13] See the web page of the EU KLEMS project at `http://www.euklems.net/`

Figure 1: Regional patterns of labor-productivity level and growth, 2003-2006 (average)



(a) Labor productivity (level), thousands of euro per worker



(b) Labor productivity (growth), % change

3.3. Measures of offshoring

Data on offshoring have been recovered from *fDi Markets*, an online database maintained by fDi Intelligence —a specialist division of the Financial Times Ltd—, which monitors crossborder greenfield investments covering all sectors and countries worldwide.[14] This source tracked 60,301 worldwide greenfield investments projects appeared on publicly available information sources in the period 2003-2008. For each project, fDi Markets reports information on the investment, such as the industry and main business activity involved in the project[15], the location where the investment takes place (host country, regions and cities), as well as the name and location of the investing company (home). The database is used as the data source in UNCTAD's World Investment Report and in publications by the Economist Intelligence Unit.

One of the limitations of the *fDi Markets* database is that it collects planned future greenfield investments. Some of these projects may not actually be realized or may be realized in a different form from the one originally announced. However, the database is regularly updated and projects which have not been completed are deleted from the database. In this regards, data on the projects for the early years of the series should be more reliable than data regarding the last years of the series. We tackle this issue by dropping the last two years of data, so we use information from 2003 to 2006. Our measures of offshoring is then built as the number of outward investment projects from each region in each year of the period 2003-2006. We have also built measures of inward

[14]A team of in-house analysts search daily for investment projects from various publicly available information sources, including, Financial Times newswires, nearly 9,000 media, over 1,000 industry organizations and investment agencies, data purchased from market research and publication companies. Each project identified is cross-referenced against multiple sources, and over 90% of projects are validated with company sources. More information at `http://fdimarkets.com/`. Unfortunately, no information is provided on mergers and acquisitions.

[15]*fDi Markets* assigns each project into one of 18 business activities, spanning from sales/marketing (the largest category), to business services, manufacturing, logistics, testing and extraction, research and development (R&D), design, development and testing (DDT), headquarters and other activities. We focus on projects in R&D, but we compare results with investment projects in other value added activities. In particular, we use projects in manufacturing activities as our main benchmark.

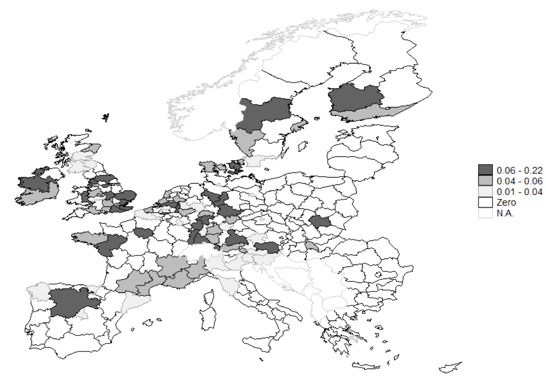
investments at the regional level, to control for the fact that regions engaged in outward internationalization may also be those attracting more foreign multinationals. We are aware that the count of investments projects may not be an accurate proxy of offshoring activity, since it does not weights investments for the value of the capital involved. In order to check the reliability of this proxy, we have calculated the correlation coefficients between the distribution of investments projects by EU countries and the actual distribution of FDI flows, as reported by UNCTAD, and the remarkably high correlations reassure us that data on investment projects are actually a good proxy for FDI flows. We cross-refer the reader to the Data Appendix A.2 for further details on this check.

Exploiting the information on the main business activity involved in each of the international projects in the *fDi Markets* database, Figure 3(a) reports the share of R&D offshoring projects over the 2003-2006 period[16], and Figure 3(b) shows, for the purpose of comparison, the share of outward investments in manufacturing activities. In line with the idea that R&D offshoring is still a limited, although increasing phenomenon, only a relatively small number of regions show some R&D offshoring activity, while manufacturing offshoring is much more pervasive and accounts for a larger share of total outward investments in each region.

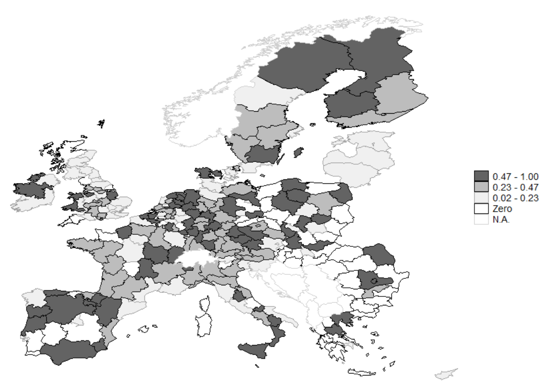
Table 1 provides some basic statistics for the variables later used in the econometric analysis (we cross-refer the reader to Table A.2 in the Data Appendix A for more descriptive statistics). With regard to offshoring, on average, from each region about 12.75 offshoring and 9.28 incoming projects per year have

[16] To clarify what is intended for R&D investments, here are two examples that *fDi Markets* reports with specific reference to IBM as an investor. Example 1: a nanotech research centre in Egypt is intended to be a world-class facility for both local engineers and scientists, and IBM's own researchers, to develop nanotechnology programs. The centre will work in coordination with other IBM Research efforts in the field in Switzerland and the US. Example 2: a business solution center to promote new technologies that help save energy used to run computer equipment and reduce hardware management costs. Teaming up with automakers and electronics manufacturers, the center will study how to make the best use of advanced technologies. IBM Japan intends to use the results of these efforts to win system development projects

Figure 2: Regional distribution of R&D and manufacturing offshoring projects, 2003-2006



(a) Share of R&D projects, % of offshored investments



(b) Share of manufacturing projects, % of offshored investments been recorded. However, the distribution of the number of projects is highly skewed: more than 25% of regions have no offshoring and more than 10% would not attract any inward investment. This skewness is even more evident in the case of R&D offshoring, which is carried out by slightly more than 10% of the regions (the 90^{th} percentile is equal to 1).

Table 1: Descriptive statistics, 2003-2005

Variable	Mean	p10	p25	p50	p90	p95	p99	Max
OFF	12.75	0	0	2	30	55	129	404
OFF^{rd}	.54	0	0	0	1	2	12	29
OFF^{manuf}	3.14	0	0	1	8	13	33	90
INW	9.28	0	1	4	23	35	75	209

4. Econometric analysis

In the first part of the empirical analysis, we investigate the effect of offshoring on the home region productivity growth regardless of the type of business activities carried out abroad, while in the second part we focus on the role of R&D offshoring. In all the econometric specifications, we control for incoming multinational activity, the growth of capital-labor ratio, country-fixed effects and other regional characteristics. The skewness of the offshoring and inward investments variables has been taken into account, modeling their effect as a combination of two dummy taking value equal to '0' for those observations (region/year) where no outward or inward investments have taken place, respectively $OFF(d)$ and $INW(d)$, and two continuous variable, $OFF(n)$ and $INW(n)$, taking the value equal to the number of investments in the case of non-zero investments, and '0' otherwise.

This specification allows to distinguish the effect of a region being generally involved in offshoring, which is captured by the dummy variable, from the effect of the extent of offshoring, which is captured by the continuous variable. The estimated equation becomes

$$\begin{aligned}\Delta y_{ij,t} = \alpha + \beta \Delta kl_{ij,t} + \delta \Delta \mathbf{x_{ij,t}} + \\ + OFF(d)_{ij,t-1} \cdot (\gamma_d + \gamma_n OFF(n)_{ij,t-1}) + \\ + INW(d)_{ij,t-1} \cdot (\lambda_d + \lambda_n INW(n)_{ij,t-1}) + \\ + \eta_j + \tau_t + \epsilon_{ij,t} \end{aligned} \quad (1)$$

where $y_{ij,t}$ refers to the (log of the) labor productivity of the ith region, located in the jth country and observed in the tth period of time; $kl_{ij,t}$ indicates the (log of the) capital-labor ratio which refers to the same region, and $\mathbf{x_{ij,t}}$ is a vector of other regional characteristics, such as the level of human capital, the stock of technological capital, the regional industrial composition and the degree of concentration/diversification of the regional industry[17]. We also include a vector of time effects, τ_t, to control for factors affecting all regions in the same way in a given year, and a vector of country dummies, η_j in order to capture the country-specific trends in labor productivity. Our working hypothesis is that foreign investments affect productivity with one-year lag, but since there is no theoretical prior suggesting this time lag, we will bring it to the data and test it against both a contemporaneous effect and a two-years lag. Unfortunately, due the relatively short time series, it is not possibile to test for longer time lags.

We estimate Equation 1 by means of OLS[18], over three pooled cross-sections of one-year growth rates: 2003-2004, 2004-2005 and 2005-2006. Results are reported in columns (1) and (2) of Table 2. In specification (1) we estimate the coefficients associated with the two dummies taking value 1 if a region has at least one outgoing or incoming investment project (respectively) on regional productivity growth: results support that offshoring regions have a 0.67 percentage points higher productivity growth, while regions receiving inward investments

[17] We cross refer the reader to the Data Appendix A.3 and A.4 for further details on how the measure of capital-labor ratio and the other control variables have been built.

[18] In this and the following regressions robust standard errors clustered by regions have been computed and reported, in order to control for the lack of independence of observations referring to the same region over time.

Table 2: The effect of offshoring on EU regional productivity growth

Dependent variable		$\Delta y_{ij,t}$	$\Delta y_{ij,t}$	$\Delta y_{ij,t}$	$\Delta y_{ij,t}$
Variable	Coefficient	(1)	(2)	(3)	(2.1)
		(OLS)	(OLS)	(OLS)	(IV-GMM)
$OFF(d)_{t-1}$	γ_d	0.0067**	0.0061**	0.0075**	0.0003
		(0.0026)	(0.0025)	(0.0034)	(0.0045)
$OFF(n)_{t-1}$	γ_n		-0.0001***	-0.0001	-0.0002
			(0.0000)	(0.0001)	(0.0001)
$OFF(d)_{t-2}$	γ_d^{lag2}			-0.0025	
				(0.0033)	
$OFF(n)_{t-2}$	γ_n^{lag2}			0.0000	
				(0.0001)	
$INW(d)_{t-1}$	λ_d	-0.0053**	-0.0055**	-0.0055**	-0.0029
		(0.0024)	(0.0024)	(0.0027)	(0.0025)
$INW(n)_{t-1}$	λ_n		0.0003**	0.0003**	0.0004*
			(0.0001)	(0.0001)	(0.0002)
Δkl	β	0.2230***	0.2386***	0.1429*	0.2377**
		(0.0845)	(0.0837)	(0.0778)	(0.0971)
Regional controls	δ	Yes	Yes	Yes	Yes
Country dummies	η_j	Yes	Yes	Yes	Yes
Year dummies	τ_t	Yes	Yes	Yes	Yes
Log-likelihood		1707	1710	1235	1684
Observations		760	760	498	749
Regions		262	262	262	259
Significance levels: * 10%, ** 5%,*** 1%; cluster robust SE in parentheses					
δ, η_j and τ_t estimates omitted to save space					
Test on IV estimates (robust to heteroskedasticity and autocorrelation)					
Underidentification; Kleibergen-Paap *rk* LM statistic (P-value, 1-stage)					0.0000
Weak identification; Kleibergen-Paap Wald *rk* F statistic					7.302
Hansen J test on overidentifying restrictions (P-value)					0.8126
Exogeneity test (OLS vs. IV)(P-value)					0.2636
Complete table available from authors upon request					

show lower performance. The numbers of both outgoing and incoming investments are introduced in specification (2), and their effects are estimated. This helps to qualify the previous result: in fact, while the positive effect of offshoring is slightly decreasing in the number of investments, a higher number of incoming multinationals is associated with higher productivity growth. From Equation 1, it is possible to compute the threshold number of offshoring investments above which the overall effect is negative. In particular, taking the partial derivative of labor productivity growth with respect to $OFF(d)$, we obtain:

$$\frac{\partial \Delta y}{\partial OFF(d)} = \gamma_d + \gamma_n OFF(n), \tag{2}$$

so the effect of offshoring will be positive as long as

$$OFF(n) > \frac{-\gamma_d}{\gamma_n}. \tag{3}$$

Taking specification (2) as a reference, with $\widehat{\gamma_d}$ = 0.0061 and $\widehat{\gamma_n}$ = -0.0001, the marginal effect of offshoring would be positive for a number of outgoing project smaller or equal to $\frac{-0.0061}{0.0001}$=61. From Table 1 we can appreciate that this is above the 95^{th} percentile, meaning that less than 5% of the regions actually experience a negative productivity growth as a result of their involvement in offshoring. This is consitent with previous theoretical and empirical results discussed in section 2 suggesting that there may be an inverted-U relationship between offhsoring and innovation (see Grimpe and Kaiser, 2010; Contractor, Kumar, Kundu, and Pedersen, 2010, among others) due to the increasing difficulties in orchestrating the value chain (Kotabe and Mudambi, 2009). The value of the coefficients of the inward investments variables is also worth commenting: the threshold for inward investments is $\frac{-0.0055}{0.0003}$=18.3, which is between the 75^{th} and 90^{th} percentile, suggesting that about one-quarter of EU regions benefit from incoming multinationals.

In column (3) and (2.1) we report two robustness checks. First, we test the assumption about the one-year lag in the effect of offshoring on regional productivity. The specification of Equation (1) is motivated by the idea that some time is needed for the effect of offshoring to take place, but we do not have a specific prior on how long this time lag should be. In order to check if a longer lag should be allowed in order to appreciate the effects of offshoring, we include the second lag of both $OFF(d)$ and $OFF(n)$ in Equation (1). Results, reported in column (3) show that offshoring at $t-2$ is not significantly correlated with regional productivity growth, whereas the one-year lag maintain its sign and significance[19]. Due to data limitation, we cannot test for longer time lags, but

[19]Actually, the γ_d parameter increase in magnitude and and γ_n becomes non-significantly different from zero, thus reinforcing our conclusions. To avoid the risk of overestimating positive effects from offshoring, we prefer to rely on the more conservative estimates in column (2).

results from column (3) are consistent with the idea that the offshoring effects do not take a long time span to manifest. Second, despite the fact that we use lagged values and control for a number of confounding factors, one may be concerned that past offshoring may still be endogenous with respect to future productivity growth, so we test whether an instrumental variable estimation (IV-GMM) should be preferred to OLS. Using the size of the region (log of total population), a dummy taking value 1 for regions hosting the country capital, the share of employment with tertiary education and the share of active population as instruments for $OFF(d)$ and $OFF(n)$, in column (2.1) we: (i) obtain a low P value of of Kleibergen-Paap rk LM test and a fairly satisfactory value for the Kleibergen-Paap F test, which, respectively, ensure us about the identification of the model and the non-negligible relationship between the instruments and the potentially endogenous regressors[20]; (ii) cannot reject the hypotheisis of no overidentifying restrictions (i.e. the validity of the instruments), as illustrated by the low value of the Hansen J statistic; and, more importantly, (iii) cannot reject the null hypothesis of $OFF(d)$ and $OFF(n)$ being exogenous, as from the C-test of exogeneity in the last row of Table 2. This latter result implies that the OLS estimates are more efficient and should be preferred to the IV-GMM ones.

We also performed a number of other robustness checks, which we do not report here to save space. In particular, (i) we tested (and rejected) that offshoring may have contemporaneous effects on productivity growth; (ii) we included controls for spatial dependence, as well as regional characteristics (in levels) – including population, a dummy for regions hosting the country capitals, the level of education, employment density, patenting activity– none of which change the results significantly [21].

Exploiting the information on the type of investment made abroad, it is

[20]The F-tests for the excluded instruments in the first-stage have been not reported to save space, but available from the authors upon request.

[21]The reader can refer to Castellani and Pieri (2011) for further details on these robustness checks.

possible to investigate the relationship between R&D offshoring (as opposed to offshoring of manufacturing or other activities) and regional productivity, by augmenting the specification (1) with the number of outward investment in R&D. Thus, the estimated equation now takes the following form:

$$
\begin{aligned}
\Delta y_{ij,t} = \alpha + \beta \Delta kl_{ij,t} + \delta \Delta \mathbf{x_{ij,t}} + \\
+ OFF(d)_{ij,t-1} \cdot \left(\gamma_d + \gamma_n OFF(n)_{ij,t-1} + \gamma_n^{ba} OFF(n)_{ij,t-1}\right) \\
+ INW(d)_{ij,t-1} \cdot (\lambda_d + \lambda_n INW(n)_{ij,t-1}) + \\
+ \eta_j + \tau_t + \epsilon_{ij,t}.
\end{aligned} \tag{4}
$$

where $y_{ij,t}$, $kl_{ij,t}$, $\mathbf{x_{ij,t}}$, $OFF(d)$, $OFF(n)$, $INW(d)$, $INW(n)$ are defined as above, and ba denotes the business activity in which investments abroad have been made (i.e. R&D or manufacturing).

Results reported in column (4) and (5) of Table 3, show that R&D offshoring is associated with significantly higher productivity growth, while offshoring in manufacturing activities is not. In the case of R&D offshoring there seems to be no inverted-U relation with productivity growth. We submit that this may be related to the fact that the level of the internationationalization of R&D of European regions is still relatively low, and have not reached the threshold where the 'hollowing-out' effects may (eventually) kick-in.

While an increase in labor productivity is a desirable outcome for the long term growth of a region, if it was achieved by shedding labor (the denominator of the labor productivity measure), the policy maker would be worried about its short term consequences. We test for this eventuality by estimating separate regressions of the growth of (deflated) value added and employment in columns (4.1), (4.2), (5.1) and (5.2). Results do not show any negative effect of offshoring on employment. On the contrary, offshoring regions exhibit higher growth both in value added and employment than the non offshoring ones, but the growth in output is larger than the one of employment, thus determining positive productivity effects.

Table 3: Offshoring of R&D and manufacturing activity and the growth of value added and employment in EU regions

Dependent variable		$\Delta y_{ij,t}$	$\Delta VA_{ij,t}$	$\Delta L_{ij,t}$	$\Delta y_{ij,t}$	$\Delta VA_{ij,t}$	$\Delta L_{ij,t}$
Variable	Coefficient	(4)	(4.1)	(4.2)	(5)	(5.1)	(5.2)
		(OLS)	(OLS)	(OLS)	(OLS)	(OLS)	(OLS)
$OFF(d)_{t-1}$	γ_d	0.0063**	0.0085***	0.0022***	0.0059**	0.0080***	0.0021***
		(0.0025)	(0.0025)	(0.0007)	(0.0025)	(0.0025)	(0.0007)
$OFF(n)_{t-1}$	γ_n	-0.0002***	-0.0002***	0.0000	-0.0002**	-0.0002**	0.0000
		(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0000)
$OFF(n)^{rd}_{t-1}$	γ^{rd}_n	0.0013**	0.0016***	0.0003			
		(0.0005)	(0.0006)	(0.0002)			
$OFF(n)^{man}_{t-1}$	γ^{man}_n				0.0002	0.0003*	0.0001
					(0.0002)	(0.0002)	(0.0001)
$INW(d)_{t-1}$	λ_d	-0.0055**	-0.0073***	-0.0018*	-0.0057**	-0.0075***	-0.0019*
		(0.0024)	(0.0022)	(0.0010)	(0.0024)	(0.0023)	(0.0010)
$INW(n)_{t-1}$	λ_n	0.0003***	0.0003**	-0.0000	0.0003**	0.0003**	-0.0000
		(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0000)
Δkl	β	0.2393***	0.0078	-0.2315***	0.2392***	0.0079	-0.2313***
		(0.0838)	(0.0551)	(0.0614)	(0.0837)	(0.0552)	(0.0615)
Regional controls	δ	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	η_j	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	τ_t	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood		1711	1717	2627	1710	1716	2627
Observations		760	760	760	760	760	760
Regions		262	262	262	262	262	262

Significance levels: * 10%, ** 5%,*** 1%; cluster robust SE in parentheses
δ, η_j and τ_t estimates omitted to save space
Complete table available from authors upon request

In order to have more insights on the relationship between R&D offshoring and the home region productivity growth, we can distinguish R&D offshoring towards countries outside Europe, as opposed to offshoring within the European area. Table 4 presents some descriptive statistics of R&D offshoring both intra and extra Europe. Rather interestingly, less than one-third of R&D offshoring projects are directed towards other European countries, so the bulk of investments is actually directed to non-European countries. As already stressed in a report for the EU (Pro Inno Europe, 2007) the main non-European recipients of R&D offshoring are China and India, then the developed countries and the other South-East-Asian countries follow. Other developing countries, which include important destinations such as Brazil and Russia, attract also a considerable number of projects.

In column (6) of Table 5 we assess the effect of offshoring R&D within Europe versus non-European countries. Results suggest that offshoring R&D within Europe does not bring significantly different productivity gains than

Table 4: Descriptive statistics on R&D offshoring, 2003-2006

Variable	Mean	p50	p90	p95	p99	Max
OFF^{rd}	.549	0	1	2	12	29
$OFF^{rd\text{ - }Intra\ EU}$	.171	0	0	1	4	9
$OFF^{rd\text{ - }Extra\ EU}$	.377	0	1	2	10	20
$OFF^{rd\text{ - }Developed}$	.071	0	0	0	2	5
$OFF^{rd\text{ - }China}$	.104	0	0	1	3	6
$OFF^{rd\text{ - }India}$	.074	0	0	0	2	6
$OFF^{rd\text{ - }South\ East\ Asia}$	.047	0	0	0	2	5
$OFF^{rd\text{ - }Others}$	.079	0	0	0	2	7

offshoring R&D outside Europe: both the coefficients are similar in magnitude, but they are rather imprecisely estimated. This is not surprising, given that the number of destination countries is relatively small but rather heterogeneous in terms of the characteristics of the destination countries. When we consider R&D offshoring towards specific (and more homogeneous) areas (column 7), we find differences across destinations. The effect on productivity growth is mostly positive, including the case of China, but it is often imprecisely estimated. The effect is larger and significant in the case of R&D offshoring toward South-East-Asian countries. Conversely, regions which are offshoring R&D intensively towards India experience significantly lower productivity growth rates.

This may be related to a combination of country and sector specific characteristics. As a matter of fact, Table 6 shows that the patterns of R&D offshoring towards South-East Asia and India have quite peculiar profiles. Whereas the former is disproportionally concentrated in high-tech manufacturing (43% of all R&D projects in the area are in these industries), the latter is much more concentrated in knowledge-intensive services (52%). Mudambi and Venzin (2010) provide interesting insights for interpreting these results. Using illustrations from the mobile handset and financial services industries, they provide a novel perspective on the disintegration, mobility, and reintegration of value chain activities in a global context. One of their findings is consistent with the idea that orchestrating the value-chain in knowledge-intensive services, such as the finan-

Table 5: R&D offshoring by areas of destination and the productivity growth of EU regions

Dependent variable		$\Delta y_{ij,t}$	$\Delta y_{ij,t}$
Variable	Coefficient	(6)	(7)
		(OLS)	(OLS)
$OFF(d)_{t-1}$	γ_d	0.0063**	0.0061**
		(0.0025)	(0.0025)
$OFF(n)_{t-1}$	γ_n	-0.0002***	-0.0002***
		(0.0001)	(0.0001)
$OFF(n)_{t-1}^{rd-IntraEU}$	$\gamma_n^{rd-IntraEU}$	0.0011	0.0019
		(0.0019)	(0.0020)
$OFF(n)_{t-1}^{rd-ExtraEU}$	$\gamma_n^{rd-ExtraEU}$	0.0014	
		(0.0010)	
$OFF(n)_{t-1}^{rd-Developed}$	$\gamma_n^{rd-Developed}$		0.0022
			(0.0026)
$OFF(n)_{t-1}^{rd-China}$	$\gamma_n^{rd-China}$		0.0027
			(0.0019)
$OFF(n)_{t-1}^{rd-India}$	$\gamma_n^{rd-India}$		-0.0067***
			(0.0026)
$OFF(n)_{t-1}^{rd-SouthEastAsia}$	$\gamma_n^{rd-SouthEastAsia}$		0.0051***
			(0.0015)
$OFF(n)_{t-1}^{rd-Others}$	$\gamma_n^{rd-Others}$		0.0008
			(0.0020)
$INW(d)_{t-1}$	λ_d	-0.0055**	-0.0059**
		(0.0024)	(0.0024)
$INW(n)_{t-1}$	λ_n	0.0003***	0.0003***
		(0.0001)	(0.0001)
Δkl	β	0.2393***	0.2447***
		(0.0839)	(0.0846)
Regional controls	δ	Yes	Yes
Country dummies	η_j	Yes	Yes
Year dummies	τ_t	Yes	Yes
Log-likelihood		1711	1713
Observations		760	760
Regions		262	262

Significance levels: * 10%, ** 5%,*** 1%; cluster robust SE in parentheses
δ, η_j and τ_t estimates omitted to save space
Complete table available from authors upon request

cial industry, is more complex than in the case of the manufacturing industry (mobile handsets). This implies that offshoring and international outsourcing are less pronouced in the service industries, and when they are developed, like in the case of India, the risk of 'hollowing out', due to difficulties in orchestrating the value chain are greater (Kotabe and Mudambi, 2009). Conversely, in the case of high-tech manufacturing the organizational problems are lower, and the 'gains' of R&D offshoring may be larger than the 'pains'. The case of South-East Asia fits well in this interpretative framework: the last decade has witnessed the rapid growth of electronics firms such as Samsung and LG from South Korea, or HTC from Taiwan and virtually all multinationals have R&D centers producing cutting-edge technologies in these countries. In this respect, by offshoring R&D to South-East Asian countries European firms can tap-into these sources of advanced knowledge, which foster the introduction of new product and boost productivity growth at home.

Table 6: R&D offshoring areas of destination and sectors

	Macro areas		Non-European destinations			
Sectors	Europe	Non-European	Developed	India	China	South-East Asia
Manufacturing	**60%**	**54%**	**63%**	**45%**	**61%**	**73%**
High-tech manufacturing	33%	27%	37%	23%	20%	43%
Medium-tech manufacturing	20%	19%	18%	21%	28%	11%
Low-tech manufacturing	7%	8%	8%	1%	13%	19%
Services	**39%**	**45%**	**35%**	**53%**	**39%**	**27%**
Knowledge-intensive services	39%	44%	33%	52%	39%	24%
Less knowledge-intensive services	0%	1%	2%	1%	0%	3%
Other industries	**1%**	**1%**	**2%**	**1%**	**0%**	**0%**
Total	100%	100%	100%	100%	100%	100%
Number of investments	148	293	51	75	71	37

Before heading towards the concluding remarks, it is worth laying out a few caveats of our analysis. First, while we did our best to exclude reverse causality from productivity growth to offshoring (using lagged regressors and IV), the relatively short time series and the difficulty in finding suitable external instruments suggest caution in interpreting our results as the causal effect offshoring on the home region productivity growth. Second, our empirical analysis suggests that offshoring would affect productivity growth with one-year lag. One may argue that this is a relatively short period of time for reverse technology transfer to occur. As a matter of fact, our dependent variable is the aggregate productivity growth in the home regions, which increase both as the result of within-firm productivity dynamics (in the MNC and in other local firms), but also through firm entry and exit and reallocation effects. We believe the latter may play a role in the short run and contribute to explain our results. In the short run, R&D offshoring may have a positive impact on firms' market access, thus boosting their foreign sales and increasing their size and market share. Therefore R&D offshoring may reallocate market shares towards the more productive firms in the regions (which are more likely to be engaged in R&D offshoring), and contribute to aggregate productivity growth. Third, as it often happens with studies using a comprehensive quantitative approach, we are able to provide a much needed assessment of the statistical relationship between R&D offshoring and productivity for all NUTS 2 regions of the EU over a 4 years period, but we cannot provide precise evidence on the mechanisms underlying this relationship, which is more easily gathered through qualitative and granular studies (such as, for example, Borras and Haakonsson (2013)). Fourth, our data allow to build a fairly reliable measure greenfield investments in R&D, in the form of international investment projects aimed at the creation of some R&D facility, but we are not be able to directly assess neither whether these investments are relocation of activities nor whether firms engage in international R&D outsourcing through non-equity alliances and global networking. While the former should not be an issue, since the relocation of R&D would most likely reduce value-added in the home country, and would thus be picked-up by our dependent variable (the labor productivity of the home region)[22], the latter is of greater concerns, especially in the perspective of GINs. In particular, lacking information on offshore outsourcing we may underestimate the negative effects of international R&D if 'hollowing out' is more likely to occur through outsourcing than through 'captive' offshoring (Nieto and Rodriguez, 2011). However, as

[22]Thus, we would be more likely to find a negative effect of offshoring on productivity at home.

shown by Barnard and Chaminade (2011), while there is a non-negligible number of stand-alone companies involved in GINs, the overwhelming majority of firms are subsidiaries or headquarters of multinationals. Furthermore, internal and external networks are often complementary and inter-firm linkages are fostered by the presence of a local subsidiary which acts as a bridgehead for cooperation (Zanfei, 2000; Castellani and Zanfei, 2002). In this perspective, we believe that 'captive' R&D offshoring may be a proxy of the extent of the involvement of European regions into GINs, and our paper complementary to other more qualitative and detailed studies stressing the external networking aspects of GINs in this special issue. Finally, one may want to distinguish the different association of competence-creating vs competence-exploiting R&D offshoring projects with home productivity. As a matter of fact, our data are probably best suited to identify the former type of projects so, to the extent that these may be more conducive of positive effects for the national innovation system (as reported, for example, by Borras and Haakonsson (2013)), this may yield some overly optmistic conclusions about the effects of R&D offshoring on the home region productivity.

5. Concluding remarks

In recent years, multinational firms have increasingly resorted to offshoring of R&D activities, in order to cope with the need to integrate differentiated sources of knowledge and implement a faster and cheaper innovative process. This have raised fears of 'hollowing out' the knowledge base in the former group, but at the same time, economic research has emphasized that R&D offshoring may actually strengthen the home economies, by allowing some form of reverse technology transfer, firm growth and spillovers. This paper investigates a part of this story, focusing on 'captive' offshoring of R&D and analysing to what extent productivity growth in 262 EU regions is related with the propensity (and extent) of firms based in the regions to set up facilities abroad, with special reference to the creation of R&D labs.

Overall, this paper brings novel econometric evidence, based on a comprehensive cross-regional and longitudinal sample, on the relationship between R&D offshoring and EU regional competitiveness. In the light of both the high policy relevance of offshoring and regional competitiveness in the EU, and the lack of large sample empirical analyses, we believe this paper provides a significant contribution to the extant literature and to the policy debate. In this perspective, this work is also nicely complemented by rich and more descriptive case studies and survey-based evidence in this special issue. Furthermore, in our econometric exercise, we are able to look at the effect of outward R&D investments taking into account the extent to which each European region is also attracting multinational activity, thus overcoming another major gap in the existing literature which has mainly focused either on the outward or on the inward dimensions. Finally, combining information on the sectors and the destination countries in which EU firms offshore R&D, we able to provide a tentative interpretation of the mechanisms through which the effects on the home economies manifest.

Our results suggest that regions experience a higher productivity growth when firms based in the region initiate some offshoring activity, but this positive association fades down with the number of investment projects carried out abroad. These results are consistent with theoretical arguments suggesting that, whereas increasing use of offshoring and outsourcing allows to adapt existing products to new markets and to access new or complementary forms of knowledge, it may also determine a dilution of firm-specific resources, deterioration of integrative capabilities and the need of greater supervision by managers (Kotabe and Mudambi, 2009; Grimpe and Kaiser, 2010). However, these 'decreasing returns' to offshoring do not seem to occur in the case of R&D. In fact, our estimates suggest that one additional R&D offshoring project is associated with a significantly higher regional productivity growth the next year. This is to be expected given that offshoring of European R&D is still relatively low, so that the tipping point where the 'pains' outweigh the 'gains' may have not been reached yet.

Exploiting the information on the area of destination and the sector in which the R&D investments abroad are made, we are able to better qualify our results. In particular, offshoring is positively associated with the home region productivity grwoth, regardless of whether offshoring occurs within Europe or towards other emerging or advanced countries. This positive association is particularly strong in the case of R&D offshoring toward the South East Asian countries. The only exception is the case of R&D offshoring towards India, which is negatively associated with productivity growth in the home regions. We submit that the results for South East Asian countries and India may be explained by a combination of destination country characteristics and sectoral composition of the offshored R&D activities. As a matter of fact, one should note that while in the former case the largest share of investments concentrates in high-tech manufacturing sectors, in the latter, they are heavily concentrated into knowledge-intensive services, such as software, business, financial and bank services. As Mudambi and Venzin (2010) underline, orchestrating the value-chain in such knowledge-intensive services may be more complex than in the case of the manufacturing industry. This increases the risk of 'hollowing out' for offshoring firms (and the regions in which they are based), due to the greater difficulties in orchestrating the global value chain. On the contrary, the relatively lower organizational problems in high-tech manufacturing and the concentration of cutting edge technologies developed in South-East Asian countries, contribute to a soundly positive association of offshoring R&D in this area with the productivity growth of EU regions.

Although more research is needed to understand and separate the channels underlying the positive relation between R&D offshoring and productivity growth at home, our study sends a reassuring message to EU policymakers, since it supports the idea that carrying out R&D abroad –on average– is associated with strengthening rather than 'hollowing out' of European sources of competitiveness. In this perspective, governments should not discourage offshoring (of R&D in particular) and, to the contrary, they should implement policies that allow firms to engage in global R&D projects, gaining access to complementary assets, technologies which are not available in their home economies, as well as to qualified research staff. However, in order to leverage from R&D activities abroad, EU firms need to strenghten their managament and organizational capabilities in the area of R&D, innovation and technology. To this end, the quality of the human capital available to European firms is crucial, and efforts should be devoted both from the business side, through further investments in training, and from the public institutions, by improving the higher education systems, also fostering University-industry relationships, and providing incentives to labour mobility both within the EU and attracting skilled workers from third countries.

A. Appendix

A.1. Labor productivity

Some remarks on the labor-productivity measure should be made. First, data on the regional employment are drawn from the European Regional Database. We chose to use this source, since the employment series of the Regio database has a higher number of missing values which would have decreased the set of regions under analysis. The downside of this choice is that in the version of the European Regional Database available to us, values for 2005 and 2006 were forecast. However, we checked that correlation with the actual (non missing) values, reported by the more updated Regio dataset is very high (0.95). Second, in order to build deflators for regions belonging to Cyprus, Estonia, Latvia, Lithuania and Malta (which are actually all single-region country) we have used the series of price index in the previous release of the EU KLEMS database (2008) given that they were not available in the last release yet. Third, for Bulgarian and Romanian regions we have used the 'Eurozone' series of price index, given that the national series were not available in the database.

A.2. Offshoring

Relying on media sources and company data, *fDi Markets* collects detailed information on cross-border greenfield investments (available since 2003) . The database is used as the data source for FDI project information in UNCTAD's World Investment Report and in publications by the Economist Intelligence Unit. This source tracked 60,301 worldwide investments projects appeared on publicily available information sources in the period 2003-2008.

The correlation coefficients (0.82 and 0.83), reported in Table A.1, between the distribution of investments projects provided by *fDi Markets* and the actual distribution of FDI flows in EU countries, as reported by UNCTAD, reassures us that data on investment projects are actually a good proxy for FDI flows. As expected, almost 90% of EU outward investments are made from EU-15 countries, while inward investments are split more evenly among EU-15 and EU-12 countries: United Kingdom, Germany and France result to be the leading countries both in terms of inward and outward FDIs in the period which goes from 2003 to 2006. As for the inward investments, Poland, Romania, Hungary, Czech Republic and Bulgaria show a good performance[23].

Table A.1: fDi Markets projects vs. UNCTAD Flows, 2003-2006

	Outward			Inward	
Country	# proj.	flows	Country	# proj.	flows
Germany	22.2	11.7	United Kingdom	16.0	25.8
United Kingdom	20.3	16.3	France	9.2	15.2
France	13.8	17.6	Germany	8.3	8.1
Italy	6.3	5.7	Poland	6.5	3.0
Netherlands	5.9	13.7	Spain	6.2	7.2
Sweden	5.9	4.7	Romania	5.9	1.7
Austria	5.1	2.0	Hungary	5.4	1.4
Spain	4.6	11.7	Czech Republic	4.1	1.5
Finland	3.1	0.3	Bulgaria	4.1	1.1
Belgium	2.5	7.9	Ireland	4.1	-1.6
Denmark	1.9	1.4	Italy	3.9	5.9
Ireland	1.4	2.7	Sweden	3.2	3.4
Slovenia	1.1	0.1	Netherlands	3.1	5.1
Greece	0.9	0.4	Belgium	2.9	10.8
Latvia	0.9	0.0	Slovakia	2.6	0.8
Estonia	0.6	0.1	Lithuania	2.4	0.2
Portugal	0.5	1.2	Austria	2.2	1.9
Luxembourg	0.5	1.0	Denmark	1.9	1.2
Poland	0.5	0.7	Latvia	1.7	0.2
Czech Republic	0.5	0.1	Estonia	1.5	0.4
Hungary	0.4	0.4	Portugal	1.3	1.5
Lithuania	0.4	0.0	Greece	1.1	0.6
Cyprus	0.2	0.1	Finland	0.9	1.2
Romania	0.2	0.0	Slovenia	0.8	0.2
Slovakia	0.1	0.0	Luxembourg	0.4	2.7
Bulgaria	0.1	0.0	Cyprus	0.3	0.3
Malta	0	0.0	Malta	0.2	0.2
Total	100	100		100	100
Pearson corr. coefficient	0.82			0.83	

Unfortunately, official statistics on inward and outward investments at the regional level are not available, so we cannot benchmark *fDi Markets* data as

[23] A careful inspection reveals that the number of projects overestimates inward FDIs to some New Member States, such as Poland, Romania, Bulgaria, Hungary and Czech Republic, probably due to the fact that these countries received a large number of relatively small-scale investments projects.

this finer geographical level. However, a casual inspection based on Figure 3 highlight some expected patterns. In particular, they appear highly concentrated in a limited number of clustered regions within each country, including the regions around the major cities.

A.3. Capital-labor ratio

We have included the capital-labor ratio (KL_{ijt}) in our regressions, in order to control for the regional factor share. The variable has been computed as the ratio of the regional capital stock (K_{ijt}) to employment (thousands) in the region (L_{ijt}). The capital stock at the regional level, has been obtained applying the perpetual inventory method (PIM) to the series of capital investments in the region (at 1995 prices in millions of euro)[24] taken from the European Regional Database. As for the employment series, capital investments' information for 2005 and 2006 are forecast.

We followed Hall and Mairesse (1995), and the capital stock at the beginning of the first year has been defined as below:

$$K_{ij,t=1} = \frac{I_{ij,t=1}}{g_{ij} + \delta}, \tag{5}$$

where $I_{ij,t=1}$ is the amount of capital investments taken by the region i in the first year of the series[25], g_{ij} is the rate of growth of capital investments observed in the region in a given span of time (in this case is from 1995-2002[26]), and δ is depreciation rate which has been set equal to 7.5%[27]. Capital stock from the second year onward has been computed using the following formula:

$$K_{ij,t} = (1 - \delta) \cdot K_{ij,t-1} + I_{ij,t}. \tag{6}$$

The variable has been included in logs in the econometric analysis, kl_{ijt}.

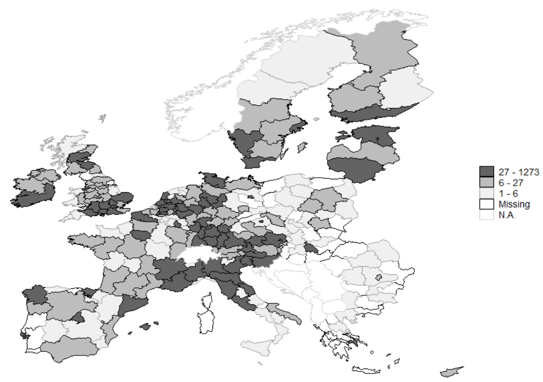
[24] The series comprehend aggregate investments by the following sectors: agriculture, total energy and manufacturing, construction, market and non-market services.

[25] We start computing the capital stock series at 1995 up to 2006, even if in the econometric analysis we use the values from 2002 to 2006. The main motivation relates to the possibility to rest on a more reliable capital stock at the left hand side of Equation 6 for the years under analysis.

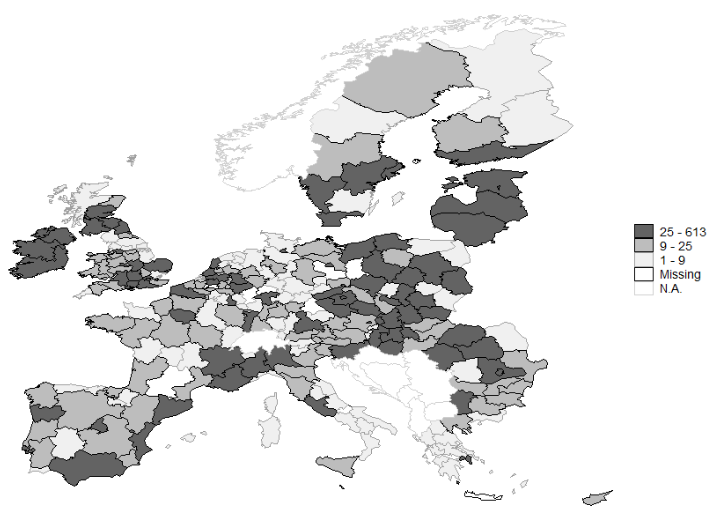
[26] For Romanian regions the investments' growth rate has been computed for the period 1998-2002, given the lack of data for the years 1995, 1996 and 1997.

[27] As robustness checks we also computed the capital stock assuming depreciation rate of 5% and 10%, and we did not register significantly different results.

Figure 3: Regional distribution of offshoring projects, 2003-2006



(a) Total number of offshoring projects



(b) Inward investments

A.4. Other regional characteristics

In this Section, we detail how regional characteristics — i.e. the level of human capital, the technological capital and the regional industrial mix — have been measured.

- Human capital ($HCAP_{ijt}$) has been proxied by the (log of the) share of population aged 25 or more (thousands) with tertiary-type education degree (ISCED 5-6) in each region. Information come from the EU Regional Database, maintained by Eurostat.

- The regional technological capital ($TECH_{ijt}$) has been proxied by the ratio of the stock of patents applications ($INNOV_{ijt}$) to the total population (thousands) in the region (POP_{ijt}). The stock has been recovered using information on the number of patent applications to the European Patent Office (EPO) coming from each European region, which are available in the database maintained by Eurostat[28]. Data on total population comes from the database developed by Cambridge Econometrics. The stock for the years t = (2003,2004,2005,2006) has been computed as the sum of the patent applications in all sectors in the previous five years ($PATAPP_{ijt}$):

$$INNOV_{ij,t} = \sum_{t=t-5}^{t} PATAPP_{ijt}. \tag{7}$$

  The ratio has been included in logs in the econometric analysis, $tech_{ijt}$.

- We have taken into account the regional industrial mix (SH_{s*ijt}), by introducing the share of employment in six broad sectors s^* of the regional economy: Agriculture, hunting, forestry and fishing (AC), Electricity, gas, water supply and Constructions (EF), High-tech manufacturing & Medium high-tech manufacturing (HD), Medium low-tech manufacturing & Low-tech Manufacturing (LD), Knowledge-intensive services (KI) and

[28]Data on patent applications are regionalised on the basis of the investors' residence: in the case of multiple investors proportional quotas have been attributed to each region.

Less knowledge-intensive (LKI) services. Each share has been computed in the following way:

$$SH_{s*ijt} = \frac{L_{s*ijt}}{L_{ijt}}$$

where L_{ijt} and L_{s*ijt} denote, respectively, total employment in the region i which belongs to country j (thousands), and employees belonging to the sector $s*$. To avoid multicollinearity we introduced five coefficients in the regressions. The excluded sectoral share is the AC sector (Agriculture, hunting, forestry, fishing, mining and quarrying). Data regarding employees in each sector come from the database maintained by Eurostat.

Data on employment by sectors are missing for a number of (region/year) observations; in order not to loose those observations, we have used linear interpolation to fill the gaps for all the observations that were 'missing', but which had 'non-missing' observations the year before and the year after the missing ones. We further filled in a small amount of missing observations in the High-tech manufacturing sector (which showed the highest number of missing observations) as the difference between total regional employment and the sum of employees in all the others sectors (AC, EF, Medium-high tech manufacturing, Medium-low tech manufacturing, Low-tech manufacturing, KI, LKI).

- We have controlled for the degree of concentration/diversification of the regional industrial mix. Following the literature (see Cingano and Schivardi, 2004; Bracalente and Perugini, 2008, among others), we have used the Herfindahl-Hirschman index as a proxy for concentration/diversification computed as follows:

$$HHI_{ijt} = \sum_s SH^2_{sijt} = \sum_s \left(\frac{L_{sijt}}{L_{ijt}}\right)^2, \qquad (8)$$

where SH_{sijt} are a more detailed disaggregation of the employment shares defined above. In fact, as elements of the HHI we take into account 8 broad sectors, s: Agriculture, hunting, forestry and fishing (AC), Electricity, gas, water supply and Constructions (EF), High-tech manufacturing (HTD), Medium high-tech manufacturing(MHTD), Medium low-tech manufacturing (MLTD), Low-tech Manufacturing (LTD), Knowledge-intensive services (KI) and Less knowledge-intensive (LKI) services. In particular, we consider the HTD and the MHTD as two separate sectors here, and the same holds for the LTD and the MLTD which are considered separate elements of the HHI[29]. The HHI index, which is equal to '1' for regions with all employees in one sector and which goes toward '0' for more diversified regional structures, allows us to control for the sectoral concentration/variety of the region, while by introducing the $SH_{s^{*}it}$ ratios, we account for the different 'quality' of the industrial mix. For any given level of HHI we expect regional productivity to be higher in regions where the share of high-value added activities (such as High-tech Manufacturing and Knowledge-intensive services) is higher[30].

The HHI enters in logs in the econometric analysis, hhi.

The taxonomy of broad sectors —which have been used in order to build the Herfindahl index of diversification and the shares of employment which proxy the regional industrial mix— has been taken from the list which has been proposed by Eurostat in the EU regional database. We cross-refer the reader to the technical repost by Felix (2006) for further details on the employed taxonomy. Sectors are presented in Table A.3.

A.5. List of regions

The list of the NUTS 2 regions which have been considered in the baseline Specification (2) is reported in Table A.4. Overall, we can account for 262 regions (and 760 observations) belonging to the EU in our analysis, for the

[29]The detailed taxonomy of sectors s is presented in Table A.3 of the Data Appendix.

[30]The use of different levels of aggregation in the HHI with respect to these employments shares is motivated both by the achieved greater precision of the Herfindahl-Hirschman index, which aims at capturing the variability in the regional industrial mix, and –on the contrary– by the attempt to minimize over-specification in the estimates of the coefficients of the sectoral employment shares.

Table A.2: Descriptive statistics, 2003-2006

Variable	Notation	Unit	Obs.	Mean	Std. Dev	p10	p25	p50	p75	p90
Labor productivity	y	ratio (log)	1017	3.360	0.751	1.956	3.202	3.651	3.856	3.948
Capital-labor ratio	kl	ratio (log)	1036	4.148	0.863	2.714	3.949	4.387	4.753	4.923
Human capital	$hcap$	ratio (log)	1010	-1.468	0.378	-2.040	-1.728	-1.403	-1.189	-1.035
Herfindahl index	hhi	formula (log)	922	-1.377	0.177	-1.602	-1.514	-1.391	-1.246	-1.144
Innovation stock	$tech$	formula (log)	1036	-0.992	1.859	-3.721	-2.360	-0.416	0.397	0.982
Share of other industies	SH_EF	share	922	0.089	0.023	0.062	0.072	0.084	0.101	0.119
Share of High-tech man.	SH_HT	share	922	0.066	0.035	0.028	0.043	0.060	0.084	0.112
Share of Low-tech man.	SH_LT	share	922	0.125	0.046	0.068	0.088	0.122	0.153	0.191
Share of KI svcs	SH_KIS	share	922	0.316	0.088	0.212	0.254	0.309	0.379	0.431
Share of LKI svcs	SH_LKIS	share	922	0.336	0.047	0.280	0.312	0.338	0.364	0.392
Labor productivity-growth rate	$\Delta_{(t,t-1)}y$	ratio (log, differences)	1017	0.020	0.044	-0.017	0.003	0.017	0.034	0.059
Capital-labor ratio-growth rate	$\Delta_{(t,t-1)}k$	ratio (log, differences)	1036	0.022	0.026	-0.003	0.007	0.018	0.032	0.053
Human capital-growth rate	$\Delta_{(t,t-1)}hcap$	ratio (log, differences)	1002	0.039	0.072	-0.037	-0.002	0.036	0.074	0.119
Herfindahl index-growth rate	$\Delta_{(t,t-1)}hhi$	formula (log, differences)	891	0.009	0.035	-0.033	-0.009	0.008	0.028	0.048
Innovation stock-growth rate	$\Delta_{(t,t-1)}tech$	formula (log, differences)	1036	0.047	0.156	-0.079	-0.018	0.033	0.081	0.174
Share of other industries-growth rate	$\Delta_{(t,t-1)}$ SH_EF	share (differences)	891	0	0.009	-0.010	-0.004	0.001	0.006	0.012
Share of High-tech man.-growth rate	$\Delta_{(t,t-1)}$ SH_HT	share (differences)	891	0	0.009	-0.011	-0.006	-0.001	0.004	0.009
Share of Low-tech man.-growth rate	$\Delta_{(t,t-1)}$ SH_LT	share (differences)	891	0	0.011	-0.016	-0.009	-0.002	0.003	0.009
Share of KI svcs.-growth rate	$\Delta_{(t,t-1)}$ SH_KI	share (differences)	891	0	0.015	-0.012	-0.003	0.004	0.013	0.022
Share of LKI svcs.-growth rate	$\Delta_{(t,t-1)}$ SH_LKIS	share (differences)	891	0	0.016	-0.017	-0.009	0.002	0.010	0.020

Table A.3: Breakdown of sectors (Nace Rev. 1.1 codes)

Agriculture, hunting, forestry and fishing	01 to 05 Agriculture, hunting, forestry and fishing
Electricity, gas, water supply and constructions	40 to 41; 45 Electricity, gas, water supply and constructions
High-tech Manufacturing	30 Manufacture of office machinery and computers 32 Manufacture of radio, television and communication equipment and apparatus 33 Manufacture of medical, precision and optical instruments, watches and clocks
Medium High-tech Manufacturing	24 Manufacture of chemicals and chemicals products 29 Manufacture of machinery and equipment n.e.c. 31 Manufacture of electrical machinery and apparatus n.e.c. 34 and 35 Manufacture of transport equipment
Low and medium-low-tech Manufacturing	15 to 22 Manufacture of food products, beverages and tobacco; textiles and textile products; leather and leather products; wood and wood products; pulp, paper and paper products,publishing and printings 23 Manufacture of coke, refined petroleum products and nuclear fuel 25 to 28 Manufacture of rubber and plastic products; basic metals and fabricated metals product; other non-metallic mineral products 36 to 37 Manufacturing n.e.c.
Knowledge-intensive services	61 Water Transport 62 Air Transport 64 Post and telecommunications 65 to 67 Financial intermediation 70 to 74 Real estate, renting and business activities 80 Education 85 Health and social work 92 Recreational, cultural and sporting activities
Less knowledge-intensive services	50 to 52 Motor trade 55 Hotels and restaurants 60 Land transport ; transport via pipelines 63 Supporting and auxiliary transport activities; activities of travel agencies 75 Public administration and defence; compulsory social security 90 Sewage and refuse disposal, sanitation and similar activities 91 Activities of membership organization n.e.c. 93 Other service activities 95 Activities of households as employers of domestic staff 99 Extra-territorial organizations and bodies

period 2003-2006.

Table A.4: List of the regions considered in the present study, by country

NUTS	Name	# regions	NUTS	Name	# regions	NUTS	Name	# regions	NUTS	Name	# regions
Austria		9	**Germany**		39	ITD3	Veneto		ES41	Castilla y Len	
AT11	Burgenland		DE11	Stuttgart		ITD4	Friuli-Venezia Giulia		ES42	Castilla-la Mancha	
AT12	Niedersterreich		DE12	Karlsruhe		ITD5	Emilia-Romagna		ES43	Extremadura	
AT13	Wien		DE13	Freiburg		ITE1	Toscana		ES51	Catalua	
AT21	Krnten		DE14	Tbingen		ITE2	Umbria		ES52	Comunidad Valenciana	
AT22	Steiermark		DE21	Oberbayern		ITE3	Marche		ES53	Illes Balears	
AT31	Obersterreich		DE22	Niederbayern		ITE4	Lazio		ES61	Andalucia	
AT32	Salzburg		DE23	Oberpfalz		ITF1	Abruzzo		ES62	Regin de Murcia	
AT33	Tirol		DE24	Oberfranken		ITF2	Molise		ES70	Canarias (ES)	
AT34	Vorarlberg		DE25	Mittelfranken		ITF3	Campania		**Sweden**		8
Belgium		11	DE26	Unterfranken		ITF4	Puglia		SE11	Stockholm	
BE10	Brussels		DE27	Schwaben		ITF5	Basilicata		SE12	stra Mellansverige	
BE21	Prov. Antwerpen		DE30	Berlin		ITF6	Calabria		SE21	Smland med arna	
BE22	Prov. Limburg (B)		DE41	Brandenburg-Nordost		ITG1	Sicilia		SE22	Sydsverige	
BE23	Prov. Oost-Vlaanderen		DE42	Brandenburg-Sdwest		ITG2	Sardegna		SE23	Vstsverige	
BE24	Prov. Vlaams Brabant		DE50	Bremen		**Latvia**		1	SE31	Norra Mellansverige	
BE25	Prov. West-Vlaanderen		DE60	Hamburg		LV00	Latvia		SE32	Mellersta Norrland	
BE31	Prov. Brabant Wallon		DE71	Darmstadt		**Lithuania**		1	SE33	vre Norrland	
BE32	Prov. Hainaut		DE72	Gieen		LT00	Lithuania		**United Kingdom**		36
BE33	Prov. Lige		DE73	Kassel		**Luxembourg**		1	UKC1	Tees Valley and Durham	
BE34	Prov. Luxembourg (B)		DE80	Mecklenburg-Vorpommern		LU00	Luxembourg		UKC2	Northumberland, Tyne and Wear	
BE35	Prov. Namur		DE91	Braunschweig		**Malta**		1	UKD1	Cumbria	
Bulgaria		6	DE92	Hannover		MT00	Malta		UKD2	Cheshire	
BG31	Severozapaden		DE93	Lneburg		**Poland**		16	UKD3	Greater	
BG32	Severen tsentralen		DE94	Weser-Ems		PL11	Ldzkie		UKD4	Lancashire	
BG33	Severoiztochen		DEA1	Dsseldorf		PL12	Mazowieckie		UKD5	Merseyside	
BG34	Yugoiztochen		DEA2	Kln		PL21	Malopolskie		UKE1	East Riding and North Lincolnshire	
BG41	Yugozapaden		DEA3	Mnster		PL22	Slaskie		UKE2	North Yorkshire	
BG42	Yuzhen tsentralen		DEA4	Detmold		PL31	Lubelskie		UKE3	South Yorkshire	
Cyprus		1	DEA5	Arnsberg		PL32	Podkarpackie		UKE4	West Yorkshire	
CY00	Cyprus		DEB1	Koblenz		PL33	Swietokrzyskie		UKF1	Derbyshire and Nottinghamshire	
Czech Republic		8	DEB2	Trier		PL34	Podlaskie		UKF2	Leicestershire, Rutland and Northants	
CZ01	Praha		DEB3	Rheinhessen-Pfalz		PL41	Wielkopolskie		UKF3	Lincolnshire	
CZ02	Stredn Cechy		DEC0	Saarland		PL42	Zachodniopomorskie		UKG1	Herefordshire, Worcestershire and Warks	
CZ03	Jihozpad		DED1	Chemnitz		PL43	Lubuskie		UKG2	Shropshire and Staffordshire	
CZ04	Severozpad		DED2	Dresden		PL51	Dolnoslaskie		UKG3	West Midlands	
CZ05	Severovchod		DED3	Leipzig		PL52	Opolskie		UKH1	East Anglia	
CZ06	Jihovchod		DEE0	Sachsen-Anhalt		PL61	Kujawsko-Pomorskie		UKH2	Bedfordshire, Hertfordshire	
CZ07	Stredn Morava		DEF0	Schleswig-Holstein		PL62	Warminsko-Mazurskie		UKH3	Essex	
CZ08	Moravskoslezko		DEG0	Thringen		PL63	Pomorskie		UKI	London	
Estonia		1	**Greece**		12	**Portugal**		5	UKJ1	Berkshire, Bucks and Oxfordshire	
EE00	Estonia		GR11	Anatoliki Makedonia, Thraki		PT11	Norte		UKJ2	Surrey, East and West Sussex	
Finland		5	GR12	Kentriki Makedonia		PT15	Algarve		UKJ3	Hampshire and Isle of Wight	
FI13	It-Suomi		GR13	Dytiki Makedonia		PT16	Centro (PT)		UKJ4	Kent	
FI18	Etel-Suomi		GR14	Thessalia		PT17	Lisboa		UKK1	Gloucestershire, Wiltshire and North Somerset	
FI19	Lnsi-Suomi		GR21	Ipeiros		PT18	Alentejo		UKK2	Dorset and Somerset	
FI1A	Pohjois-Suomi		GR22	Ionia Nisia		**Romania**		8	UKK3	Cornwall and Isles of Scilly	
FI20	land		GR23	Dytiki Makedonia		RO11	Nord-Vest		UKK4	Devon	
France		22	GR24	Sterea Ellada		RO12	Centru		UKL1	West Wales and The Valleys	
FR10	le de France		GR25	Peloponnisos		RO21	Nord-Est		UKL2	East Wales	
FR21	Champagne-Ardenne		GR30	Attiki		RO22	Sud-Est		UKM2	Eastern Scotland	
FR22	Picardie		GR42	Notio Aigaio		RO31	Sud		UKM3	South Western Scotland	
FR23	Haute-Normandie		GR43	Kriti		RO32	Bucuresti		UKM5	North Eastern Scotland	
FR24	Centre		**Hungary**		7	RO41	Sud-Vest		UKM6	Highlands and Islands	
FR25	Basse-Normandie		HU10	Kzp-Magyarorszg		RO42	Vest		UKN0	Northern Ireland	
FR26	Bourgogne		HU21	Kzp-Dunntl		**Slovakia**		4	**Netherlands**		12
FR30	Nord-Pas-de-Calais		HU22	Nyugat-Dunntl		SK01	Bratislavsk		NL11	Groningen	
FR41	Lorraine		HU23	Dl-Dunntl		SK02	Zpadn Slovensko		NL12	Friesland(NL)	
FR42	Alsace		HU31	szak-Magyarorszg		SK03	Stredn Slovensko		NL13	Drenthe	
FR43	Franche-Comt		HU32	szak-Alfld		SK04	Vchodn Slovensko		NL21	Overijssel	
FR51	Pays de la Loire		HU33	Dl-Alfld		**Slovenia**		1	NL22	Gelderland	
FR52	Bretagne		**Ireland**		2	SI0	Slovenia		NL23	Flevoland	
FR53	Poitou-Charentes		IE01	Border, Midlands and Western		**Spain**		17	NL31	Utrecht	
FR61	Aquitaine		IE02	Southern and Eastern		ES11	Galicia		NL32	Noord-Holland	
FR62	Midi-Pyrnes		**Italy**		21	ES12	Principado de Asturias		NL33	Zuid-Holland	
FR63	Limousin		ITC1	Piemonte		ES13	Cantabria		NL34	Zeeland	
FR71	Rhne-Alpes		ITC2	Valle d'Aosta/Valle d'Aoste		ES21	Pais Vasco		NL41	Noord-Brabant	
FR72	Auvergne		ITC3	Liguria		ES22	Comunidad Foral de Navarra		NL42	Limburg(NL)	
FR81	Languedoc-Roussillon		ITC4	Lombardia		ES23	La Rioja				
FR82	Provence-Alpes-Cte d'Azur		ITD1	Provincia Autonoma Bolzano-Bozen		ES24	Aragn				
FR83	Corse		ITD2	Provincia Autonoma Trento		ES30	Comunidad de Madrid		**Total**		

Acknowledgments

The authors wish thank two anonymous referees, as well the Guest Editors of this Special Issue and the Associate Editor (Martin Bell) for their useful remarks. Comments from Carlo Altomonte, Antonio Alvarez, Gianfranco Di Vaio, Florian Mayneris, Bruno Merlevede, Cristiano Perugini, Alessandro Sembenelli, Hylke Vandenbussche, Francesco Venturini and the participants at the conferences and seminars in Rome (November 2009), Oviedo (December 2009), CORE-Louvain (May 2010), Catania (September 2010), Tubingen (November 2010), Madrid (December 2010) are also greatly appreciated. Financial support from the European Community's Seventh Framework Programme (Project INGINEUS, Grant Agreement No.225368, www.ingineus.eu) is greatly acknowledged. Fabio Pieri acknowledges the financial support of the Spanish Ministry of Science and Innovation (project ECO 2011-27619/ECON). This work is dedicated to the memory of Jo Lorentzen.

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