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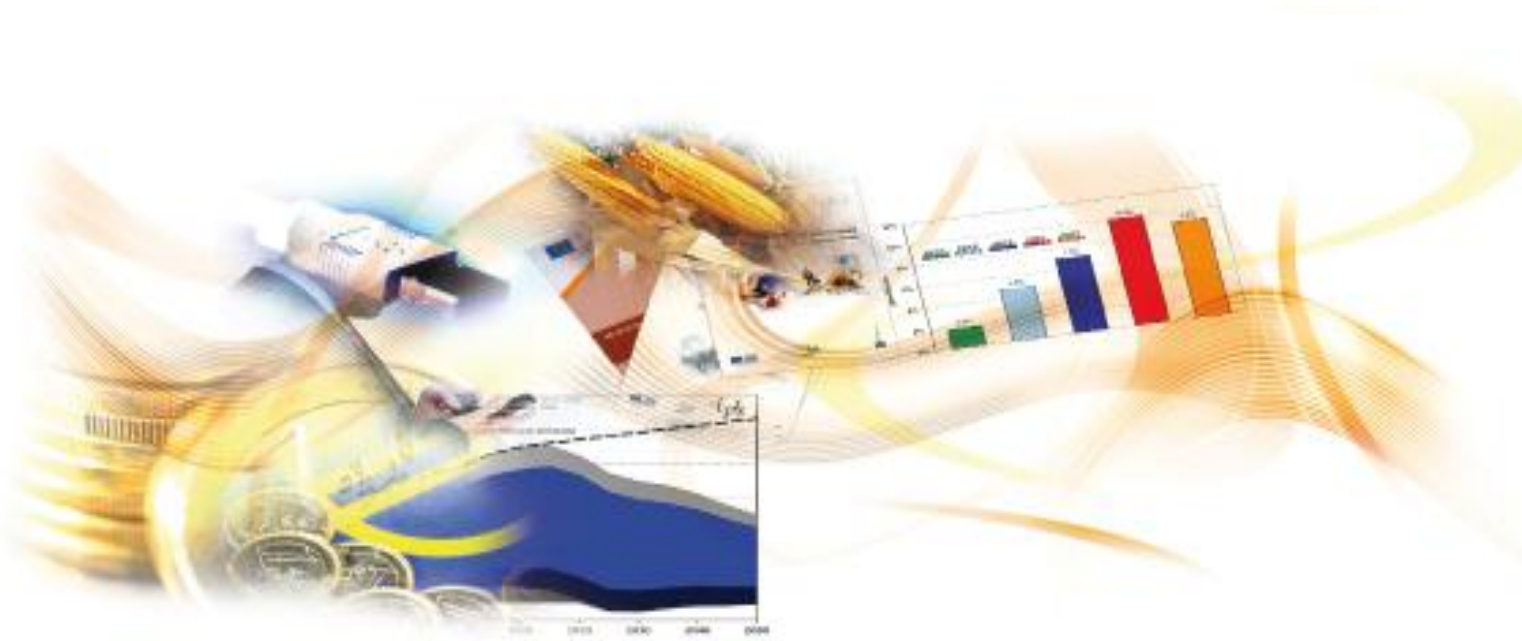

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Multinationality, R&D and Productivity Evidence from the top R&D investors worldwide

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Abstract

The paper investigates the impact that the multinational scope of firms' activities can have on their productivity. First, we argue that such an impact is both direct and indirect, and that the latter is channelled through higher incentives to invest in R&D. Second, we posit that the composition of these direct and indirect effects is different if multinationality is measured at the intensive margin (higher share of multinational on total activities) rather than at the extensive margin (greater geographical dispersion of multinational activities). Using a large sample of top R&D investors in the world, we propose an econometric model based on an R&D and a productivity equation, which are both allowed to depend on multinationality. With this model we can disentangle the direct and indirect effects of multinationality on productivity appropriately. We find: i) a positive direct impact of multinational intensity on productivity, while the geographical dispersion of multinationality is negatively correlated with productivity; ii) multinationality (along both dimensions) has a positive indirect impact through higher investments in R&D; iii) this positive indirect effect is however not large enough to compensate the negative direct one at the extensive margin. Results are largely consistent with a theoretical approach that combines transaction cost theory with an economic analysis of how incentives to invest in R&D depend on multinationality.

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Keywords: Multinationality; R&D; Productivity; Europe

JEL codes: F23; F61; O32.

1. Introduction

The relationship between multinationality and performance (M-P) is one of the most investigated topics in the field of international business (IB). There is a variety of reasons to believe that the former exerts a positive impact on the latter, spanning from efficiency gains resulting from diverse production locations and larger market access up to differentiation and learning advantages from serving an array of international markets.

However, a consensus on the impact of multinationality on performance has not yet emerged. This is because several authors have argued that the advantages of multinationality are counterbalanced by its disadvantages, typically represented by the higher transaction costs and more complex organisational structures that arise from operating on a multinational scale. As a consequence, studies of the M-P relationship yield mixed empirical results.

A recent review of the literature by Yang and Driffield (2012) highlights the fact that some studies have found a U-shaped relationship, while others have found an inverted U-shaped relationship, or even a cubic (or higher order) relationship between M and P. The inconclusiveness of this class of models arises from an as yet incomplete and/or inaccurate analysis of the 'contingency factors' that underpin the functioning of the M-P relationship. Given that one of the major alleged advantages of multinationality is the access to new knowledge, the focus of most attention has been the R&D activity of multinational enterprises (MNEs), as a positive moderator of the expected impact of M on P (Bausch and Krist, 2007). However, while treating R&D as a moderating variable providing additional clarity on the complexities of the M-P relationship, the results are far from unambiguous.

All in all, in spite of the progressive refinement of the approaches developed to deal with the M-P relationship, some additional aspects might not yet be sufficiently well addressed, and analysing them could help to shed new light on the M-P relationship. In particular, we highlight three areas of concern. The first is the question of *how performance is measured*. The second relates to a potential *lack of differentiation between the channels* through which multinationality can affect performance. The third is that there might be a *difference between the intensive margin of multinationality* (the size of the share of international activities) *and the extensive margin* (the extent to which multinational activities are geographically dispersed). All of these aspects have received insufficient attention in the empirical literature so far.

Concerning the measurement of performance, we submit that focusing on company profits, as most IB studies so far have done, may be problematic, especially when one wants to highlight the crucial role of R&D in the M-P relationship. As the accounting literature has shown (e.g. Chan et al., 2001; Guo et al., 2006; Xu et al., 2007), the impact of R&D on profitability is 'confounded' by the effect of the former on the current and future market value of the investing firms, as well as by the strategic use that firms make of their 'reported' R&D. Furthermore, investing in R&D may increase labour costs (as researchers may have relatively higher wages) and thus negatively affect profits, while having a positive effect on a firm's knowledge accumulation and long-term competitiveness. Following the research onto innovation and international economics, we therefore focus rather on productivity as a measure of performance, which is much closer to technological capabilities but has not been frequently used in IB. Thus, we propose a more direct account of the performance benefits

that firms can achieve by investing in R&D and increasing their degree of multinationality.

As to the second concern, that of the lack of differentiation between the channels through which multinationality exerts its impact on performance, it should be carefully considered that the M-P relationship is complex and involves market-related (e.g. access to larger markets or new clients), cost-related and learning-related mechanisms. Part of the confusion in assessing the impact of multinationality on performance might stem from generalisations that are too simplistic, which implicitly lump these mechanisms together. In order to avoid this confounding of effects, and in particular to allow learning-related mechanisms to emerge more clearly, we posit that the impact of multinationality on productivity should be divided into a direct effect, accounting for its impacts on market size, closeness to international end-users and regulation issues or costs, and an indirect effect, channelled through the impact of multinationality on the incentives to invest in R&D activities. In terms of results, we expect that this approach could help to reduce the ambiguity affecting the M-P relationship or, at least, to identify its causes.

With respect to the third aspect, as Contractor et al. (2010) put it, multinationality can be split into two separate dimensions, both of which involve decision making. The first relates to the intensity of multinationality (*how much*), while the second relates to where to locate the disintegrated tasks geographically (*where and how dispersed*). While these two dimensions of multinationality are well known in the literature, their different roles in affecting productivity have not yet been fully recognised. In order to consider both types of decisions, in the following econometric analysis, we first estimate separate regressions for the two indicators of multinationality (intensity and extension) and then plug them jointly into our model. We expect that the direct and indirect effects we have discussed above could be set at work differently by the different experiences that firms can have by internationalising at the extensive (variety experience) and intensive (internationalisation experience) margin.

These three aspects make the analysis of the M-P relationship considerably more complex. Rather than a more sophisticated functional form (e.g. non-linear and with moderating factors), this analysis requires a novel econometric strategy to be carried out consistently. In this paper, we claim that an appropriate choice in this respect is represented by a seemingly unrelated regression (SUR) including separate (though interlinked) productivity and R&D regressions. The direct effect is captured by the inclusion of the multinationality indicators in the productivity equation, while, in contrast, the indirect effect is retained by modelling R&D as a function of multinationality and by allowing productivity to be influenced by R&D in turn. We argue that this two-equation approach models the interdependencies among multinationality, productivity and R&D much more accurately than the more conventional moderating factors approach.

This econometric strategy is applied to a sample of more than 2000 companies, resulting from the combination of two data sources. First, we retrieve R&D investments and other economic and financial data at the company level from the EU Industrial R&D Investment (IRI) Scoreboard (http://iri.jrc.ec.europa.eu/), mapping the top R&D investors worldwide. Second, we build the subsidiaries structure of these companies, as provided by the Ownership Database of Bureau van Dijk (ORBIS), in order to obtain measures of both the intensity and the geographical spread of the companies' multinationality. This original focus on the top R&D investors allows us to deal with companies that are almost all multinationals and

looking at the productivity gains of different degrees of multinationality, rather than at the productivity impact of multinationality *per se*. Moreover, we are able refer to companies for which internationalisation of R&D is an integral part of their business and corporate strategy.

Our results indicate that the intensity of multinationality has a direct impact on productivity, providing that the geographical spread of multinational activities is controlled for. Once the effects of the geographical spread have been netted out, a more consolidated history of internationalisation could allow *per se* a firm's more committed and efficient involvement in host markets. At the extensive margin, in contrast, the direct impact is even negative and points to possible coordination costs in accessing and establishing relationships with geographically dispersed and socio-culturally different markets. In both respects, multinationality is positively correlated with investments in R&D. As R&D intensity is positively associated with productivity, we uncover a positive indirect effect of multinationality on performance. The correlation between multinationality and R&D is greater along the extensive margin: MNEs with a network of subsidiaries in many countries have higher R&D intensity. However, this indirect effect is not large enough to compensate for the negative direct effect.

The rest of the paper is structured as follows: in Section 2 we put the research question at stake into the relevant theoretical context; in Section 3 we illustrate the dataset and econometric strategy of the empirical application; in Section 4 we present and discuss its results; and in Section 5 we sum up and draw conclusions.

2. Theoretical background

Operating on a worldwide scale through a network of subsidiaries – in brief, *multinationality* – can boost firms' productivity through different mechanisms. We will highlight both direct and indirect mechanisms operating at both the intensive and the extensive margins of multinationality.

2.1 The direct effects of multinationality on productivity

Multinationality can exert a *direct impact* on the inner elements of a firm's productivity, which pertain to aspects of organisation, market strategy, closeness to international end-users and regulations, and which can improve the efficiency with which MNEs turn their production inputs into economic output. However, in this section we argue that this impact may differ according to the pattern of multinational activity. Indeed, multinationality is in fact a manifold process, which can provide firms with advantages at both the intensive and the extensive margins (Mayer and Ottaviano, 2007; Hillberry and Hummels, 2008; Bombarda, 2013).

In particular, by extending their network of subsidiaries abroad, MNEs can gain two different forms of internationalisation experience (Castellani and Zanfei, 2004), whose impact on productivity and R&D, and on their combination, is arguably different. The first one is related to the *intensity* of a firm's multinational activity, irrespective of its geographical dispersion and/or country-specific concentration, and can be measured by the

share of its total activities accounted for by its international subsidiaries. This intensity increases the firm's knowledge of the characteristics of foreign markets in general - including their demand and institutional and technological characteristics - as well as its ability to deal with foreign markets, for example through dedicated administrative procedures and organisational bodies/divisions. Accordingly, the greater this intensity, the more likely it is that the focal firm has developed a long history of relations with its international partners, which makes it less opportunistically inclined and more willing to commit resources and capabilities to those partners.[1] The hypothesis of higher commitment is consistent with some empirical evidence showing that higher multinational intensity increases the probability of resorting to ownership-based international relationships (e.g. mergers and acquisitions), rather than more flexible and collaborative modes of governance (e.g. joint ventures and strategic alliances) (Castellani and Zanfei, 2004). Both of these aspects suggest that a more intensive multinational presence could be associated with greater engagement in irreversible and relatively specific investments, whose productivity impact outweighs the costs that a more intense degree of multinationality also involves, making the expected direct impact positive.

The direct productivity impact of multinationality is arguably different when, *ceteris paribus*, i.e. for a certain level of intensity, MNEs extend their network in a larger number of countries. The reference here is to the potential advantages and disadvantages of the geographic dispersion of a firm's multinationality and is usually measured in terms of the number of countries a MNE reaches with its activities. A greater geographical dispersion yields a 'variety' experience (Castellani and Zanfei, 2004), amounting to the firm's capacity for exploring and selecting among a wide range of markets and for shifting across them in search of new and diverse business opportunities. An extensive multinational presence offers MNEs the potential to access a variety of (especially tacit) knowledge sources and technological opportunities, which can be leveraged for the introduction of new (or improved) products, as well as process and organisational innovations, which in turn boost firms' productivity.[2] However, such positive effects of the variety experience are accompanied by other effects, which could make its direct productivity impact lower than that of a more intense multinationality. First, and for reasons in line with those illustrated above, the variety experience can be expected to increase less committed international behaviours in terms of resources and capabilities dedicated to individual foreign markets. Once again, this is confirmed by the greater resort to the flexible and reversible forms of international governance (e.g. strategic alliances) found at higher levels of multinationality of this kind (Castellani and Zanfei, 2004), suggesting that specific and irreversible investments with a high productivity impact could be lower. Second, for a given intensity of multinationality, a more extensive internationalisation strategy is accompanied by significant additional layers of complexity that could hamper productivity. In particular, it could lead to: (i) agency-related costs, as coordination or monitoring becomes less effective with more

[1] This is consistent with a view of the internationalisation process as a cumulative commitment towards operations in a foreign market (Johanson and Vahlne, 1977). It is worth mentioning that recent contributions have highlighted that such commitment does not need to increase in a deterministic way, as MNEs may reduce their commitment when performance and prospects are not sufficiently promising (Johanson and Vahlne, 2009; Meyer and Santangelo, 2011). In the context of this paper, we contend that higher multinational intensity is consistent with a long history of internationalisation and thus with a sequence of positive learning from foreign markets.

[2] See, among others, Cantwell and Mudambi (2005), Narula and Zanfei (2005), Castellani and Zanfei (2006) and Cantwell and Santangelo (2009).

geographically dispersed units; (ii) social/cultural/institutional costs, in terms of adaptation to a larger number of cultures and; (iii) institutional set-ups - organisational costs - attributable to an increased degree of organisational complexity (e.g. the need to create 'interfaces' for organising MNEs' operational interdependencies) (see Bartlett and Ghoshal, 1998; Medcof, 2001; Zaheer, 2002; Ethiraj and Levinthal, 2004; Miller, 2004; Baier et al., 2015).

The previous arguments lead us to put forward our first two research hypotheses with respect to the direct productivity impact of multinationality:

Hp1: *For a given multinational extension, a greater intensity of multinational activities has a positive direct impact on productivity.*

Hp2: *Because of the additional costs associated with multinational extension, the direct impact on productivity is greater for a more intense than for a more extended kind of multinationality.*

2.2 The indirect effects of multinationality on productivity

Apart from the direct effects discussed above, we submit that multinationality affects productivity indirectly, via a greater incentive to invest in R&D. On the one hand, it is relatively undisputed that R&D investments can boost firms' productivity, although there is no consensus on the magnitude of this effect.[3] On the other hand, several works have claimed that multinationality increases firms' incentives and opportunities to invest in R&D through a number of mechanisms related to the different facets of multinationality (Petit and Sanna Randaccio, 1998; Markusen, 2004; Barba Navaretti and Venables, 2004; Cantwell and Mudambi, 2005; Narula and Zanfei, 2005; Dunning and Lundan, 2009; Wolfmayr et al., 2013). Although these two streams of research have developed quite independently, they jointly point to an additional impact on productivity of multinationality, which passes through R&D and can thus be termed *indirect*. An accurate analysis of the M-P relationship should consider both of these effects simultaneously and as being equally important. In particular, it should consider that, far from representing an environmental contingency (external to the firm), with the simple effect of augmenting the returns of R&D (Mork and Yeung, 1991; Anón Higón and Manjón Antolín, 2012),[4] multinationality could autonomously provide firms with new incentives to invest in R&D, which in turn would increase productivity.

The distinction between an intensive and an extensive form of multinationality is arguably also relevant when the indirect impact of multinationality on productivity is considered. Because the indirect effect is channelled through R&D, we have to consider how the incentives to invest in R&D depend on multinationality. Following this last perspective, the relative balance of the indirect effects between intensive and extensive multinationality is reversed compared with the direct ones, given the impact that the two forms of multinationality have on R&D *per se*. On the one hand, the presence in a greater number markets increases a firm's market access, and creates incentives to invest in R&D to spread the multi-plant fixed costs and to exploit firm-level economies of scale in a wider market (Petit and Sanna Randaccio, 1998; Markusen, 2004; Barba Navaretti and Venables, 2004). Given its nature as a non-rival good, technological knowledge does not in fact deteriorate, but

[3] See the review of the literature in Hall and Mairesse (1995), and Doraszelski and Jaumandreu (2013).
[4] This is somehow implicit in the diffused practice, in the IB literature, of considering R&D as a 'moderating' variable on the impact of multinationality on the firm's (financial) performance (e.g. Kotabe et al., 2002; Yang and Driffield, 2012).

rather tends to appreciate, in multiple market applications. On the other hand, a more substantial impact on R&D could accrue from a greater 'variety experience' gained through a more geographically extended multinationality. Indeed, such an internationalisation strategy enables firms to establish a spatially (and sectorally) diffuse system for the absorption and creation of new competencies (Dunning, 1993; Patel and Vega, 1999; Zander, 1999; Cantwell and Mudambi, 2005; Cantwell and Piscitello, 2005; Cantwell and Santangelo, 2009), which has been shown to be a fundamental asset for increasing the so-called firm's 'exploration potential' (Cantwell, 1995, Castellani and Zanfei, 2002). Accordingly, a more extended multinationality can be thought of as a more powerful input (relative to a more intensive multinational expansion) of R&D efforts that actually lead to improvements in innovation and productivity. In addition, while we have argued that variety experience can cause organisational problems that adversely affect productivity, there is no obvious reason to think that the increased complexity determined by being active in a variety of markets should decrease the incentives to invest in R&D.

On the basis of this last argument, a second set of hypotheses can be put forward:

Hp3: *For a given multinational extension, a greater intensity of multinational activity has a positive direct impact on R&D.*

Hp4: *Because of the advantages of knowledge variety and market access, a more geographically extended multinationality has a positive impact on R&D investments.*

2.3 The overall effects of multinationality on productivity

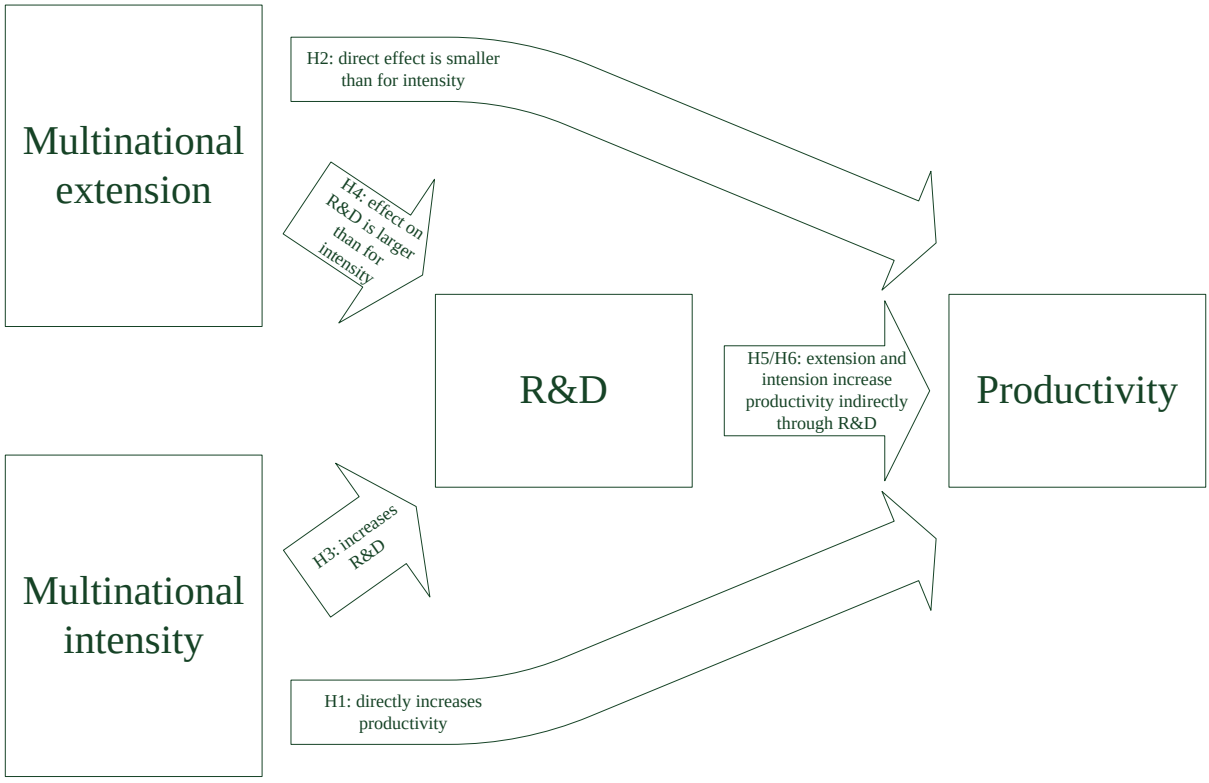
The above arguments suggested that both the intensity and the extension of multinationality can have particular benefits, where the former is likely to be more beneficial in terms of the direct effect on productivity and the latter will be more beneficial with respect to R&D. These differential impacts emerged because both types of multinationality entail certain accompanying costs that play out either for the direct effect (extension) or for the indirect effect (intensity). Although it ultimately remains an empirical issue, if we assume that these additional costs are not too large, the total effects (direct plus indirect) of multinationality should be positive:

Hp5*: For a given multinational extension, a greater intensity of multinational activity has a positive total impact on productivity.*

Hp6*: For a given multinational intensity, a greater geographical extension of multinational activities has a positive total impact on productivity.*

A summary of the hypotheses displaying the basic structure of our M-P model augmented with R&D is shown in Figure 1.

Figure 1: Graphical summary of the structural model



3. Empirical application

3.1. Data

Two data sources are used for the empirical application. We retrieve R&D investments and other economic and financial data from the EU Industrial R&D Investment (IRI) Scoreboard (http://iri.jrc.ec.europa.eu/). This is a scoreboard analysis of the top R&D investors worldwide, which the Institute of Prospective Technological Studies (IPTS, Joint Research Centre (JRC), European Commission) has conducted annually since 2004 (European Commission, 2013).[5] In particular, starting with the top 2800 ranked companies for 2012, historical economic and financial data are collected to analyse their trajectories along the time period considered.

These data have been completed with information on the ownership structure of these companies, as provided by ORBIS. Of the 2858 companies available, 2746 are the global ultimate owner of at least one subsidiary in ORBIS.[6] Owing to missing values in some of the variables used in the econometric estimation, the actual number of usable observations is 2124. Most of these companies are headquartered in a European country (32%) or in the USA (31%) (Table 1). Finally, the sample is composed mainly of companies operating in the

[5] In 2012, JRC published information for the top 2000 R&D investors worldwide. For the current exercise, we had the potential to access a larger sample, composed of about 2850 companies.
[6] The remaining 112 companies are not matched to any subsidiary in ORBIS. This is probably because these companies may be in an intermediate position within a group (such as when holding companies control the actual industrial company).

Industrial Goods & Services (27%), Technology (24.5%) and Health Care (13%) sectors[7], which are normally recognised as high or medium-high technological sectors (Table A1). It should be noted that our sample need not be representative of the population of firms, across countries and sectors, as it is explicitly compiled to represent the largest R&D investors, which may be relatively more concentrated in some countries and sectors. This can lead to a selection bias. Although this issue cannot be easily addressed with the current data, it should be noted that R&D expenditures are highly skewed, implying that the R&D Scoreboard captures a large proportion of world R&D expenditure, which limits the effects of any potential selection bias.

Table 1: Distribution of companies across world regions (estimation sample)

Region	# of companies	Freq (%)
EU	679	32.0
(DE	*142*	*6.7)*
(GB	*135*	*6.4)*
(FR	*106*	*5.0)*
USA	655	30.8
Japan	414	19.5
RoW	376	17.7
(CN	*129*	*6.1)*
(TW	*94*	*4.4)*
Total	2,124	100

These companies control a total of 588540 subsidiaries, which are mainly industrial companies (37%) and branches (57%). However, the higher number of branches hides an extremely skewed distribution across companies, providing unreliable figures on the network size of some company. Moreover, there are large country differences in the share of branches, ranging from 18 % in the 'Rest of the World'[8] to 64% among Japanese companies. For these reasons we decided to drop branches from the analysis.

Data on the companies' subsidiary structure were available only for the last year of the period referred to, 2012. For this reason, although we have an unbalanced panel dataset for the economic and financial information, we are able to exploit only the cross-sectional nature of our data when estimating the impact of our different multinationality measures.

In order to measure the different aspects of multinationality described in the theoretical background, we calculate two different indicators. The first is the share of international subsidiaries, calculated as the number of international subsidiaries over the total number of subsidiaries, which is meant to be a proxy for the intensive margin of multinationality. For Europe-based companies, this measure has been calculated by considering only subsidiaries located in non-EU-28 countries. In so doing, we consider the EU as an homogeneous socio-economic area (like the USA). As a robustness check, we also report results using a more

[7] The Technology sector includes the Software & Computer Services and the Technology Hardware & Equipment subsectors, whereas the Health Care sector includes the Health Care Equipment & Services and the Pharmaceuticals & Biotechnology subsectors.
[8] The 'Rest of the World' region includes all countries outside the EU, USA and Japan. This country group represents about 17% of the companies in the sample, a figure very close to that of the estimation sample (see Table A2).

standard measure, which defines as international all the subsidiaries outside the national borders, including those within the EU-28. As for the second indicator, in order to measure multinationality at the extensive margin, we follow a consolidated tradition[9] by constructing a measure of the network spread, computed as the number of foreign countries in which a firm has subsidiaries. Also in this case we compute the indicator either using or excluding intra-EU-28 subsidiaries. This measure is intended to capture the 'variety experience' of MNEs as opposed to the overall 'international experience', which is proxied by the share of international subsidiaries (Castellani and Zanfei, 2004; Laursen and Salter, 2006).

Not surprisingly, given the fact that firms in our sample are relatively large, the degree of multinationality of our companies is quite high. On average, 47% of the subsidiaries are located abroad (see Table 2), but differences arise across macro-regions (i.e. groups of geographically close countries). US companies are the most internationalised, whereas European ones tend to be less internationalised. However, the low degree of multinational intensity is largely derived from the exclusion of the intra-European linkages when calculating the internationalisation measure. When we calculate multinationality based on actual national borders, EU firms turn out to be more internationalised, although the share of international subsidiaries is still lower than that for US firms (59% vs. 62%). This is confirmed when considering the multinational spread. Even so, US companies have a wider geographical diversification (17 countries), whereas European companies are very similar to Japanese ones (12 vs. 11). It is worth noting that the average and median of the multinational intensity indicator are relatively close, suggesting a low degree of skewness in the distribution; the indicator measuring the multinational spread is right skewed with the median always lower than the average.

Table 2 Descriptive statistics, by region of origin (2012)

	Stats	EU	Japan	RoW	USA	***All regions***
Multinationality intensity *(Share international subsidiaries)*	*Average*	33% (59%)	46%	53%	62%	***47%***
	Std. dev.	0.22 (030)	0.28	0.38	0.25	***0.30***
	Median	33% (67%)	49%	60%	68%	***49%***
Multinational spread *(# of countries where a firm has subsidiaries)*	*Average*	12 (21)	11	9	17	***12***
	Std. dev.	15 (21)	12	14	17	***15***
	Median	6 (14)	7	3	12	***7***
R&D intensity *(log of R&D per employee)*	*Average*	2.23	2.26	1.83	3.22	***2.46***
	Std. dev.	1.58	0.99	1.25	1.54	***1.52***
	Median	2.20	2.19	1.75	3.26	***2.34***
Labour Productivity *(log of sales per employee)*	*Average*	5.35	5.79	5.07	5.45	***5.40***
	Std. dev.	0.93	0.75	0.90	0.91	***0.92***
	Median	5.36	5.72	5.06	5.47	***5.41***
Capital Intensity *(log of fixed assets per employee)*	*Average*	4.67	4.74	4.03	4.80	**4.60**
	Std. dev.	1.21	0.92	1.21	1.03	**1.14**
	Median	4.57	4.67	3.95	4.87	**4.57**
Size *(log of number of employees)*	*Average*	8.21	8.90	9.00	7.93	**8.38**
	Std. dev.	2.09	1.38	1.51	1.98	**1.91**
	Median	8.27	8.76	8.98	8.02	**8.51**

** For EU firms, we report the indicators of multinationality intensity and multinational spread both excluding the subsidiaries located in other EU countries, and including them (in brackets)*

[9] See, for example, Morck and Yeung (1991), Ietto-Gillies (1998) and UNCTAD (2004).

Finally, concerning our two outcome variables of interest, namely the (logarithm of) labour productivity and the (logarithm of) R&D intensity,[10] Table 2 suggests a low degree of skewness (averages and medians are very close). The average values of labour productivity do not vary widely across regions. Companies headquartered in Japan have the highest values for labour productivity, companies from the Rest of the World have the lowest, and European and US companies have very similar values. R&D intensity shows a higher degree of variation across regions. US companies are, on average, the most R&D intensive (3.22), while Japanese and European ones have similar average values (2.26 and 2.23, respectively). Companies headquartered in the Rest of the World are, on average, the less R&D intensive (1.83). Part of the difference is due to the different distribution of companies across sectors. In fact, while European and Japanese companies are more concentrated in medium–high R&D-intensive sectors, US ones are more frequent in high technological sectors (European Commission, 2013). Indeed, when looking for causal relationships, these sector and geographical specificities should be taken into account.

3.2 Econometric strategy

The analysis of the complex relationship between multinationality and R&D, and of the direct and indirect impact of multinationality on productivity that it entails, makes it opportune to resort to a relatively structured econometric strategy. In particular, a system of equations for the direct and indirect aspects of the M-P relationship offers the opportunity to detect more precise channels of intervention. This methodological choice represents an additional added value of this paper.

The model used in this paper expresses both labour productivity and R&D intensity as functions of multinationality. Beyond that, we propose a step-wise model structure by assuming that R&D intensity is an explanatory variable in the labour productivity regression. Using a log-log specification, which allows the coefficients to be interpreted as elasticities, this model structure therefore looks as follows:

$$\begin{aligned} \log(rdint) &= \delta_1 \log(multi) + x'\beta_1 + u_1 \\ \log(lprod) &= \delta_2 \log(multi) + \gamma \log(rdint) + x'\beta_2 + u_2 \end{aligned} \qquad \text{(1a, b)}$$

where x' is the vector of the control variables. The two regressions can be easily estimated using ordinary least squares (OLS) for each equation separately. This holds, despite the fact that the R&D intensity appears as an explanatory variable in the labour productivity regression, which might at first sight raise issues of simultaneity. However, as labour productivity does not appear to be an explanatory variable in the R&D regression (which is reasonable, because R&D is conceptualised as an input into efforts to improve productivity), the structure of the model is purely triangular. This last property would allow us to treat each equation separately by OLS.

[10] Labour productivity is calculated as the company's production output, measured as total turnover, divided by the number of employees, while R&D intensity is measured as the company's corporate R&D investments (defined as the cash investment funded by the companies themselves and excluding R&D undertaken under contract for customers such as governments or other companies) divided by the number of employees. Admittedly, it would have been desirable to use value added as a measure of output, but this information is missing for most non-EU firms. Therefore, in the trade-off between a better measure of output and greater coverage, we opted for the latter.

Although the triangularity property evades estimation problems of simultaneity, the two equations are clearly linked. Therefore, as the errors of the two equations may be correlated, we implement the seemingly unrelated regressions estimation procedure proposed by Zellner (1962, 1963) and Zellner and Huang (1962), assuming an unstructured variance–covariance matrix for the error terms. Moreover, using (1a,b) we are able to distinguish a direct and an indirect effect of internationalisation that is channelled through R&D intensity. In particular, the direct effect is defined by differentiating (equation 1a,b) with respect to the internationalisation variable but ignoring any indirect effects. The indirect effects are channelled through the variables that appear as explained in one regression but explaining in another. The total effect, as the sum of the indirect and direct effects, takes the following form for each equation:

$$\begin{aligned} \frac{\partial \log(rdint)}{\partial \log(multi)} &= \underset{tot.effect=dir.effect}{\delta_1} \\ \frac{\partial \log(lprod)}{\partial \log(multi)} &= \underset{dir.effect}{\delta_2} + \underset{indir.effect}{\gamma\delta_1} \end{aligned} \qquad (2a,b)$$

Obviously, as labour productivity is not an explained variable in the R&D intensity equation, there is no indirect effect, and the total and the indirect effects coincide. Once we have consistent estimators for the individual coefficients and the relative covariance matrix, it is easy to also calculate the direct and indirect effects.

In addition to multinationality and R&D, labour productivity (and R&D) could also be affected by other variables, which enter the x' vector. We control for the effect of capital intensity, measured as physical capital per employee. Let us note that, by regressing (the log of) labour productivity on (the log of) capital intensity, we are implicitly assessing the correlation of the other independent variables with a measure of total factor productivity. Among other things, this also allows us a more flexible interpretation of the correlations between multinationality, R&D investment and productivity. In particular, we are not forced to impose a form of function and we can interpret R&D and multinationality both as shifters of the production function and as inputs into the production function. Similarly to Banker et al. (1994), we also control for the size of company (and its square) to control for the presence of economies (and diseconomies) of scale. Finally, a series of industry and region fixed effects complete the list of controls.

4. Results

4.1. The baseline regressions

As explained in Section 3, we rely on two variables for determining the degree of multinationality of firms. First, we use the international subsidiaries as a share of all subsidiaries (multinational intensity). Second, we use the geographical diversification in terms of the location of the international subsidiaries (multinational spread). Finally, we consider their joint effect. The results from these regressions are shown in Table 4. Before commenting on the results, let us observe that our data show no evidence of non-linearities in

the impact of multinationality on a firm's performance, such as those that have often been found in IB studies (Contractor et al., 2003; Contractor, 2007; Yang and Driffield, 2012), The results reported in Table 3 show no evidence of either a U- or an inverted U-shaped relationship between multinationality and productivity. This could be on account of the focus on productivity as a measure of performance, or because our sample includes mainly large firms with relatively high degrees of multinationality. But, either way, it means that focusing on linear specifications is not an undue over-simplification.

Our main regressions, reported in Table 4, indicate that, when we include only the share of international subsidiaries as a measure of multinationality, we find evidence of a positive effect of a higher share of international subsidiaries on R&D intensity but not on labour productivity. The positive effect on R&D is largely expected and consistent with the arguments presented in Section 2 (Hp. 3), highlighting that the incentives to invest in R&D increase with the degree of multinationality. In this context, multinationality creates access to new knowledge sources, which can prove a valuable input into current R&D activities. Thus, more internationalised firms are expected to invest more into R&D because their returns on R&D are higher. Furthermore, as firms increase their degree of multinationality, they gain better access to foreign markets; thus, they have more incentives to invest in R&D. The reason for this lies in firm-level economies of scale resulting from the fact that R&D costs can be distributed over a larger sales base.

Table 3 Impact of multinationality (excluding intra-EU28 activities) on labour productivity and R&D intensity - Share of international subsidiaries

	Labour Productivity (M-P Linear)	Labour Productivity (M-P Quadratic)
Multinationality Intensity	-0.017	0.014
	(0.013)	(0.043)
Multinationality Intensity square		-0.006
		(0.009)
R&D Intensity	0.177***	0.178***
	(0.015)	(0.016)
Subsidiaries per employee	0.106***	0.105***
	(0.016)	(0.016)
Capital Intensity	0.332***	0.330***
	(0.015)	(0.015)
Size	0.518***	0.516***
	(0.060)	(0.060)
Size square	-0.025***	-0.025***
	(0.003)	(0.003)
Sector fixed effects	*Included*	*Included*
Country group fixed effects	*Included*	*Included*
Constant	2.368***	2.352***
	(0.288)	(0.289)
Observations	2,124	2,124
R-squared	0.483	0.483

*** p<0.01, ** p<0.05, * p<0.1 - Standard errors in parentheses

The non-significance of multinational intensity in the labour productivity equation seems to contradict Hp.1 but, as we are about to show, this is a due to a specification error deriving from the fact that we do not account for the geographical spread.

Furthermore, it is worth noting that the R&D intensity variable in the productivity regression is significant, which gives rise to the potential for significant indirect effects. In fact, the intensity of multinationality exerts a positive impact on productivity channelled by the increase in R&D intensity. A 100 % increase in multinational intensity translates into a 2 % increase in labour productivity (see Table 5).

If we use only the geographical spread as a measure of multinationality, we obtain different insights. On the one hand, when considering the multinationality at the extensive margin, it appears that the extra transaction, agency and organisational complexity costs of a larger number of international relationships may outweigh the positive benefit derived from operating in different markets. In the productivity equation, the coefficient attached to the multinationality spread is negative and significant. This is consistent with Hp.2, although the negative sign was not expected. On the other hand, in line with the arguments that a spatially diffuse system allows better absorption and creation of new competencies, the incentives to invest in R&D are higher, when considering multinationality at the extensive margins, than in the case of multinational intensity, as predicted in Hp.4. This also translates into a stronger indirect effect on labour productivity than that obtained when considering the intensive margin (+4.5 %). However, this positive indirect effect is not strong enough to compensate for the negative direct one, and the overall relationship between multinationality at the extensive margin and labour productivity is negative. These results support Hp.5 but not Hp.6.

In the last two columns of Table 4, we consider both margins of multinationality. In fact, while they may be correlated, our theory - and the results that we have just discussed - suggests that they may have different relations with productivity and R&D. Indeed, considering the intensive and extensive dimensions of multinationality jointly provides interesting results. The first important piece of evidence is that the relationship between labour productivity and multinational intensity becomes positive and significant when controlling for multinationality at the extensive margin (as predicted by Hp.1). This suggests that, for a given geographical spread, more intense multinational activity is associated with higher productivity. However, for a given level of multinational intensity, a greater geographical spread, entailing higher organisational complexity, is associated with lower productivity (consistent with Hp.2). On the other hand, the positive impact of the two measures of multinationality on R&D is confirmed when considering them jointly. The incentives to invest in R&D increase with the degree of multinationality, and more so at the extensive margin than at the intensive one (Hp.3 and Hp.4).

Table 4 Impact of multinationality (excluding within-EU28 countries) on labour productivity and R&D intensity - Seemingly unrelated regressions

	Multinationality Intensity		Multinational spread		Both measures	
	R&D Intensity	Labour Productivity	R&D Intensity	Labour Productivity	R&D Intensity	Labour Productivity
Multinationality Intensity	0.141***	0.004			0.047**	0.065***
	(0.019)	(0.013)			(0.022)	(0.015)
Multinational Spread			0.271***	-0.118***	0.241***	-0.162***
			(0.025)	(0.017)	(0.029)	(0.020)
R&D Intensity		0.142***		0.167***		0.164***
		(0.015)		(0.015)		(0.015)
Capital Intensity	0.266***	0.376***	0.310***	0.344***	0.307***	0.342***
	(0.019)	(0.013)	(0.019)	(0.014)	(0.019)	(0.014)
Size	-1.673***	0.483***	-1.574***	0.501***	-1.597***	0.468***
	(0.081)	(0.060)	(0.080)	(0.058)	(0.080)	(0.059)
Size square	0.069***	-0.026***	0.069***	-0.028***	0.070***	-0.028***
	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)
Sector fixed effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Country group fixed effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	8.862***	1.904***	8.817***	1.839***	8.771***	1.774***
	(0.387)	(0.291)	(0.380)	(0.287)	(0.381)	(0.286)
Observations	2,124	2,124	2,124	2,124	2,124	2,124
R-squared	0.584	0.462	0.597	0.474	0.597	0.479
RMSE	0.900	0.605	0.886	0.598	0.886	0.596
Indirect Effect						
Multinationality Intensity		2% ***				0.8%**
Multinational spread				4.5% ***		3.9%***
Total Effect						
Multinationality Intensity		2.4%*				7.2%***
Multinational spread				-7.3%***		-12.2%***

*Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1*

Overall, the indirect effect of multinationality on labour productivity operating through the R&D channel appears to be slightly lower than in the previous regressions, with estimated elasticities of 0.8% and 3.9% for the intensive and the extensive margin, respectively. However, the indirect impact of multinationality at the extensive margin it is not big enough to counterbalance the negative direct effect. Overall, the elasticity of productivity with respect to the geographical spread of the subsidiary structure turns out to be significantly negative (–12.2%), in contrast to the positive effect derived from greater engagement in international markets (+7.2%).

Table 5: Direct, indirect, and total effects for R&D and productivity (elasticities with respect to changes in multinationality)

		Only intensity	Only extension	Both intensity and extension
R&D	**Multinational intensity**			
	Total=direct effect	14.10% ***		4.66% **
	Multinational extension			
	Total=direct effect		27.11% ***	24.09% ***
Productivity	**Multinational intensity**			
	Direct effect	0.40%		6.44% ***
	Indirect effect	2.00% ***		0.76% **
	Total effect	2.40% *		7.20% ***
	Multinational extension			
	Direct effect		-11.81% ***	-16.24% ***
	Indirect effect		4.53% ***	3.95% ***
	Total effect		-7.28% ***	-12.29% ***

This picture does not seem to be significantly affected by our decision to consider Europe as a unique socio-economic area (and excluding intra-EU-28 subsidiaries from our measures of multinationality). In Table A2 we report the results of estimations in which multinational intensity and spread are defined in a more standard way, by including all subsidiaries outside the national borders. The differences in Table 4, in terms of both sign and magnitude, are very limited. Slightly larger differences in the results emerge when the two dimensions of multinationality are considered jointly. First of all, when taking into account multinationality at the extensive margin, the impact on R&D at the intensive margin is rather imprecisely measured (although greater in magnitude). Second, the direct effect of multinationality on labour productivity at the intensive margin is much greater when we measure multinationality including intra EU-28 subsidiaries. This means that the overall elasticity of labour productivity with respect to multinational intensity increases and becomes much closer in absolute value to the negative elasticity of labour productivity with respect to multinational spread: +12.2% and –13.2%, respectively.

To sum up, our evidence supports the view that costs and benefits derived from different international settings of the subsidiary structure have to be traded off. Firms should consider the different dimensions carefully, adapting their internationalisation process in order to maximise the net benefit derived from it.

5. Discussion and Conclusions

Multinationality, that is the extent to which firms extend their networks of activities across borders, can create opportunities to enhance a firm's performance and incentives to invest in knowledge-related activities, but also costs and complexities that have negative effects on performance. Therefore, from a theoretical point of view, the sign of this relation cannot be clearly predicted. The IB literature has investigated this issue for many years without coming to a conclusive understanding. Two main directions of research have been followed. On the one hand, it has been argued that, in order to properly account for the dynamics of the costs and benefits of multinationality, a non-linear specification is needed. This has led to evidence showing an inverted U-shaped (but also, in some cases, a U-shaped) relationship, and more recent evidence pointed to an S, or an M, shape. On the other hand,

many studies have argued that the M-P relationship is contingent on some moderating factors, and R&D is frequently found to be important in this regard.

In this paper we challenge both these views. Concerning the first, we argue that the cost side needs a more structural treatment. In this paper we do that by distinguishing between the extensive and the intensive margin of multinationality. With respect to the second issue, we have argued that R&D is a strategic choice made by firms and should thus be considered an input into productivity. Treating it as a moderating factor implicitly defers R&D to the state of some exogenous contingency, which is external to the firm. Beyond the inaccuracies associated with this treatment, such an approach foregoes considerable opportunities for more in-depth analyses of the role of R&D in the M-P relationship. In particular, by conceptualising R&D as an input into productivity and modelling it in a separate regression, we cannot only differentiate between direct and indirect effects of multinationality but also explicitly test theories about how multinationality affects the incentives for investing more in R&D.

These methodological improvements allow a more accurate representation of an R&D-augmented M-P relationship and offer interesting insights. In particular, we show that multinationality – both at the intensive and at the extensive margin – increases the incentive to invest in R&D. This may be explained, first, by an argument relating to increasing returns to scale in R&D, as R&D represents sunk fixed costs that can be distributed over a larger sales base (Cohen and Klepper, 1996). Second, it can be explained by the motive of tapping new knowledge sources through multinationality (Bardhan and Jaffe, 2005; Cantwell and Mudambi, 2005; DeSarbo et al., 2005; Narula and Zanfei, 2005; Barthélemy and Quélin, 2006; Maskell et al., 2007,). In that respect, gaining access to more or more relevant knowledge creates additional incentives to further invest in R&D and leverage the externally acquired knowledge. In particular, this perspective suggests why multinationality at the extensive margin leads to a greater increase in R&D than at the intensive margin. Because the latter is likely to be associated with some general abilities to deal with international markets or with foreign regulation issues and the former genuinely represents access to many different knowledge sources (Castellani and Zanfei, 2004), as well as larger markets to exploit firm-level economies of scale in R&D (Petit and Sanna Randaccio, 1998), we would expect precisely this pattern.

Adding to this, we find that the effects of multinationality at the intensive and extensive margins are reversed for direct effects on productivity. The argument for this is a straightforward extension of what has already been stated above: multinationality does not only bestow benefits, in terms of larger markets or improved access to new knowledge, it may also lead to considerable costs. These costs are likely to take the form of increased organisational complexity and transaction costs, which can hamper a firm's productivity. Although multinational intensity reflects the capacity to deal with these complexities for a given level of multinational extension, multinational extension increases the organisational complexity for a given level of multinational intensity.

If we focus on the total effects, we find that multinationality contributes to greater productivity only at its intensive margin, whereas at the extensive margin (more geographical dispersion) it appears to be detrimental. In particular, the positive indirect effect of multinational extension is more than compensated by the negative direct effect.

These findings have important theoretical and managerial implications. Starting with the former, we suggest that much of the confusion that has arisen around the M-P relationship in the past may have been due to a somewhat broad-brush characterisation of this relationship. In this paper we have proposed a much more structural characterisation, first, by treating R&D as an input rather than as a moderating factor and, second, by differentiating between the effects of multinationality at the extensive and the intensive margins. We have argued that both variables measure fundamentally different concepts, the former reflecting the ability to access more knowledge sources and the latter reflecting general managerial capabilities in organising international markets when considered simultaneously. We believe that this more structural approach allows consideration of the M-P relationship in a more in-depth and analytical way.

Concerning the managerial implications, we find strong support for the view that multinationality increases investment in R&D. This indirectly evidences the argument that multinationality is also about gaining access to knowledge. To the degree that, at the extensive margin, these positive indirect effects are overcompensated when considering productivity, this highlights the fact that multinationality should be more rewarding for more R&D-intensive firms (Bausch and Krist, 2007), because, without this focus, the (positive) indirect effects are forgone. It also shows, however, that there are considerable costs associated with multinationality that come in the form of organisational and transactional complexity. This reinforces the claims made by Baier et al. (2015) and Medcof (2001), both of whom emphasise the repercussions of multinationality on the organisational structure. As for whether or not a firm should become more multinational, that also depends on how R&D intensive it is or how able it is to manage the increased level of complexity.

ANNEX A – Descriptive statistics and alternative specification

Table A1 – Distribution of companies across industries (estimation sample)

ICB Sector	# of companies	Freq (%)
Oil & Gas	43	2.02
Chemicals	128	6.03
Basic Resources	62	2.92
Construction & Materials	65	3.06
Industrial Goods & Services	576	27.12
Automobiles & Parts	125	5.89
Food & Beverage	69	3.25
Personal & Household Goods	119	5.6
Health Care	278	13.09
Retail	22	1.04
Media	20	0.94
Travel & Leisure	23	1.08
Telecommunications	26	1.22
Utilities	33	1.55
Financial Services	14	0.66
Technology	521	24.53
Total	2,124	

Table A2 – Impact of multinationality (including within-EU28 activities) on labour productivity and R&D intensity - Seemingly unrelated regressions

	Multinationality Intensity		Multinational spread		Both measures	
	R&D Intensity	Labour Productivity	R&D Intensity	Labour Productivity	R&D Intensity	Labour Productivity
Multinationality Intensity	0.125***	0.015			0.054	0.114***
	(0.020)	(0.014)			(0.043)	(0.027)
Multinationality Spread			0.321***	-0.123***	0.295***	-0.179***
			(0.028)	(0.018)	(0.035)	(0.022)
R&D Intensity		0.141***		0.159***		0.157***
		(0.015)		(0.014)		(0.014)
Capital Intensity	0.264***	0.377***	0.332***	0.348***	0.332***	0.347***
	(0.019)	(0.013)	(0.020)	(0.013)	(0.020)	(0.013)
Size	-1.672***	0.477***	-1.608***	0.328***	-1.609***	0.323***
	(0.081)	(0.060)	(0.088)	(0.059)	(0.088)	(0.059)
Size square	0.069***	-0.025***	0.072***	-0.019***	0.072***	-0.020***
	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)
Sector fixed effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Country group fixed effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	8.811***	1.884***	8.696***	2.666***	8.477***	2.217***
	(0.391)	(0.291)	(0.420)	(0.289)	(0.456)	(0.307)
Observations	2,124	2,124	1,994	1,994	1,994	1,994
R-squared	0.581	0.462	0.576	0.497	0.576	0.502
RMSE	0.904	0.605	0.897	0.559	0.897	0.557
Indirect Effect						
Multinationality Intensity		1.8%***				-
Multinational spread				5.1%***		4.6%***
Total Effect						
Multinationality Intensity		3.2%**				12.2%***
Multinational spread				-7.2%***		-13.2%***

*Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1*

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