The University of Nottingham

research paper series

Research Paper 2015/18

Multinationals and the Globalization of R&D

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GEP

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Acknowledgements

We would like to thank Johannes Biesebroeck, Giammario Impullitti, Simon Gächter, Beata Javorcik, María Rochina, and Joel Stiebale for their helpful comments as well as seminar participants at the University of Nottingham, Trento, and 14th ETSG Conference (Leuven), ZEW (Mannheim) and 5th ISGEP workshop (Ljubljana), ICTNET workshop (London), 27th EEA Conference (Malaga), 39th Annual EARIE Conference (Rome).

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Abstract

We consider theoretically and empirically how the location and organization of knowledge production evolve within domestic firms during the period of their acquisition by foreign multinationals. Acquisitions do not increase the risk of closure of the subsidiary's research labs unless acquired by MNEs at the technological frontier. Conditional on keeping research in the subsidiary, there is a large decrease of innovation expenditures, transfer of knowledge and reorganization towards high-skilled workers. We show that innovations increase, which is a consequence of the complementarity between foreign technology transfers and skilled-workers in the subsidiary.

JEL classification: F23; O33; D22; L2

Keywords: MNE; Knowledge Production Function; Acquisition FDI; Knowledge Complementarities; R&D: innovation.

Outline

The Pfizer-Allergan merger could "*deprive the US Treasury of billions of tax dollars, put thousands of jobs at risk and erode the country's science base*"

Financial Times, Nov. 19, 2015.

1. Introduction

Does foreign acquisition enhance or damage knowledge production by acquired firms? To answer this question we examine for the first time how the location and international organization of knowledge production evolves within domestic firms after their acquisition by foreign multinationals.

The motivation to this study comes from the fierce political scrutiny that has followed the announcement of mergers or acquisitions involving knowledge intensive firms from different countries. A recent prominent example within the US has been the reaction to the proposed merger between Pfizer-Allergan. Both Democrat and Republicans politicians criticized its announcement, while President Obama denounced it as "unpatriotic". This plays on the fear that the combined company, headquartered in Ireland, will change the location of Allergan R&D from the US. Yet, it might alternatively be the case that the multinational chooses instead to retain its current R&D locations in order to benefit from its global research excellence and its access to high skilled researchers within both countries. Nor are these concerns a peculiarly US phenomenon: the proposed takeover of Astra-Zeneca by Pfizer a few years ago, led to requests for guarantees for the retention of research jobs in the UK from the Prime Minister, the leader of the Opposition and the president of the Royal Society, as well an appearance by the chairman of Pfizer before a Commons Select Committee in the UK Parliament.[1]

Understanding how multinationals (MNEs) organize their R&D and what adjustments occur as a consequence of changes in ownership is of interest not only because it reflects the fears of different interest groups about the closure of R&D facilities and consequent losses of high-skilled jobs. It is important from an economic perspective given the central role that innovation, technology transfers and human capital play in economic growth and development (Acemoglu et al, 2007; Arora et al, 2011; Bloom et al, 2012; Aghion et al, 2014). MNEs are major producers of global knowledge, employ a large number of high skilled workers, and their international structure generate opportunities for international technology transfer (Helpman, 1984; Markusen, 1984; Branstetter et

[1] Previous debate in the UK was based on the experiences from the takeover of Cadbury by Kraft and the view of some that pre-acquisition promises about the security of jobs and plant-openings were broken. In France, there were objections to the bid by GE for Alstom and PepsiCo for Danone; while in Spain to the bid for Endesa AS by Eon

al, 2006; Javorcik, 2010; Keller and Yeaple, 2013). If R&D activities generate geographically concentrated externalities (Griliches, 1992; Jaffe, 1986; Bloom et al, 2013) and the location of R&D changes after foreign acquisition, then there may be further effects on welfare.

Our starting point holds that MNEs care about the efficiency of innovation production and will organize R&D across their entire multinational structure to maximize innovation value. This introduces an opportunity cost from choosing a globalized R&D strategy and retaining innovation within the subsidiary following its acquisition. If the opportunity cost is too high, the R&D labs may be closed and knowledge creation concentrated within a single location, as occurs in most standard models of multinational production.[2] In these circumstances the political fears about the loss of domestic R&D capabilities are likely to be realized. The alternative is that the MNE will exploit complementarities in the knowledge base across R&D labs in different locations by sharing scientific knowledge.[3] In this case, the MNE may choose to decentralize R&D globally and retain the affiliate R&D – an outcome which has been generally overlooked in the literature.[4] We show that in such circumstances the inputs of the R&D process in the acquired lab will be restructured to take advantage of these intrafirm transfers of technology. The effects of acquisition-FDI on the domestic science base therefore depend on the survival of R&D labs within newly acquired domestic firms alongside the consequences of the complementarity more broadly. This is the first time this mechanism has been applied to the study of the R&D by multinational firms.

We formalize this mechanism using a partial equilibrium model that includes the inputs used within the research process and the decision to retain R&D in the affiliate. This structure highlights the role of technology transfers and its complementarity with high-skilled researchers as one explanation for the improved innovation performance of acquired firms. Within the model acquisition both allows for the sharing of R&D knowledge from the parent and reductions in the fixed-cost of innovation as duplicated effort is eliminated or some supportive and administrative jobs are centralized. We assume that the cost savings are the same for all MNEs whereas the extent of technology transfers might differ. MNEs at the technological frontier have the greatest scope to share technical information between their labs, but they are also more likely to have highly innovative labs

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[2] Moreover Bilir and Morales (2015) report the stylized fact that foreign affiliates participate in innovation only in around half of US firms.

[3] As Nocke and Yeaple (2007, 2008) pointed out, acquisitions arise to exploit mutual complementarities. For example, Financial Times (2014) reports the growing importance for large firms to generate innovations through collaboration and sharing ideas across different labs.

[4] This is consistent with the observation that MNEs have collectively become more globalised in the location of their R&D over time (NSF, 2011).

elsewhere. As a consequence, MNEs at the technological frontier are the most likely to close the subsidiary R&D and centralize their research.

If the research facility within the acquired firm is retained, the MNE decides what combination of inputs best maximizes its innovation output. We assume that any cost-efficiencies from acquisition will decrease total expenditures in the acquired R&D lab and will impact disproportionately on lower skilled researchers, technicians and administration in the R&D process. The effects of technology transfer on expenditures work in the opposite direction. The scientific knowledge that the MNE shares, enhances the productivity of skilled researchers, leading to an increase in the number of scientists in the subsidiary. It follows that the reductions in R&D costs are less pronounced for firms acquired by a MNE at the technological frontier, even though they were also more likely to shut the acquired R&D lab. Finally, the combination of more high skilled research scientists and international technology transfers increases the efficiency of innovation. This model therefore provides one explanation for the ample evidence of the productivity and research advantage enjoyed by foreign MNEs,[5] where this increase in inventiveness is again largest when acquisition is from a frontier-MNE (Branstetter and Drez, 2014; Chen, 2011; Criscuolo and Martin, 2009).

The theoretical model motivates some new empirical questions related to the organization of research, intra-firm technology transfers, as well as other knowledge inputs and changes to the rate of innovation. For this task we use the annualized version of the Spanish Community Innovation Survey (CIS) which covers 10,628 firms over the period from 2004 to 2009 and which contains the information necessary for our research question. That Spain represents a country that would not typically be viewed as on the technological frontier[6] provides an important aspect of our contribution as it ensures the heterogeneity in knowledge transfers that we exploit in the theoretical and empirical applications. Our methodology is a difference-in-differences (DID) approach comparing before and after-acquisition changes in R&D inputs and outputs versus those in firms that have not been acquired. In order to control for possible selection on observables we use the propensity score matching method previously used in the study of the productivity and employment effects of foreign acquisition by Chen (2011), Girma and Görg (2007), Girma et al. (2007), Guadalupe et al. (2012) amongst others.

[5] See for example Harris and Robinson (2002), Girma et al. (2007), Greenaway and Kneller (2007), Arnold and Javorcik (2009), Keller (2010), Chen (2011), and Maksimovic et al. (2011) among others.

[6] According to the European Commission Spain is considered a moderately innovative country (European Innovation Scoreboard, 2009). Similarly, using OECD data on the ratio of business enterprise R&D expenditures over GDP, Spain ranks 20th out of 27 countries (including Spain) in our sample.

A main empirical finding of our paper is that once we control for the fact that foreign MNEs acquire the more R&D intensive domestic firms, there is no evidence that acquisition-FDI increases the risk of R&D closure. This does not hold for all types of acquisitions, however. Acquisitions from a technologically-leading MNE, defined as those from the US, Germany and Japan, increase the risk the acquired R&D lab will be shut by 72%. Consequently, the political questions about the effects of foreign acquisition on the risk of closure of domestic-R&D plants, at least for FDI from these countries, have a strong empirical foundation.

A second key finding is the effect of acquisitions on the knowledge production function when the research outpost in Spain is retained. Compared to the counterfactual of non-acquired firms, we show that the number of low-skilled workers and total R&D expenditures in the subsidiary fall dramatically. This effect is particularly strong for acquisitions from non-frontier MNEs. When acquisitions occur from a technologically advanced country, there is a rise in employment of high-skilled workers, defined in this case by those with a PhD. We also find evidence of technology transfers of scientific knowledge from the MNE to the affiliate, particularly from frontier MNEs. Finally, our results suggest that the efficiency of innovation improves: subsidiaries that receive larger technology transfers and increase employment of high-skilled researchers increase their number of patents, even though on average total innovation expenditures decrease. This is consistent with the existence of knowledge complementarities across locations as an explanation for rising post-acquisition productivity.

Starting with the seminal papers by Helpman (1984) and Markusen (1984) a large number of articles study the international structure of final and/or intermediate good production by the MNE using intangible knowledge or technology as an input. The production of this intangible knowledge is usually centralized and then transferred from the centre to the foreign affiliates (Helpman et al, 2004; Burstein and Monge-Naranjo, 2009; McGrattan and Prescott, 2010; Irarrazabal et al., 2012). In contrast to this literature we consider the possible global structure of the creation of innovation rather than tangible goods. We find that for acquisitions from MNEs at the technological frontier, the substitutability of innovation across locations is very likely, as in Arkolakis et al (2014). However, we also show that knowledge complementarities within MNEs can lead to a globalized R&D structure. Our results provide direct support for the role of ownership and the transfer of intangibles within MNEs discussed by Atalay et al (2014) and Ramondo et al (2015).

The mechanism that generates our results is distinct from Guadalupe et al (2012), who show that the increase in innovation following foreign acquisition in Spanish domestic firms is due to increased market access. In contrast, we focus on the importance of heterogeneous technology transfers and skill improvements in the subsidiary. The relevance of transfers of intangibles within MNEs have been discussed by Bilir and Morales (2015), who study how the MNE leverages the R&D of its affiliates to increase the productivity of the firm and also by Griffith et al. (2006), who evaluate how the performance of the target firm affects the investor's productivity. In contrast, we consider how differences between investors influence closure, technology transfers, innovation inputs and outputs of target firms. Moreover, these papers do not directly observe technology transfers, as we do. Our contribution is to show empirically the scale and heterogeneity of technology transfers within MNEs alongside the organizational changes that take place and how these combine to impact innovation.

The empirical findings from our paper contribute to the literature on changes in R&D expenditures and innovation outputs following foreign acquisition (Bandick et al., 2010; Bertrand, 2009; Stiebale and Reize, 2011; Stiebale, 2014). The general conclusion from this literature is that the results are dependent on the context being considered. Compared to this literature, we study total expenditures alongside other organisational changes, including closure, and provide an explanation for the ambiguous changes in total spending. Our results suggest that measures of aggregate R&D are a misleading guide to the effect of acquisition on the knowledge base and high-skilled jobs. We find that a decrease in total R&D expenditures can be associated with a simultaneous increase in innovation efficiency due to technology transfers and a skill upgrading in the research unit. Our results offer an explanation for the inconsistent within the empirical literature.

The rest of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 details the data that we use. Section 4 explains the empirical methodology. Section 5 describes our main empirical results. Section 6 presents the robustness checks. Finally, we draw the conclusions from the study in Section 7.

2. Theoretical background

This section develops a partial-equilibrium model of the R&D decisions of domestically owned firms that become acquired by foreign MNEs. Before considering the effects of acquisition, we describe the decision whether to undertake research and development by a domestically owned firm. On condition that the decision to undertake research is positive, we calculate the optimal level of research, its costs and the composition of the labour force employed within the research centre. Given those outcomes we study how acquisition by a foreign multinational affects those choices.

Our model shares with Guadalupe et al (2012) the starting point that MNEs determine the level of innovation by maximizing the value of the innovative subsidiary. The key novelties in our setting are that we introduce a production function for innovation, we allow for the possibility that a firm does not innovate, and we explore the effects of cost-savings and complementarities between high-skilled workers and technology transfers after foreign acquisition. Moreover, we consider that there might be differences in these outcomes between investors at the technological frontier and those that lie behind.

As in Melitz (2003), we assume that firms are heterogeneous in their productivity, denoted by φ_i, and that preferences of a representative consumer include the consumption of the numeraire good plus a standard index of consumption of the differentiated products with constant elasticity of substitution equal to $\sigma = \frac{1}{1-\rho}$. More productive firms have an advantage both in terms of lower marginal costs in the production of final goods and of innovation, with the marginal costs of production further decreasing with successful innovation. The cost of producing one unit of output after innovation is equal to $\frac{1}{\varphi_i \gamma_i}$, where the variable $\gamma_i > 1$ denotes innovation output.[7] Price is a constant mark-up over marginal costs and it is equal to $\frac{1}{\rho \varphi_i \gamma_i}$.

The profits of firms that undertake research are equal to $\Pi_i^I = A_i \left(\frac{1-\rho}{\rho}\right) \rho^\sigma (\varphi_i \gamma_i)^{\sigma-1}$, where A_i is the market size relevant to firm *i*. Profits of firms that do not research are equal to $\Pi_i^0 = A_i \left(\frac{1-\rho}{\rho}\right) \rho^\sigma (\varphi_i)^{\sigma-1}$. In order to simplify the notation we drop sub-indices, we denote by $B = A\left(\frac{1-\rho}{\rho}\right)\rho^\sigma$, and we take increasing transformations of the productivity and innovation variables in the following way $\mu = \varphi^{\sigma-1}$ and $\lambda = \gamma^{\sigma-1}$. Consequently, the profits of an R&D active firm can be written as $\Pi^I = B\mu\lambda$, while those of firms that are not R&D active are equal to $\Pi^0 = B\mu$. We denote by V^I the value of R&D active firms, which equals the firm's profits minus the cost of research, and by V^0 the value of firms that do not have R&D, which is just equal to its profits.

Innovation outputs, inventions, are produced with R&D personnel. R&D personnel include scientists and researchers, which we label as high-skilled workers (H) and those in support and administrative roles, which we label as low skilled (L), although we recognise that these may not be viewed as low skilled in the traditional sense. Researchers generate ideas needed for inventions. The number of researchers required to produce one unit of innovation is equal to $\lambda = \mu(E_H H)^\alpha$ with

[7] This multiplicative specification is similar to Bustos (2011) or to Guadalupe et al (2012).

$\alpha < 1$, which captures decreasing returns to knowledge generation or that innovating is more difficult as innovation advances (Aghion and Howitt, 2007). This allows for the possibility of decentralization of the research. The term μ is the increasing transformation of the firm's exogenous productivity defined above and the index $E_H > 1$ denotes the productivity of high-skilled labour. The fixed costs, denoted by $\bar{L}$, are in units of low-skilled workers[8] and reflect the need of administrative staff, lab managers and other support functions to run the research unit.[9]

Each period the firm has to decide whether to undertake research and development or not. If a firm decides to innovate, it chooses the level of innovation output that maximizes its value. This affects the demand for high-skilled workers and research expenditures. We solve the problem by backward induction. First, given the conditional demand for high-skilled workers, we calculate the cost function of research for a given level of innovation output and then determine the optimal innovation output. We then calculate the cost function of research at the optimal innovation output. Finally, we compare the value of the firm if it is R&D active with its value if it is inactive to determine if R&D occurs or not.

2.1 Innovation by Domestic firms

Firms are assumed to operate by minimizing the cost of innovation. Let w_H and w_L be the salaries of high-skilled and low-skilled workers respectively and the conditional demand of high-skilled workers be as follows: $H(\lambda) = \frac{1}{E_H}\left(\frac{\lambda}{\mu}\right)^{\frac{1}{\alpha}}$. The corresponding cost function is equal to: $C(\lambda) = w_H H(\lambda) + w_L \bar{L}$=$\left(\frac{w_H}{E_H}\right)\left(\frac{\lambda}{\mu}\right)^{\frac{1}{\alpha}} + w_L \bar{L}$. Holding everything else constant, firms with higher productivity μ have lower costs of R&D than less productive firms and the cost of research is an increasing function of innovation output.

The firm chooses the optimal level of innovation output that maximizes the value of innovating. The value of an R&D active firm is equal to $V^I = B\mu\lambda - \left(\frac{w_H}{E_H}\right)\left(\frac{\lambda}{\mu}\right)^{\frac{1}{\alpha}} - w_L \bar{L}$. The optimal innovation output is such that the marginal revenue of innovation equals its marginal costs and is therefore equal to $\lambda^* = \left(\frac{B\alpha E_H}{w_H}\right)^{\frac{\alpha}{1-\alpha}} \mu^{\frac{1+\alpha}{1-\alpha}}$.

[8] This is in line with Rossi-Hansberg and Wright (2007) who have a model with fixed costs that depend on the average number of workers to measure organizational costs.

[9] We do not allow for the possibility of substitutability between high and low-skilled workers because we consider that administrative staff cannot replace researchers or scientists in the systematic generation of knowledge. The current specification could be extended for the case of complementarity between these inputs.

Finally we study the decision to whether innovate. A domestically owned firm will choose to innovate if its value from doing so is larger than its value from being R&D inactive. The value function of R&D active firms evaluated at the optimal innovation level equals to $V^I(\lambda^*(\mu)) = V^I(\mu) = T\mu^{\frac{2}{1-\alpha}} - w_L\bar{L}$ with $T = \left(\frac{B\alpha E_H}{w_H}\right)^{\frac{\alpha}{1-\alpha}}(B-1)$. An equilibrium with firms that undertake R&D requires that $B > 1$, and $T\mu^{\frac{2}{1-\alpha}} > w_L F$ for some positive values of μ. The value of a firm that is R&D inactive is equal to $V^0(\mu) = B\mu$. In equilibrium not all firms will innovate. In particular, there exists a unique efficiency threshold, which we label $\bar{\mu}^D$, where firms are indifferent in this choice. This is consistent with evidence from Doraszelski and Jaumandreu (2013) and Hall et al (2010) that show that R&D active firms are typically 'better' than non-R&D firms. Note that if $\bar{\mu}^D$ increases then the probability a domestically owned will be R&D active decreases. The proof is as follows. We want to show that there exists one unique value $\bar{\mu}^D > 0$ such that $V^I(\bar{\mu}^D) = V^0(\bar{\mu}^D)$. The function $V^0(\mu)$ is an increasing linear function of μ with $V^0(0) = 0$. The value function for R&D active firms $V^I(\mu)$ is also an increasing function of μ with $V^I(0) = -w_L F$ and first and second derivatives of V^I with respect to are μ positive. Since the slope of $V^I(\mu)$ is larger than the slope of $V^0(\mu)$, for positive values of μ, these two functions intersect only once. We provide representation of these two value functions and the efficiency threshold in Figure 1.

2.2. The effect of acquisition FDI on innovation

After acquisition, the MNE has to decide whether to conduct R&D in the subsidiary or close the research unit and locate the R&D elsewhere. In other words, do they concentrate R&D in a single location or do they decentralise it. Conditional on decentralization, the MNE then chooses the new level of innovation output, costs and type of R&D workers used in the innovation production function. We consider that these decisions depend critically on three elements: the extent of any knowledge transfers to the subsidiary; current duplications of R&D effort and other cost savings; and thirdly, changes to the opportunity cost of innovation.

We assume that MNEs are able to transfer knowledge from the business group to their affiliates[10] and that this knowledge is complimentary to the high-skilled scientists and researchers in the acquired lab. As motivation, Bloom et al (2012) find that firms taken over by American MNEs

[10] International economists have emphasized the importance of technology transfers within MNEs (Adams and Jaffe, 1996; Bilir and Morales, 2015; Branstetter et al. 2006; Helpman, 1984; Keller, 2010, 2013). There is also evidence that large technological firms like Microsoft or Google have special teams to specifically transfer knowledge across different research units (The Economist, 2007).

increase their productivity of IT while firms acquired by other MNEs do not. This implies that technology transfers require complementary factors to be present to generate new innovations. This framework is general enough to capture innovations in the subsidiary that customize products to the requirements of the local markets or disruptive innovations. We formulate this idea in the simplest way: knowledge transfer leads to an increase in the marginal productivity of high-skilled researchers E_H. This implies that technology transfers increase the demand for researchers and scientists by the affiliate lab and its output, and so the value of innovating in the subsidiary. It of course also affects costs. [11] Consistent with Acemoglu et al (2007), we consider that technology transfers are more likely to occur when acquisition is by an MNE that is at the technological frontier.

We further assume that within the MNE there are economies of scope that are realised by eliminating duplicated R&D activities across the domestic and foreign R&D labs of the MNE. Conditional on the subsidiary remaining R&D active, these economies of scope are likely to happen in support activities such as administration, IT, or advertisement (Harvard Business Review, 2014). We model this as a reduction in the demand for low-skilled workers and the fixed costs of research.

Finally, we assume that acquisition FDI affects the opportunity cost of continuing with R&D in the affiliate. The foreign-multinational firm can locate its R&D expenditures in the most efficient way across the entirety of the business, it can therefore choose to retain the R&D facilities within the subsidiary or close them and relocate those scientists to other R&D labs that it operates abroad. [12] We consider that the opportunity cost of innovating in the subsidiary rather than elsewhere is likely to be highest when acquisition is by a technologically-leading MNE because they are more likely to have highly innovative research units in other parts of the business. Bringing these elements together allows us to study the alternative locations for R&D.

The R&D lab in the new affiliate will be retained if the incremental value of the subsidiary when it innovates with respect to its value when it does not, is larger than the opportunity cost of innovating in elsewhere in the business. We denote by $V^{F,I}(\mu)$ the value function of a firm that has been acquired by a foreign multinational if it is R&D active and by $V^{F,0}(\mu)$ if it is not R&D active. [13] We denote by $\bar{\mu}^F$ the productivity threshold of a subsidiary acquired by a foreign multinational such

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[11] See Appendix.

[12] For example, in the model of Ekholm and Hakkala (2007), the mechanism is through localized knowledge spillovers and a home market effect. In Arkolakis et al (2014) innovation is produced with increasing returns of scale and there are no complementarities with the knowledge of the recently acquired firm.

[13] For ease of exposition, we abstract from the motives for acquisition FDI and consider that the value function of innovative firms increase after innovation but the value function of non-innovative firms remains constant. Our results do not significantly change if we assume that the value of non-innovative firms also increase after acquisition FDI provided that the value of the acquired firm if it innovates is higher than its value if it does not innovate.

that if $\mu > \bar{\mu}^F$ the foreign owned firm innovates (with equality meaning indifference). We can calculate this threshold by solving $V^{F,I}(\bar{\mu}^F) - V^{F,0}(\bar{\mu}^F) > W$, where $W > 0$ is the opportunity cost of innovating for the recently acquired subsidiary. Note that for a non-acquired domestic firm, because R&D activity can only occur at home, this decision simply depends on whether this difference is greater than zero. The probability that innovation occurs in the home country will therefore be lower for a foreign owned firm than for a domestically owned firm if $\bar{\mu}^F > \bar{\mu}^D$. To put this differently, out of the group of R&D active firms, foreign-owned firms will one average display superior characteristics to domestically-owned firms. We show this case in Figure 2.[14]

Our model suggests that for retained research facilities, there is an increase in innovation output and in the number of high skilled workers due to their complementarity with technology transfers. These effects are likely to be strongest if the MNE is at the technological frontier because those firms transfer more knowledge. Any reduction in total R&D expenditures is owed to organizational changes that decrease required numbers of low-skilled personnel. This implies that the reductions in R&D expenditures for firms acquired by MNEs at the technological frontier are lower than those experienced when acquisition is by non-frontier MNEs because of the increase in the number of high-skilled workers in the former. A further implication of the model is that if the opportunity cost of innovation is large, then R&D within the newly acquired subsidiary will be stopped and the scientists will moved to other R&D labs elsewhere or released.

In the next sections we investigate the following implications of the model:

1. Acquisition increases the likelihood that R&D in the subsidiary ceases due to the increase in the opportunity cost of innovating. This effect should be amplified for firms acquired by MNEs with the highest opportunity cost, which are most likely to be MNEs close to the technological frontier.

Conditional on continued R&D in the subsidiary, there is a change in its organization which takes the form of:

2. An effect on R&D expenditures and R&D personnel: (a) A decline in R&D expenditures owing to the removal of duplicated low-skilled R&D activities. For firms acquired by MNEs at the technological frontier this effect is attenuated by an increase in high-skilled scientists. We also expect increased technology transfers from the business group to the subsidiary which are stronger for acquisitions from high technology countries. (b) These same changes can be captured by the composition of employment within the subsidiary.

[14] An alternative scenario would imply that some firms start innovating after foreign acquisition. This possibility is indeed very rare in our data where only 1.6% of firms start R&D, while 24% stop R&D after foreign acquisition.

We anticipate an increase in high-skilled R&D personnel, in particular for subsidiaries acquired by MNEs at the technological frontier.

3. There is an increase in innovation output which we anticipate is driven by the complementarity between technology transfers and high-skilled workers.

3. Data

The data we use is drawn from a yearly survey of Spanish firms called *Panel de Innovación Tecnológica* (PITEC). This survey has been conducted since 2004 by the Spanish National Institute of Statistics as an annualised version of the Spanish Community Innovation Survey (EUROSTAT). We use information for all years between 2004 and 2009. The survey is designed to be an unbalanced panel sample of firms operating in the manufacturing and service sectors.[15] Each year firms are asked to provide information on a number of key performance characteristics, such as sales, number of employees, ownership and industry and, of interest in this paper, answer detailed questions about their R&D expenditures and innovation activities. In order to study the effects of acquisition relative to a counterfactual of non-acquired firms we exclude from the sample firms that are always foreign owned and those that were acquired more than once, along with public firms. Our chosen sample is an unbalanced panel of 10,628 firms, of which 7,719 (73%) have positive R&D expenditures in at least one year and 2,909 (27%) have no R&D expenditures throughout the sample period.

A feature of this data is the detail it contains on different innovation expenditures (these are shown in Tables 1 and 3 and Tables A1 and A2 in the Appendix). The most aggregated measure of expenditure is labelled *total innovation expenditures*. This includes three categories of spending: *internal R&D* (R&D undertaken within the plant); spending on *external R&D* (a firm's purchases of R&D conducted by other firms, including other plants from the same business group); and *non-R&D* expenditures (which includes expenditures on training, market preparations of products or market research and advertising).[16] These three categories account for 73%, 11% and 16% of total innovation expenditures respectively for the average firm.

[15] The panel is unbalanced with 12,817 firms generating a total of 76,902 firm-year observations with an average of five observations per firm.

[16] *External R&D* expenditures are defined as: *"Acquisitions of R&D services through contracts, informal agreements, etc. Funds to finance other companies, research associations, etc, which do not directly imply purchases of R&D services are excluded"*. R&D services are defined as: *"Creative work to increase the volume of knowledge and to create new or improved products and processes (including the development of software)"*. The exact definitions of all other innovation variables are documented in the Table A1 in the Appendix.

The data further allow for the further disaggregation of *external R&D* into domestic purchases or imports. We label these variables *external-domestic R&D*, and *external-foreign R&D*, respectively. For the average firm, external domestic spending accounts for the majority of total external R&D expenditures (93% on average). Finally, the survey also provides information on R&D spending by type of provider. With this information, we can further classify *external-foreign R&D* into *external-foreign R&D within the same business group*, which includes imports from the headquarters and from other affiliates within the same business group. Following Branstetter et al. (2006) we use and denote this measure as direct *technology transfers* within the MNE. [17] External-foreign R&D expenditures additionally include *external-foreign R&D from other private firms*, namely imports from foreign private providers (outside of the same business group), and *external-foreign R&D from foreign non-private providers*, such as Universities, public administration, non-profit organisations (NPO) and other international organizations. These three categories account for 12%, 69% and 19% of expenditures on external foreign R&D respectively, or just 1%, 6% and 1.5% of total innovation expenditures in the average firm. We report evidence on all categories of expenditure except non-R&D expenditures and expenditures on external-foreign private and non-private R&D which are shown in the Appendix.

Alongside detailed innovation expenditures the PITEC data also contain information on the ownership of the firm, specifically the location of the headquarters of the owner. These are provided on a consistent basis across time, therefore allowing us to determine changes in ownership. Following Balsvik and Haller (2010), Bandick et al. (2010), and Guadalupe et al. (2012) among others, we identify foreign acquisition in the sample when we observe a change in the majority equity holder of the firm (i.e. who controls more than 50% of the equity) and the country location of the owner changes from Spanish to some other country.[18] In the data we identify 492 acquisitions of domestic firms by foreign multinationals during the period 2004-2009. Of these 300 (60%) have positive R&D expenditures and 192 (40%) never undertake R&D.

We are also interested in differences across MNEs, in particular whether they are headquartered in technologically intensive countries or not. We adopt a conservative classification of countries as technologically intensive and include only MNEs from Japan, Germany and USA in this group (see Acemoglu, 2009 or Griffith et al., 2004). In the analysis we label these as *JUG countries*

[17] Branstetter et al. (2006) consider royalty payments for the use or sale of intangible assets made by affiliates to parent firms.

[18] This measure is consistent with the IMF (2009) definition of who has ultimate control of the acquired firm and is attractive for the purposes of this paper in that it allows us to assign a unique country of origin to the new affiliate. There is a small number of acquisitions for which the foreign equity share moves to majority ownership but the headquarters is registered as being within Spain. Given our interest in foreign ownership, we drop these firms from the analysis.

and remaining countries as *non-JUG*.[19] In Table 2 column (i), we show the number of acquisitions by country before the matching procedures that we will implement in the following sections. There are 171 acquisitions from JUG countries and 321 from non-JUG countries, mostly from the European Union. We test the robustness of our findings to various categorisations of countries as technology intensive in Section 6. We use three alternative classifications in that section of the paper. In column (ii) of Table 2, we report the average business enterprise R&D expenditures (BERD) as percentage of GDP using OECD data for the period 2004-2009. We use this data to identify the 10 most technologically intensive countries in the data (see column iv) and the 5 least (see column vi). For the final classification we use the list of countries defined by the European Commission as technologically intensive (listed in column v).

Given our interest in the effects of acquisition-FDI on the domestic scientific base, we describe firms as “R&D active” according to whether they record positive internal R&D expenditures. That is, they operate a domestic R&D lab. It follows that some firms whom we view as R&D inactive may have non-zero *total* R&D expenditures in the data because of their marketing or advertising budgets. We denote as *R&D quitters* those firms with positive internal R&D expenditures in one time period that stop, and do not record positive values in any future time period. Within the data, 3,530 non-acquired firms quit R&D at some point during the sample period, which represents 33% of the 10,136 non-acquired firms. Of the 492 acquired firms, 117 cease their R&D operations post-acquisition, which represent 24% of acquired firms. This would appear to suggest that acquisition-FDI reduces the likelihood that R&D facilities in Spain will be shut, but as we show below, as foreign MNEs are more likely to acquire ‘better-performing’ firms and these firms are less likely to shut-their R&D such a conclusion is premature. Finally, we note that there are 8 firms in the dataset that are acquired by a foreign firm and then begin R&D. Given this small number we are unable to provide any formal analysis of their number and note only that it appears to be a relatively unimportant feature of Spanish R&D following FDI.

4. Empirical strategy

The main goal of this paper is to determine the effect of acquisition on the R&D of recently acquired firms. The fundamental evaluation problem when modelling empirically these effects is that

[19] The dataset contains information on the industry in which the acquired firm operates in but does not contain the same information for the acquiring MNE. For this reason we chose against classifying industry-country combinations as on, or behind, the technical frontier.

the counterfactual outcome of not being acquired is unobserved. We follow Balsvik and Haller (2010) and Stiebale (2014) and use a difference-in-differences (DID) approach comparing before and after-acquisition changes in R&D inputs and outputs (treatment group) versus those in firms that have not been acquired (control group). The identifying assumption maintained throughout is that conditional on observable firm, time, industry and region effects that determine selection, acquisition is random. This assumption implies that acquired and non-acquired firms should have similar characteristics on average before acquisition. Therefore, we select the control group using a matching function based on the pre-acquisition observable characteristics of the firm, including their R&D.

To reflect the different questions that we seek to answer we calculate two matching procedures for two different samples. The first set of matched firms is used to analyse the probability that the firm will shut its Spanish R&D facility after foreign acquisition. To reflect this, in the sample from which the control group are drawn we include non-acquired firms that have positive internal R&D expenditures.[20] Some of these firms, both in the treatment and the control group, subsequently close their R&D operations. That is we consider the effects of acquisition on R&D exit, conditional that the firm was R&D active in the past. For the second question we are interested in the predictions form the model of changes to the knowledge production function after acquisition if the MNE chooses to decentralise R&D and retain the newly acquired R&D lab. We therefore restrict the sample of treated and control firms to those firms that maintain open their R&D labs throughout the period. Here, we study the effects of acquisition on R&D expenditures and patents (R&D output), conditional on the firm remaining R&D active.

For both questions, as a first step we estimate a model of the probability of being acquired. Using the information from this regression we apply a caliper propensity score matching procedure. Given that finding a match for a treated unit is difficult when controlling for more than a few variables, Rosenbaum and Rubin (1985) suggest controlling by a function of the vector X instead, which is the conditional probability of receiving treatment given the set of characteristics.[21] In the Appendix, we examine in detail the observed characteristics of the firms that are acquired by foreign multinational firms with respect to non-acquired firms. In Table A3, we show that firms acquired by foreign MNEs are significantly different from non-acquired firms in Spain, with strong evidence of

[20] For example, for firms acquired in the year 2007, we consider firms with internal R&D in any of the years before 2007. The reason for this sample selection is that it only makes sense to analyse the probability of stopping R&D for the sample firms with some internal R&D in the past and that have not stopped previously.

[21] Rosenbaum and Rubin (1983) show that if conditioning on X makes the non-participation outcome independent of the treatment status it is also independent when conditioning on P(X).

cherry-picking.[22] In addition to firm characteristics such as size and productivity this selection is also determined by differences in the knowledge production function. Foreign owned firms target firms that have greater internal R&D expenditures or are multinational in their R&D. While we find some suggestive evidence that there may also be differences in the type of firms acquired by MNEs at the technological frontier from those that lie behind, these differences are not statistically significant. We pair each acquired firm with the closest non-acquired firm in the same industry and year by caliper matching with replacement. [23,24] The matching procedure works well for almost any variable (see Table A4 in the Appendix) implying that control and treatment groups are equivalent in their observable characteristics before acquisition.

5. The Effects of Foreign Acquisitions on the Knowledge Production Function

The next two sections of the paper describe the empirical effects of acquisition-FDI on R&D. The main questions that we seek to understand are: 1) does acquisition-FDI make it more likely that R&D is stopped. For the surviving firms we analyse: 2) what happens to their R&D organization. In particular to (a) their R&D expenditures including their technology transfers and (b) their R&D personnel and 3) what happens to their innovation output, and the complementarity between technology transfers and skilled labor. For all these questions, we compare the outcomes for acquisitions from countries at the technological frontier (Japan, USA and Germany) and elsewhere. In section 6 we test the robustness of that definition of the technological frontier.

5.1. Does Foreign Acquisition Increase the Likelihood Spanish R&D Labs are Shut?

The model in Section 3 predicts that the decision to retain or close the R&D lab in the acquired firm will be made by the MNE by comparing the value of the firm under the strategies of centralising or decentralising this activity. If the increase in the value of the acquired firm is lower than the increase in the opportunity cost of innovating elsewhere in the group, the MNE will shut its newly acquired R&D lab. The model considers that the increase in opportunity cost is likely to be highest

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[22] Harris and Robinson (2002), Benfratello and Sembenelli (2006), Chen (2011), Balsvik and Haller (2010) and Guadalupe et al. (2012) have shown that foreign MNEs are more likely to select domestic firms that are more productive, larger and more likely to conduct R&D.

[23] A presentation of alternative matching possibilities is given in Caliendo and Kopeinig (2008) as well as in Sianesi (2004). Matching is carried out with STATA command PSMATCH2 by Leuven and Sianesi (2003).

[24] To validate the quality of the matching procedure we test whether after matching pre-acquisition variables are balanced between acquired and non-acquired firms. The results of our balancing tests are displayed in Table A4 in the Appendix.

when acquisition is by MNEs at the technological frontier. We examine econometrically the probability of stopping internal R&D expenditures using a Cox proportional hazard model.[25] This model assumes that the observed fraction of firms that ceased internal R&D expenditures in year t, relative to those that do not stop at year t is:

$$h(t) = h_0(t) * \exp\{\varphi Acquisition_{it} + \tilde{\varphi} Acquisition_{it-1} + z_i'\phi\}, \qquad (2)$$

where $h_0(t)$ is the baseline hazard of stopping internal R&D. A value larger than one on φ and $\tilde{\varphi}$ implies that acquisition (either the year of acquisition or one year later) is associated with an increase in likelihood of quitting R&D. Owing to limits on the time series dimension of the panel available to us, we study post-acquisition effects for just two years. The vector x_i' are control variables, and ϕ are the associated parameters to be estimated. Our matching procedure ensures that domestic and acquired firms are similar prior to acquisition.

Before we present the effects of acquisition on the probability of quitting R&D, in Table 3, we provide summary statistics on the firms that remain R&D active alongside those of firms that quit their internal R&D (labelled R&D-quitters). For R&D-quitters, we distinguish between newly acquired firms (from JUG and non-JUG countries) and domestically owned firms never acquired and use data on the year prior to their cessation of R&D. As already noted above a large number of firms stop R&D during the sample period; 33% of non-acquired firms and 24% of acquired firms. There are a number of notable differences between domestically owned firms that stop R&D versus those that remain R&D active and newly acquired firms that stop R&D. In terms of total expenditures the average R&D expenditure of those firms that remain R&D active is €150,000. These expenditures are on average lower for domestically owned that stop R&D (€100,000), but higher for foreign owned firms (€238,000). There are small differences between whether those acquisitions are by JUG or non-JUG MNEs. On average R&D quitters, including foreign acquired ones, also spend a greater share of total R&D on internal R&D.

The table provides some suggestion that the efficiency of R&D (the number of patents they achieve versus their expenditure) is lower for quitters than for those remain R&D active, particularly so for those stoppers that have been acquired by a foreign MNE. The average number of patents is equal to 0.12 for R&D quitters, 0.24 for R&D active and 0.08 for acquired firms that then quit R&D. Those that are acquired by JUG MNEs have on average the lowest recorded patents. This suggests that foreign acquired firms that shut their R&D have on average larger labs than domestically owned

[25] As additional robustness checks not presented here, we also conduct regressions using probit models and linear probability models with fixed effects.

labs that remain open, but given their higher expenditures, they are less efficient at turning these expenditures into successful patents. This is consistent with the findings of Braguinsky et al (2015) suggesting that acquired firms are less profitable.

In Table 4 where we present formal evidence of the effect of foreign acquisition on the probability of stopping for the matched sample. In this table we present the estimated coefficients rather than the hazard ratios, such that a positive (negative) value in the estimated coefficients indicates that acquisition increases (decreases) the probability of quitting R&D. Column (i) shows the effect of acquisition not distinguishing between the effects of location of the headquarters of the acquiring MNEs and column (ii) separates acquisitions that occur from countries technologically leading countries (Germany, Japan and the US) and those from elsewhere.

The results in column (i) show that acquired firms are statistically no more likely to shut their R&D facilities than a domestic firm with similar characteristics prior to acquisition. However, this result changes once we distinguish between firms acquired by JUGs or non-JUGs countries. Compared to the matched sample of firms, acquisition by JUG countries significantly increases the risk of stopping internal R&D expenditures and by a large amount (by 71.6%) in the year of the acquisition. This is supportive of the argument that the opportunity cost of innovating has increased for subsidiaries from technologically leading MNEs. It also suggests that the political fear that foreign MNEs are more likely to shut R&D facilities has some basis.

5.2. Does Acquisition Affect How R&D is Organized?

From our theoretical set-up we would expect that, conditional on the affiliate remaining R&D active, foreign acquisition will lead to an increase in high-skilled workers if knowledge transfers are high-skilled biased. Any decrease in total R&D expenditures is mostly likely to be associated with a decline in the numbers of low-skilled workers. Before drilling down into those specific outcomes we begin by presenting evidence on a more aggregated class of expenditures.

Our measure of innovation expenditures in the subsidiary is *internal R&D*, although for completeness we also report results for *total innovation expenditures and external R&D*. We next report results for various components of external R&D, where this includes those from other domestic firms (*external domestic R&D*) and imported knowledge (*external foreign R&D*). Finally we separate *external foreign R&D* further into knowledge imported within the same business group which is our measure of *technology transfers*. The remaining sub-component of total R&D expenditure (*non-R&D expenditures*) and the remaining components of external foreign R&D

(*external foreign non-private R&D*) and that from other private firms (*R&D external foreign from other private*) are presented in Table A5 in the Appendix. To measure high- and low-skilled workers we use information on the level of education of employees working in R&D. Rather than aggregate these we include them as they are reported in the original data; that is *total employment in R&D*, as well as *employees with a PhD*, *employees with a 5-year BA degree, employees with a 3-year BA degree* and *employees without higher education*. All of the regressions have the standard difference-in-difference form set out in equation (3) estimated on the matched sample of firms that remain R&D active:

$$Y_{it} = \delta + \varphi Acquisition_{it} + \tilde{\varphi} Acquisition_{it-1} + z_i' \phi + \gamma_i + d_t + \vartheta_{it} \quad (3)$$

where represents different elements of the knowledge production function (various measures of innovative expenditures and types of R&D workers).[26] We include in the regression a set of firm-fixed effects, γ_i, such that Equation (3) can be interpreted as a difference-in-differences estimator, examining whether acquired firms deviate in their innovative behaviour compared to that in the pre-acquisition period and compared to the non-treated group. The coefficients of interest are φ and $\tilde{\varphi}$ which measure the post-acquisition change in Y for the treatment group, where we allow this effect to differ in the year of acquisition versus one-year later. Time-dummies are denoted by d_t and capture the effects of any common-shocks that affect both the treatment and the control group together, while ϑ_{it} is the error term. All regressions include the same set of control variables – these are firm size, measured by a set of non-overlapping dummies indicating the lagged number of employees, industry, regional and year dummies. The regression is estimated using robust variance-covariance matrix estimators with clustering at the country level of the parent MNE for acquired firms and of Spain and non-acquired firms.

5.2.1. The effect on post-acquisition R&D expenditures

The effect of foreign acquisition on the different measures of innovation expenditures including technology transfers are presented in Table 5. In Panel A, we show the overall effect of acquisition without distinguishing the country of origin of the acquiring MNE. We make this separation in Panel B.

From Panel A we find significant changes to the pattern of R&D expenditures associated with foreign acquisition. Compared to the control group of R&D active non-acquired firms, total

[26] All the dependent variables are in logarithms. We add one to all these measures to include zero values.

innovation expenditures decrease by 0.634 log points in the year of acquisition (column i). This is equivalent to a decrease of 46.9% from pre-acquisition values. Comparing the results for internal (column ii) versus external R&D (column iii) indicates that this adjustment in the total is associated with a decline in internal R&D spending. According to our results internal expenditures decrease both in the year of acquisition and one year after acquisition, by 17.1% and by 18.1% respectively. As a reminder, internal R&D expenditures consist of the various costs of running a domestic R&D lab. Total R&D spending in the data is also made up of external and non-R&D spending. We find no significant effect on external R&D (column iii), a result which holds for domestic external R&D expenditures (iv) or those from private firms abroad (see Panel A in Table A5 in the Appendix).

The other striking change that occurs to R&D expenditures following foreign-acquisition is the increase in R&D expenditures from outside of Spain (column v), which in this case is accounted for by increases in knowledge flows from elsewhere in the MNE. The value of technology transfers to the acquired R&D lab rise following acquisition indicating the sharing of technical information between the various R&D labs that the MNE operates. The effect of this increase in expenditures would appear to be large; in the period of acquisition transfers of technology from elsewhere in the business group rise by 0.276 log points. This equates to a rise of 31.7% on pre-acquisition levels, although as the summary statistics in Table 1 indicate this is from very relatively low level. Such evidence helps to explain why MNEs have been found to use more intensively external sources of knowledge in the cross-section evidence of Veugelers and Cassiman (2004) and Criscuolo et al. (2010). Our evidence suggests a causal relationship from multinational status and knowledge transfers from abroad.

Panel B extends the analysis to allow for differences in the country of origin of the acquiring firm. Overall the results suggest that the effects of acquisition in Panel A masked some variation in innovation expenditures according to whether the MNE was from a technologically intensive country or not. For both JUGs and non-JUGs countries there is a significant fall in the expenditures on internal R&D in the year of acquisition and in the year following acquisition (column ii) and a contemporaneous increase in the international technology transfers from the same business group (column vi). According to our estimates, when the acquiring MNE is from a technologically advanced country expenditures on internal R&D fall by 10% and then 21.7% following acquisition, whereas technology transfer between the business group rise by 55% and by 18.9%, compared to their pre-acquisition levels. When acquisition is from a non-JUGs country, internal R&D decreases by 19.7% and by 17.1% in the two-years following acquisition and technology transfers increase but only during the year after acquisition by 24%. For JUG countries we also observe a decrease in external R&D expenditures, and in particular on domestic expenditures.

5.2.2. The effect on post-acquisition R&D personnel

Table 6 show the effect of foreign acquisition on the skill mix of employment in R&D. As expected they indicate a shift in the pattern of employment away from low-skilled R&D workers to higher-skilled employment. Evidence from Panel A indicate that acquisition decreases the total number of employees working in R&D (column i). In the year of acquisition there is a decrease by 5% in the number of employees and in the following year the drop is by 6.6%. This decrease is mostly for employees with a 5-year BA degree (column iii) and for those without higher education (column v).

Once we differentiate between JUGs and non-JUGs countries in Panel B, we again observe that there are important differences between types of acquisitions. For acquisitions form JUG countries there is an increase in the number of employees with a Ph.D. (by 3.7%) with respect to the pre-acquisition level and a decrease in the number of employees with a 3-year BA degree (by 7.1% one year after acquisition) as well as those without any higher education (by 5.1% in the year of acquisition and by 18% one year after acquisition). When acquisition is by an MNE from a non-JUG country the number of employees with the highest education or with a 3-year BA degree remain constant compared to the counterfactual, whereas there is a reduction in the number of employees with a 5-year BA degree or without further education. Overall these results are supportive of the idea of skilled bias technology transfer and that any cost savings occur by reducing employment in the lowest skill category groups.

5.3. Does Acquisition Affect Successful Innovation? The role of complementary for Innovation

5.3.1. The effect on post-acquisition innovation output

In previous sections, we have shown that acquisition decreases innovation expenditures, increases technology transfers and reallocates R&D employees towards high-skilled workers. Do these changes make the firms more efficient at generating innovation output, as our model suggests? In this sub-section, we explore the effect of acquisition on innovation output using information on the number of patents, which are measured over 2 and 3 years after acquisition. We begin by follow the same econometric specification than in equation (3) and later extend this to explore more formally the complementarity between technology transfers and high-skilled researchers. Following Bloom et al (2013) we control for current and lagged patenting activity throughout.

In Table 7, columns (i) we report our estimates for the effect of acquisition on the logarithm of the number of patents. We find a positive and significant coefficient of the year after acquisition. The increase in the number of patents is 2.74%. In column (ii) we differentiate between acquisitions by JUG and non-JUG countries. Both types of acquisition have a significant effect on the number of patents and this effect seems strongest when acquisition is from a non-JUG country. This suggests an improvement in the efficiency of R&D inputs after foreign acquisition since, as we have seen, there is a decrease in innovation expenditures and R&D jobs after acquisition. We explore this idea further in columns (iii) and (iv). Our alternative dependent variable is the logarithm of the number of patents measured over 2 and 3 years after acquisition over total R&D expenditures (in millions). The estimates in column (iii) show a clear positive and significant effect of acquisition on the productivity of R&D expenditures: acquired firms are able to patent more than similar domestic firms. This effect holds both for acquisition from JUG and non-JUG countries (column (iv)). The increase in the ratio of patents over total R&D is 9.86% and 26.24% in the year of acquisition and one year after acquisition for acquisitions from JUG countries and 30.08% one year after acquisition for non-JUG countries.

We use the separation of JUG and non-JUG acquisitions within the paper as an empirical tool to capture those MNEs where technology transfers are likely to be of greatest value. As a final exercise we extend this to examine whether the changes in innovation output and the increase in the efficiency in the research lab after acquisition are a consequence of the complementarity between high-skilled workers and the increased technology transfers received from the MNE. To do so we estimate the following equation:

$$Inn_{it} = \delta + \sum_{j=1}^{4} \alpha_j \, Employees\ in\ R\&D_{j,it} + \beta \, TechTransfer_{it} + \sum_{j=1}^{4} \zeta_j \, Employees\ in\ R\&D_{j,it}\, x TechTransfer_{it} + z_i'\phi + \gamma_i + d_t + \vartheta_{it} \quad (4)$$

where Inn_{it} represents the logarithm of the number of patents, measured over 3 years after acquisition, $Employees\ in\ R\&D_{j,it}$ are R&D workers classified by their educational level,[27] $TechTransfer_{it}$ are purchases of R&D form elsewhere in the business group and $Foreign_{it-1}$ is a

[27] For j= employees with a PhD, employees with a 5-year BA degree, employees with a 3-year BA degree and employees without higher education.

dummy variable that takes the value one if the company is foreign owned. As in previous regressions, we include firm-fixed effects and we control by size, industry, regional and time dummies, and current and previous innovation patents. The main variable of interest is the interaction $Employees\ in\ R\&D_{j,it}\ x\ TechTransfer_{it}$ which considers whether the effect on innovation is highest for firms for firms with more high-skilled scientists and researchers and which greater technology transfer from the parent. We anticipate that the estimated coefficient ζ_1 measuring the complementarity between high-skilled workers and technology transfers will be positive. We estimate the model with and without this interaction in regressions (v) and (vi) in Table 7 respectively.

The estimated results in column (v) suggest that technology transfer and employment of the highest-skilled workers in R&D increase significantly the number of patents of the firm. For example, an increase in 1% the number of employees with a Ph.D. increases the number of patents by 5.5% and a similar increase in technology transfers increases patents by almost 3%. In regression (vi) we show that the result for those workers with a PhD is significant only for firms with the largest technology transfers. This is consistent with the idea that technology transfers between the affiliates of an R&D contain highly technical knowledge and are therefore complementary to high-skilled workers. In this case we are able to show that this complementarity increases the number of patents that are registered by the firm. This finding provides support to the theoretical papers where complementarities in the knowledge assets of the MNE and the target firm are the reason for FDI, such as that by Nocke and Yeaple (2008).

6. Robustness checks: Alternative Definitions of Technological Frontier Countries

Within our analysis we consider Japan, USA and Germany (JUG) as countries that lie at the technological frontier.[28] While the empirical results we present in the previous Tables suggests that this assumption is a reasonable partitioning of the acquisitions that take place in the data, in Tables 12 to 15, we test the sensitivity of our results by choosing an increasingly larger set of countries that are described as on, or close to, the technological frontier. We consider three additional sets of classifications, which we describe in Table 2 columns (ii) to (vi). The first alternative classification of country's technological intensity is based on the 10 countries with the highest ratio of Business

[28] Estimating the changes in R&D expenditures separately for acquisitions from Germany, Japan and the US separately suggests that the technology transfers within the firm in column (viii) are largely explained by the FDI from Germany and the US. We find weaker evidence of the same effect for Japan, although it should be noted that there are only 3 acquisitions from this country.

Enterprise R&D expenditures (BERD) over GDP for the period 2004-2009. A second set of classifications is based on information generated by the European Commission and classifies technological leading countries according the European Innovation Scoreboard (EIS) 2009.[29] Finally, we choose the separate the 5 least technologically intensive countries for which we have data on acquisitions (Brazil, India, Mexico, Poland and Portugal) into a separate group. Under the first three measures the greatest sensitivity surrounds the classification of Austria, Hong Kong and the UK. Of these the most relevant empirically is the UK; there are 7 acquisitions by UK MNEs in our sample compared to just one for Austria and Hong Kong. The UK is classified as a frontier country by the European Commission but is not amongst the 10 most R&D intensive countries according to the OECD's BERD measure. In contrast, Austria and Hong Kong are amongst the 10 most R&D intensive countries according to OECD data, but are not classified as technological leaders by the European Commission.

The regressions separating the top 10 countries as a single group are in Panel A, results based on the European Commission classification are in Panel B and the results separating the 5 least technologically intensive countries into a separate group are in Panel C.

In Table 8, we present the regressions that analyse the probability of stopping internal R&D. Comparing the results across the panels with those in Table 4 we note that qualitatively they do not change until we get to panel C. We continue to find across panels A and B evidence of an increase in the probability of stopping internal R&D for firms acquired by technologically advanced countries.[30] Quantitatively the effects are similar in panels A and B compared to Table 4. In Panel C, where we use the broadest definition of FDI from technologically intensive countries and by definition the narrowest definition of what is not, we find little evidence of post-acquisition to the knowledge production when FDI is from technologically intensive countries. However, we do find that there are significant changes to the choice of knowledge inputs for acquisitions from the 5 least technologically intensive countries compared to the control group. For this group, and it should be noticed that these effects are identified from just 7 acquisitions, the results indicate that probability of stopping R&D increases.

In Table 9, we show the effects of foreign acquisition on the different measures on innovative expenditures. The results showed in this Table are highly supportive to Table 5. We find a significant

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[29] Following this source, technologically leading countries include Germany, Denmark, Switzerland, Finland, Sweden and UK. We also add into this group the non-European countries: USA, Japan and Israel.

[30] For panel B the probability of stopping also appears in countries that are not technologically leaders but in a lower extent that for technological leaders

decrease in total innovative expenditures, in internal R&D and a significant increase in the international technology transfers for firms acquired from countries at the technological frontier.

The effects of acquisition on different type of workers in R&D are presented in Table 10. In all panels we observe a decrease in the total number of employees and for workers without higher education for technological advanced countries. We only find evidence of an increase in the number of workers with the highest education for panel A (top 10 countries in terms of BERD as percentage of GDP), while for the other panels, the number of the highest skilled workers remain constant. These results suggest that the average quality of workers at the research centre increases for almost all acquired firms after acquisition, which is supportive to our argument that in general foreign MNEs transfer technology bias towards high-skilled workers. This effect is very pronounced for those acquisitions from leading-edge knowledge countries.

In Table 11, we show our regressions for innovation outputs. Note that in panel C we present results only for the contemporaneous effect of acquisition because the lack of observations for firms acquired from the least technologically intensive countries. Panels A and B reinforce our previous results in Table 7. In column (i), we find a positive coefficient for all groups of foreign acquisition on patents, although the estimates are not precisely measured. The evidence in column (ii) indicates that firms acquired by technological advanced countries tend to be more efficient in their generation of innovation output.

Finally and for completeness, in Table A7 in the Appendix, we re-examine the types of firms that are acquired by MNEs from countries separated according to their technological intensity. In column (i) we compare the affiliates acquired by MNEs from the JUG countries and those countries with a technology level similar to Spain, in column (ii) we compare the JUG acquisitions with those by the 5 least technologically intensive, and in column (iii) those from the technologically similar and 5 least technologically intensive. Few of the coefficients are significant within the table, suggesting that the previous finding that the types of Spanish firms acquired by foreign MNEs are statistically similar to each other continue to hold. Of the three significance coefficients within Table A7 two relate to the comparison with the technologically similar countries. In column (i) we find evidence that those firms acquired by JUG countries have significantly lower external R&D expenditures compared to acquisitions from the technologically similar and there is some evidence of acquisition for transfer pricing reasons. In column (iii) there is evidence that firms acquired by MNEs from countries with a similar technology level to Spain have less physical investment than the 5-least technological advanced countries.

7. Conclusion

In this paper, we consider how the international transfer of knowledge within MNEs and the complementarities across R&D locations affects the optimal structure of innovation activities within multinational firms. We study these within the context of the acquisition of an R&D active domestic firm by a foreign multinational. We provide evidence that only acquisition FDI from technologically advanced countries increases the probability of closing research facilities. Conditional on keeping the newly acquired R&D lab, MNEs reorganizes their research inputs to be more skill intensive. There is a decline in the number of low-skilled workers while high-skilled workers either increase or remain constant. We find that there are transfers of technology from the MNE to the subsidiary, particularly for those firms acquired by MNEs from countries at the technological frontier. Overall there is a decrease in research costs but at the same time an increase in the subsidiary's innovativeness. We find evidence that the complementarity between technology transfers and high-skilled workers is a plausible explanation for why there is a simultaneous rise in high-skilled workers, technology transfers and innovation after acquisition. We also observe that there is an increase in the productivity of high-skilled workers for foreign owned firms that receive more technology transfers from the MNE. Our evidence also suggests that knowledge assets of the target firm may be a motive for acquisition FDI. Together these findings support the role of ownership to transfer intangibles within the MNE. Our results might help to explain the post-acquisition improvements in productivity.

Acknowledgments

We would like to thank Johannes Biesebroeck, Giammario Impullitti, Simon Gächter, Beata Javorcik, María Rochina, and Joel Stiebale for their helpful comments as well as seminar participants at the University of Nottingham, Trento, and 14th ETSG Conference (Leuven), ZEW (Mannheim) and 5th ISGEP workshop (Ljubljana), ICTNET workshop (London), 27th EEA Conference (Malaga), 39th Annual EARIE Conference (Rome).

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TABLES AND FIGURES

Table 1: Summary Statistics of Innovation Expenditures by Type of Firm

	All foreign acquired firms			**Acquired by JUG country MNEs**			**Acquired by Non-JUG country MNEs**			**Non acquired**
Year	*t-1*	*t*	*t+1*	*t-1*	*t*	*t+1*	*t-1*	*t*	*t+1*	
Total Innovation Expenditure (log)	7.84	7.33	7.32	7.98	7.40	7.59	7.77	7.29	7.19	7.68
	(6.55)	(6.62)	(6.61)	(6.41)	(6.63)	(6.62)	(6.63)	(6.62)	(6.61)	(5.95)
share of total innovation expenditure on...										
Internal R&D	0.69	0.62	0.61	0.75	0.61	0.55	0.65	0.62	0.64	0.67
	(0.38)	(0.40)	(0.41)	(0.36)	(0.40)	(0.42)	(0.38)	(0.40)	(0.41)	(0.37)
External R&D	0.12	0.14	0.12	0.08	0.11	0.12	0.14	0.15	0.12	0.12
	(0.24)	(0.27)	(0.25)	(0.21)	(0.24)	(0.26)	(0.26)	(0.28)	(0.25)	(0.23)
Non-R&D innovation	0.22	0.25	0.27	0.21	0.28	0.33	0.23	0.23	0.24	0.22
	(0.35)	(0.37)	(0.40)	(0.35)	(0.38)	(0.42)	(0.35)	(0.36)	(0.39)	(0.34)
Total External R&D Expenditure (log)	2.64	2.68	2.35	1.93	2.64	2.61	3.01	2.71	2.22	2.71
	(5.01)	(5.04)	(4.83)	(4.45)	(5.03)	(5.02)	(5.26)	(5.06)	(4.75)	(4.79)
share of external R&D on...										
External domestic	0.72	0.67	0.75	0.58	0.61	0.63	0.77	0.71	0.82	0.94
	(0.41)	(0.43)	(0.39)	(0.46)	(0.45)	(0.46)	(0.39)	(0.42)	(0.34)	(0.19)
External foreign	0.28	0.33	0.25	0.42	0.39	0.37	0.23	0.29	0.18	0.06
	(0.41)	(0.43)	(0.39)	(0.46)	(0.45)	(0.46)	(0.39)	(0.42)	(0.34)	(0.19)
Total External Foreign Expenditure (log)	1.01	1.15	0.83	0.99	1.27	1.21	1.02	1.08	0.65	0.33
	(3.40)	(3.56)	(3.04)	(3.36)	(3.78)	(3.59)	(3.43)	(3.44)	(2.74)	(1.88)
share of external foreign R&D on...										
External–Foreign - same business group	0.63	0.67	0.67	0.61	0.73	0.76	0.65	0.64	0.59	0.05
(Technology transfers)	(0.47)	(0.45)	(0.46)	(0.49)	(0.41)	(0.42)	(0.48)	(0.48)	(0.50)	(0.21)
External–Foreign - other private firms	0.32	0.29	0.18	0.25	0.21	0.15	0.35	0.33	0.20	0.75
	(0.46)	(0.43)	(0.37)	(0.43)	(0.38)	(0.35)	(0.48)	(0.47)	(0.39)	(0.42)
External-Foreign - non-private firms	0.05	0.04	0.15	0.14	0.06	0.08	0.00	0.03	0.21	0.20
	(0.22)	(0.18)	(0.37)	(0.36)	(0.24)	(0.29)	(0.00)	(0.15)	(0.43)	(0.38)
Number of firms	492	492	384	171	171	122	321	321	262	10,136

Note: The symbol *t-1* denotes one year before acquisition by a foreign MNE; *t* denotes the year of the acquisition; and *t+1* means one year after acquisition. JUG countries are Japan, USA and Germany. Standard deviations are in parenthesis.

Table 2: Number of acquisitions distinguishing by headquarter of the MNE

Country of MNE	Number of acquisitions (i)	BERD as % of GDP (average 2004-2009) (ii)	JUG Countries (iii)	Top 10 BERD countries (iv)	Technological Leaders (v)	Least Technologically Intensive (vi)
Israel	3	3.54		√	√	
Sweden	16	2.62		√	√	
Japan	6	2.58	√	√	√	
Finland	3	2.52		√	√	
Switzerland	22	2.17		√	√	
USA	81	1.87	√	√	√	
Denmark	5	1.80		√	√	
Germany	84	1.79	√	√	√	
Austria	3	1.76		√		
Hong-Kong	1	1.58		√		
Luxembourg	12	1.33				
France	100	1.32				
Belgium	13	1.29				
Canada	4	1.08				
United Kingdom	50	1.08			√	
Netherlands	34	0.96				
Slovenia	1	0.97				
Czech Republic	1	0.90				
Ireland	1	0.86				
Norway	5	0.85				
Spain		0.66				
Italy	29	0.58				
Portugal	11	0.52				√
Brazil	1	0.49[(a)]				√
Mexico	1	0.18				√
Poland	2	0.17				√
Armenia	1	n/a				
India	2	n/a				√
Total	492					

Notes: Period 2004-2009. (a) Data of Brazil are for the year 2006. BERD as % of GDP data come from OECD database. Columns (iv) to (vii) refer to different classifications of technologically leading countries and technologically non-leading countries. Source for column (vi) European Innovation Scoreboard (2009).

Table 3: Summary Statistics of R&D active and R&D quitters distinguishing by headquarter of the MNE

	R&D Quitters				R&D Active
	Non-Acquired	Foreign Acquired			
		All	JUG MNE	Non- JUG MNE	
Total Innovation Expenditure (log)	11.52	12.38	12.32	12.41	11.97
	(1.41)	(1.44)	(1.38)	(1.49)	(2.94)
Share of total innovation expenditure on...					
Internal R&D	0.81	0.85	0.83	0.85	0.77
	(0.26)	(0.26)	(0.26)	(0.25)	(0.27)
Total External Foreign Expenditure (log)	0.21	0.70	0.75	0.68	0.71
	(1.52)	(2.85)	(2.84)	(2.87)	(2.73)
Share of external foreign R&D on...					
External foreign same business group	0.08	0.71	1.00	0.50	0.11
(Technology transfers)	(0.26)	(0.49)	(0.00)	(0.58)	(0.31)
Number of patents	0.12	0.08	0.05	0.10	0.24
	(0.38)	(0.36)	(0.21)	(0.43)	(0.60)
Labour productivity (log)	11.58	11.97	11.93	11.99	11.76
	(1.02)	(0.95)	(1.04)	(0.89)	(0.94)
Physical Investment (log)	8.63	9.93	9.97	9.91	10.40
	(5.40)	(5.94)	(5.65)	(6.14)	(4.97)
Size <50 employees	0.69	0.30	0.27	0.32	0.52
	(0.46)	(0.46)	(0.45)	(0.47)	(0.50)
Size: 50-99 employees	0.14	0.14	0.20	0.10	0.17
	(0.35)	(0.35)	(0.40)	(0.30)	(0.38)
Size: 200-499 employees	0.08	0.20	0.18	0.21	0.11
	(0.27)	(0.40)	(0.39)	(0.41)	(0.31)
Size: >=500 employees	0.06	0.21	0.24	0.18	0.07
	(0.24)	(0.41)	(0.43)	(0.39)	(0.26)
Number of firms	3,530	117	45	72	4,072

Note: JUG countries are Japan, USA and Germany. Standard deviations are in parenthesis. Characteristics of firms that stop R&D measured in the year prior to becoming R&D inactive. Stopping R&D identified by recording zero internal R&D expenditures.

Table 4: The Effect of Foreign Acquisition on the Probability of Quitting R&D using a matched sample of acquired and non-acquired firms

Regression No.	**(i)**	**(ii)**
Foreign acquired		
Year of acquisition	0.205	
	(0.193)	
One year after	0.071	
	(0.259)	
JUG country MNEs		
Year of acquisition		0.540**
		(0.230)
One year after		-0.332
		(0.368)
Non-JUG country MNEs		
Year of acquisition		0.033
		(0.233)
One year after		0.203
		(0.245)
Observations	1,268	1,268

Note: Cox Proportional Hazard estimates. We report coefficients: A positive (negative) value in the estimated coefficients indicates that acquisition increases (decreases) the probability of quitting R&D. Estimated standard errors are clustered at the country level and shown in parenthesis. All regressions include lagged size, sector, and region dummies. * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table 5: The Effect of Foreign Acquisition on Innovation Expenditures for a matched sample of acquired and non-acquired R&D active firms

	Dependent variable: Log(Innovation Expenditure)					
Innovation Expenditure measure:	**Total**	**Internal R&D**	**External R&D**	**External Domestic**	**External Foreign**	**Technology Transfers**
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel A						
Foreign acquired						
Year of acquisition	-0.634***	-0.188**	-0.087	-0.235	0.270**	0.276***
	(0.139)	(0.080)	(0.177)	(0.166)	(0.094)	(0.068)
One year after	-0.140	-0.200**	-0.474	-0.361	-0.108	-0.008
	(0.207)	(0.078)	(0.278)	(0.289)	(0.136)	(0.098)
Observations	1,926	1,926	1,926	1,926	1,926	1,926
R-squared	0.119	0.572	0.025	0.025	0.017	0.014
Number of firms	399	399	399	399	399	399
Panel B						
JUG country MNEs						
Year of acquisition	-0.435***	-0.105**	-0.304***	-0.413***	0.202***	0.438***
	(0.094)	(0.047)	(0.050)	(0.078)	(0.039)	(0.127)
One year after	0.146	-0.245***	-0.685***	-0.752***	-0.053	0.173*
	(0.289)	(0.077)	(0.081)	(0.197)	(0.175)	(0.091)
Non-JUG country MNEs						
Year of acquisition	-0.708***	-0.220**	-0.005	-0.168	0.296**	0.215**
	(0.173)	(0.104)	(0.214)	(0.208)	(0.121)	(0.095)
One year after	-0.228	-0.188*	-0.409	-0.243	-0.124	-0.064
	(0.278)	(0.104)	(0.326)	(0.307)	(0.179)	(0.129)
Observations	1,926	1,926	1,926	1,926	1,926	1,926
R-squared	0.120	0.572	0.025	0.026	0.017	0.015
Number of firms	399	399	399	399	399	399

Note: Fixed effects-OLS estimates. Estimated standard errors are clustered at the country level and shown in parenthesis. All regressions include firm-fixed effects, lagged size, sector, region, and year dummies. Internal and external R&D expenditures are sub-components of total innovation expenditures. Internal R&D is the R&D undertaken within the firm. External R&D is the purchases of R&D by the firm. External domestic and external foreign are sub-components of external R&D. External domestic are the purchases of R&D in Spain by the firm and external foreign are the imports of R&D. Technology transfers is a sub-component of external foreign. Technology transfers are the imports of R&D from the business group by the firm * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table 6: The Effect of Foreign Acquisition on Employment by Skill Type using matched sample of acquired and non-acquired firms

	Dependent variable: Log(Employees in Internal R&D)				
Employees in Internal R&D measure:	**Total**	**With Ph.D.**	**With 5-year Undergrad degree**	**With 3-year Undergrad degree**	**Without higher education**
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**
Panel A					
Foreign acquired					
Year of acquisition	-0.050**	0.001	-0.046**	0.006	-0.052*
	(0.023)	(0.025)	(0.019)	(0.033)	(0.026)
One year after	-0.068***	0.002	-0.057*	-0.044	-0.087**
	(0.020)	(0.023)	(0.030)	(0.033)	(0.038)
Observations	1,926	1,926	1,926	1,926	1,926
R-squared	0.305	0.036	0.163	0.065	0.085
Number of firms	399	399	399	399	399
Panel B					
JUG country MNEs					
Year of acquisition	-0.017	0.036***	-0.025	-0.021	-0.052***
	(0.010)	(0.008)	(0.037)	(0.014)	(0.012)
One year after	-0.073***	-0.009	-0.015	-0.074*	-0.199***
	(0.019)	(0.020)	(0.013)	(0.038)	(0.068)
Non-JUG country MNEs					
Year of acquisition	-0.062*	-0.013	-0.054**	0.017	-0.053
	(0.031)	(0.028)	(0.026)	(0.042)	(0.034)
One year after	-0.067**	0.005	-0.069*	-0.035	-0.054**
	(0.030)	(0.029)	(0.037)	(0.036)	(0.019)
Observations	1,926	1,926	1,926	1,926	1,926
R-squared	0.305	0.036	0.163	0.065	0.087
Number of firms	399	399	399	399	399

Note: Fixed effects-OLS estimates. Estimated standard errors are clustered at the country level and shown in parenthesis. All regressions include firm-fixed effects, lagged size, sector, region, and year dummies. * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table 7: The Effect of Foreign Acquisition on Innovation Output using a matched sample of acquired and non-acquired R&D active firms

	Dependent variable: Log(Innovation output)					
Innovation output measure:	**No. of patents**		**No. patens/total inno. expenditures**		**No. of patents**	
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Foreign acquired						
Year of acquisition	0.013		0.081			
	(0.016)		(0.053)			
One year after	0.027*		0.254***			
	(0.014)		(0.086)			
JUG country MNEs						
Year of acquisition		0.009**		0.094***		
		(0.004)		(0.014)		
One year after		0.030		0.233***		
		(0.023)		(0.057)		
Non-JUG country MNEs						
Year of acquisition		0.015		0.077		
		(0.021)		(0.066)		
One year after		0.027*		0.263**		
		(0.014)		(0.101)		
Employees in internal R&D						
With Ph.D.					0.054***	-0.043
					(0.016)	(0.056)
With 5-year Undergrad degree					-0.010	-0.018*
					(0.010)	(0.010)
With 3-year Undergrad degree					0.042	0.029
					(0.053)	(0.050)
Without higher education					-0.039*	-0.012
					(0.019)	(0.015)
Technology Transfer					0.029***	0.010***
					(0.004)	(0.003)
Complementarities:						
Technology Transfer x Employees						
With Ph.D.						0.074***
						(0.005)
With 5-year BA degree						-0.003**
						(0.001)
…With 3-year BA degree						-0.012***
						(0.004)
Without higher education						-0.009***
						(0.002)
Observations	1,128	1,128	669	669	732	732
R-squared	0.040	0.040	0.056	0.057	0.140	0.244
Number of firms	396	396	271	271	386	386

Note: Fixed effects-OLS estimates. Estimated standard errors are clustered at the country level and shown in parenthesis. In columns (i), (ii), (v) and (vi), the dependent variable is the logarithm of the number of patents for the 2 and 3 years following acquisition. In columns (iii) and (iv), the dependent variable is the logarithm of the number of patents for the 2 and 3 years following acquisition over total innovation expenditures. All regressions include the logarithm of current and previous two years patents, firm-fixed effects, lagged size, sector, region, and year dummies. * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table 8: The Effect of Foreign Acquisition on the Probability of Stopping Internal R&D Expenditures Based on Randomized Sample: Alternative Definitions of Technologically Intensive Countries

Panel A: Top 10 and non-top 10 in terms of BERD as percentage of GDP[b]	
Top 10	
Year of acquisition	0.533*
	(0.277)
One year after acquisition	-0.376
	(0.385)
Not Top 10	
Year of acquisition	-0.014
	(0.220)
One year after acquisition	0.222
	(0.246)
Panel B: Technological leaders and non-leaders (Source European Commission)[c)]	
Technological Leader	
Year of acquisition	0.545**
	(0.262)
One year after acquisition	-0.414
	(0.346)
Not Techno. Leader	
Year of acquisition	-0.165
	(0.299)
One year after acquisition	0.349*
	(0.189)
Panel C: 5 least technologically intensive countries	
More Techno. Intensive	
Year of acquisition	0.268
	(0.192)
One year after acquisition	-0.035
	(0.285)
Least Techno Intensive	
Year of acquisition	-43.820
	(0.000)
One year after acquisition	0.561***
	(0.211)

Note: See note in previous Table. For classification of countries a), b) and c) see Table 2.

Table 9: The Effect of Foreign Acquisition on Innovation Expenditures for non-stoppers Based on the Randomized Sample: Alternative Definitions of Technologically Intensive Countries

	Dependent variable: Log(Innovation Expenditure)					
Innovation Expenditure measure	**Total**	**Internal R&D**	**External R&D**	**External Domestic**	**External Foreign**	**Technology Transfers**
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel A: Top 10 and non-top 10 in terms of BERD as percentage of GDP[b)]						
Top 10						
Year of acquisition	-0.359*	-0.200*	0.036	-0.124	0.196	0.301**
	(0.191)	(0.110)	(0.278)	(0.282)	(0.170)	(0.120)
One year after acquisition	-0.128	-0.392**	-0.730***	-0.654**	-0.334	0.065
	(0.445)	(0.173)	(0.155)	(0.264)	(0.246)	(0.125)
Not Top 10						
Year of acquisition	-0.779***	-0.183*	-0.153	-0.295	0.308***	0.263***
	(0.166)	(0.105)	(0.258)	(0.235)	(0.100)	(0.086)
One year after acquisition	-0.148	-0.112	-0.358	-0.228	-0.004	-0.042
	(0.232)	(0.087)	(0.353)	(0.341)	(0.156)	(0.140)
Panel B: Technological leaders and non-leaders (Source European Commission)[c)]						
Technological Leader						
Year of acquisition	-0.524**	-0.293**	0.025	-0.221	0.290*	0.331***
	(0.202)	(0.139)	(0.212)	(0.220)	(0.140)	(0.093)
One year after acquisition	-0.007	-0.221	-0.472**	-0.401	-0.034	0.183
	(0.303)	(0.129)	(0.214)	(0.276)	(0.206)	(0.114)
Not Techno. Leader						
Year of acquisition	-0.733***	-0.094	-0.188	-0.248	0.252**	0.226**
	(0.196)	(0.087)	(0.335)	(0.269)	(0.112)	(0.092)
One year after acquisition	-0.253	-0.183	-0.476	-0.327	-0.171	-0.169*
	(0.326)	(0.112)	(0.484)	(0.464)	(0.192)	(0.088)
Panel C: 5 least technologically intensive countries						
More Techno. Intensive						
Year of acquisition	-0.657***	-0.229**	-0.026	-0.199	0.295***	0.281***
	(0.140)	(0.081)	(0.170)	(0.166)	(0.093)	(0.070)
One year after acquisition	-0.134	-0.206**	-0.389	-0.299	-0.087	-0.008
	(0.213)	(0.082)	(0.268)	(0.280)	(0.130)	(0.098)
Least Techno Intensive						
Year of acquisition	0.054	0.990	-1.798	-1.252	-0.461	0.121
	(0.911)	(0.984)	(1.736)	(1.272)	(0.550)	(0.100)
One year after acquisition	-0.358	0.044	-3.686***	-2.698*	-0.910	-0.024
	(0.260)	(0.246)	(0.552)	(1.356)	(0.978)	(0.107)

Note: See note in previous Table. For classification of countries a), b) and c) see Table 2.

Table 10: The Effect of Foreign Acquisition on Type of Workers in R&D for Non-Stoppers Based on the Randomized Sample: Alternative Definitions of Technologically Intensive Countries

	Dependent variable: Log(Employees in Internal R&D)				
Employees in Internal R&D Measure	**Total**	**With Ph.D.**	**With 5-years BA degree**	**With 3-years BA degree**	**Without Higher Education**
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**
Panel A: Top 10 and non-top 10 in terms of BERD as percentage of GDP[b)]					
Top 10					
Year of acquisition	-0.040	0.032***	-0.041	-0.046	-0.053**
	(0.033)	(0.011)	(0.032)	(0.029)	(0.022)
One year after acquisition	-0.078***	-0.012	-0.028	-0.021	-0.167**
	(0.022)	(0.016)	(0.018)	(0.057)	(0.061)
Not Top 10					
Year of acquisition	-0.054	-0.016	-0.048*	0.034	-0.052
	(0.032)	(0.029)	(0.026)	(0.041)	(0.036)
One year after acquisition	-0.064*	0.009	-0.070	-0.055	-0.051**
	(0.035)	(0.032)	(0.042)	(0.039)	(0.019)
Panel B: Technological leaders and non-leaders (Source European Commission)[c)]					
Technological Leader					
Year of acquisition	-0.050	0.015	-0.052*	-0.016	-0.071***
	(0.031)	(0.018)	(0.026)	(0.027)	(0.023)
One year after acquisition	-0.047***	-0.019	-0.003	-0.049	-0.116*
	(0.016)	(0.012)	(0.017)	(0.051)	(0.064)
Not Techno. Leader					
Year of acquisition	-0.049	-0.012	-0.041	0.027	-0.036
	(0.039)	(0.035)	(0.030)	(0.055)	(0.034)
One year after acquisition	-0.086	0.020	-0.102*	-0.040	-0.063**
	(0.050)	(0.033)	(0.050)	(0.034)	(0.024)
Panel C: 5 least technologically intensive countries					
More Techno. Intensive					
Year of acquisition	-0.055**	-0.002	-0.042**	0.004	-0.052*
	(0.024)	(0.025)	(0.019)	(0.034)	(0.027)
One year after acquisition	-0.069***	0.005	-0.056*	-0.041	-0.088**
	(0.021)	(0.024)	(0.030)	(0.033)	(0.039)
Least Techno Intensive					
Year of acquisition	0.105	0.086	-0.165	0.078	-0.056
	(0.171)	(0.125)	(0.134)	(0.113)	(0.060)
One year after acquisition	-0.036	-0.104	-0.111	-0.156	-0.061
	(0.069)	(0.069)	(0.080)	(0.193)	(0.111)

Note: See note in previous Table. For classification of countries a), b) and c) see Table 2.

Table 11: The Effect of Foreign Acquisition on Innovation Output for Non-Stoppers Based on the Randomized Sample: Alternative Definitions of Technologically Intensive Countries

	Dependent variable: Log(Innovation output)	
Innovation output measure:	**No. of patents**	**No. patens/total inno. expenditures**
Regression No.	**(i)**	**(ii)**
Panel A: Top 10 and non-top 10 in terms of BERD as percentage of GDP[b)]		
Top 10		
Year of acquisition	0.033	0.001***
	(0.031)	(0.000)
One year after acquisition	0.042	0.002***
	(0.026)	(0.000)
Not Top 10		
Year of acquisition	0.003	0.001**
	(0.022)	(0.000)
One year after acquisition	0.021	0.002***
	(0.016)	(0.000)
Panel B: Technological leaders and non-leaders (Source European Commission)[c)]		
Technological Leader		
Year of acquisition	0.029	0.001***
	(0.024)	(0.000)
One year after acquisition	0.032	0.002***
	(0.019)	(0.000)
Not Techno. Leader		
Year of acquisition	0.001	0.001*
	(0.025)	(0.000)
One year after acquisition	0.023	0.002***
	(0.017)	(0.000)
Panel C: 5 least technologically intensive countries		
More Techno. Intensive		
Year of acquisition	0.007	0.000
	(0.014)	(0.000)
Least Techno Intensive		
Year of acquisition	0.019	0.000
	(0.042)	(0.000)

Note: See note in previous Table. For classification of countries a), b) and c) see Table 2.

Appendix

The effect of the productivity of high skilled workers with respect to the demand of high-skilled workers, optimal innovation output, cost function and value function.

The derivatives of optimal innovation output, demand of high-skilled workers, cost function and value functions at the optimal innovation level with respect to E_H are respectively equal to: $\frac{\partial\lambda}{\partial E_H} = \frac{\alpha}{1-\alpha}\frac{\lambda}{E_H} > 0$; $\frac{\partial H(\lambda(E_H))}{\partial E_H} = \frac{\alpha}{1-\alpha}\frac{H}{E_H} > 0$; $\frac{\partial C(\lambda(E_H))}{\partial E_H} = \frac{\alpha}{1-\alpha}\frac{H}{E_H}w_H > 0$

and $\frac{\partial V^I(\lambda(E_H))}{\partial E_H} = \frac{\alpha}{1-\alpha}\frac{V^I + w_L\bar{L}}{E_H} > 0$

Figure 1: The decision to either innovate or not innovate

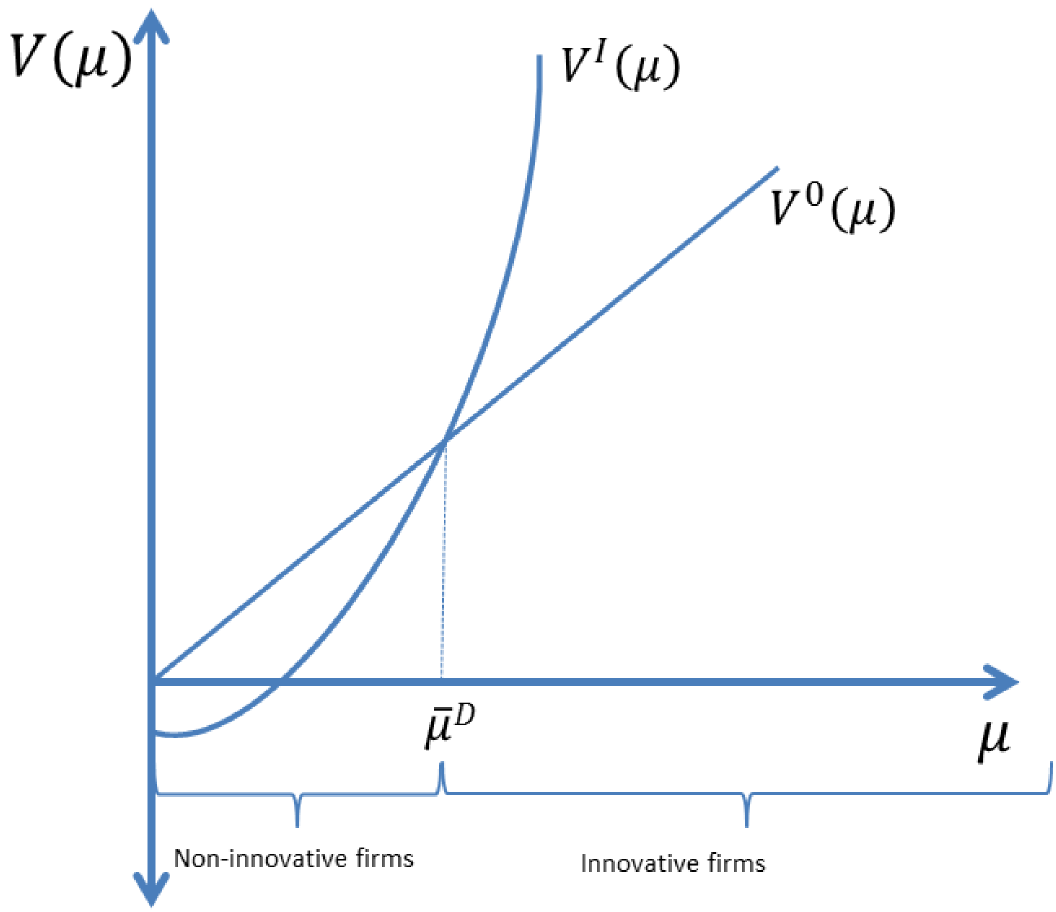

Figure 2: The effect of foreign ownership on the decision to innovate.

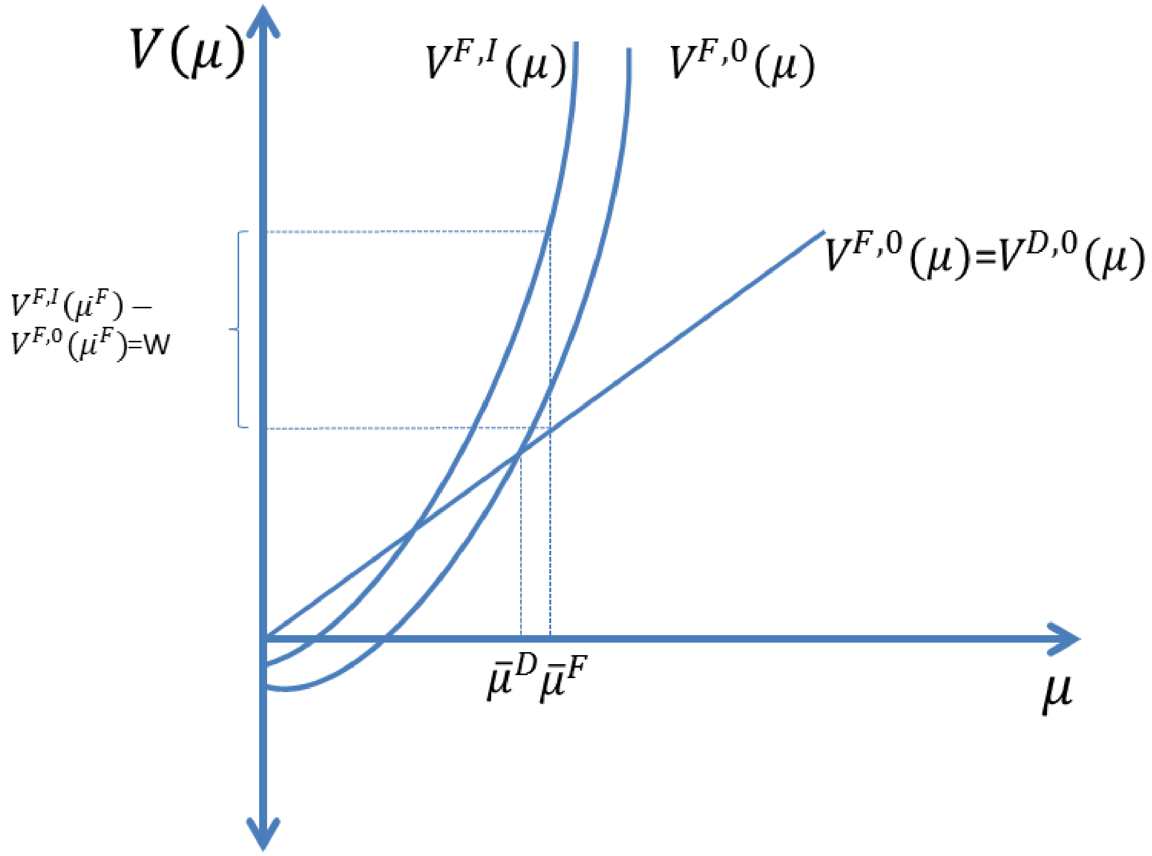

Table A1: Classification of total innovation expenditures

Subcategories of *Total innovation expenditures*	[1-3]	Definition
R&D internal	[1]	In-house or intramural R&D: Creative work undertaken within an enterprise on an occasional or regular basis in order to increase the stock of knowledge and its use to devise new and improved goods, services and processes.
R&D external	[2]	Acquisition of R&D or extramural R&D: Firm purchases of creative work on an occasional or regular basis in order to increase the stock of knowledge and its use to devise new and improved goods, services and processes form other companies (including other enterprises within the group) or public and private research organizations
R&D external-domestic	[2.1]	Acquisition of R&D in Spain.
R&D external-foreign	[2.2]	Acquisition of R&D abroad.
R&D external-foreign same business group (Technology transfers)	[2.2.1]	R&D acquisitions abroad from companies that belong to the same business group
R&D external-foreign other private	[2.2.2]	R&D acquisitions abroad from companies that are legally independent and do not belong to the same business group
R&D external-foreign non-private	[2.2.3]	R&D acquisitions abroad from public administrations, universities, non-profit organizations and other international organizations
Innovation expenditures other than R&D	[3]	*Acquisition of machinery, equipment and software*: Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes, or delivery methods. *Acquisition of external knowledge*: Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organizations. *Expenditures on design functions* for the development or implementation of new or improved goods, services and processes. Expenditure on design in the R&D phase of product development should be excluded. *Internal or external training for personnel* specifically for the development and/or introduction of innovations. Expenditures on all activities concerning *market preparation* and introduction of new or significantly improved goods and services, including market research and launch advertising.

Note: The numbers correspond to the classification of innovation expenditures, which we use in tables 3 and 6 to 9. Data are in Euros. We take the logarithms of these variables to construct the variables that we use in the empirical analysis (Source PITEC database).

Table A2: Summary Statistics of Innovation Expenditures by Type of Firm

	All acquired firms			Acquired firms from JUG countries			Acquired firms from non-JUG countries			Never acquired
Year	*t-1*	*t*	*t+1*	*t-1*	*t*	*t+1*	*t-1*	*t*	*t+1*	
Non-R&D Expenditures (log)	3.84	3.58	3.58	3.61	3.83	4.35	3.97	3.44	3.23	3.71
	(5.65)	(5.55)	(5.57)	(5.52)	(5.72)	(5.93)	(5.73)	(5.47)	(5.37)	(5.22)
External foreign same business group (log)	0.70	0.86	0.62	0.65	1.06	1.02	0.73	0.76	0.45	0.03
	(2.90)	(3.15)	(2.70)	(2.77)	(3.47)	(3.33)	(2.98)	(2.97)	(2.34)	(0.58)
External foreign other private firms (log)	0.33	0.38	0.18	0.30	0.38	0.29	0.35	0.38	0.13	0.26
	(1.95)	(2.07)	(1.41)	(1.92)	(2.24)	(1.80)	(1.96)	(1.97)	(1.20)	(1.67)
External foreign non-private firms(log)	0.04	0.04	0.11	0.12	0.06	0.09	0.00	0.03	0.12	0.08
	(0.63)	(0.65)	(1.07)	(1.08)	(0.76)	(0.94)	(0.00)	(0.59)	(1.12)	(0.92)
Number of firms	492	492	384	171	171	122	321	321	262	10,136

Note: The symbol *t-1* denotes one year before acquisition by a foreign MNE; *t* denotes the year of the acquisition; and *t+1* means one year after acquisition. JUG countries are Japan, USA and Germany. Standard deviations are in parenthesis.

Characteristics of acquired firms

In this section, we examine the characteristics of the acquired firms. We use a probit model. We regress a dummy variable indicator of whether the firm becomes acquired during the sample period on various innovation inputs, controlling simultaneously for a number of other factors that potentially influence this probability.[31] Formally,

$$Acquisition_{it} = \begin{cases} 1 & \text{if} \quad \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} > 0 \\ 0 & \text{if} \quad \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} \leq 0. \end{cases} \tag{1}$$

In equation (1), $Acquisition_{it}$ is a dummy variable that takes the value one if there is a change from domestic to foreign ownership. The rate of foreign-acquisition within the data is 4.6%.[32] The vector X_{it-1} reflects pre-treatment firm characteristics that influence acquisition, d_t denotes time dummies, and ε_{it} is the error term, which we assume is normally distributed with variance σ_{ε}^2. In all regressions we use cluster robust standard errors.

We use the results in Table A3 to test whether any of the R&D variables, the level of innovation expenditures or their intensity and the mix of expenditures on internal and external R&D, help to identify firms that were more likely to be acquired. In Table A3 column (i) we include the logarithm of total innovation expenditures and a measure of the innovation intensity of the firm. In column (ii) we add to the regression a measure of the ratio of external to internal R&D and two measures of expenditures on *external foreign R&D within the same business group*. Two measures of this type of expenditures are used because the dataset includes detailed information on the international structure of a firms' R&D, but it does not include the same information on its production structure. Put differently, we do not know whether the acquired firm is a MNE in its production or not, only whether it is an MNE in its R&D or not. As it is likely that the unobserved MNE status of its production is positively correlated with the observed MNE status of its R&D we attempt to separate the effects of these two by including in the regression a dummy variable equal to one if the plant had overseas R&D facilities alongside the level of these expenditures (*external same business*

[31] We use a pooled cross-sectional approach. The results also hold if we use a random effect probit model or with a linear probability model with fixed effects.

[32] This number is similar to the 4.3% acquisition rate that Braguisnky et al (2015) show for Japan at the beginning of the 20th century although higher than for the numbers that these authors review for the US.

group dummy).[33] Finally, in column (iii) we replace the measure of total innovation expenditures with its sub-components of logarithm of external and internal R&D, whilst retaining the *external foreign R&D* variables. Following evidence from Chen (2011) and others we also include in all regressions a set of other non-R&D variables including measures of labour productivity (measured as sales over employees), physical investment per employee, sales growth and firm size (employees). In order to test for possible non-linearity we create a set of size bands equal to one if the firm has employment of <50, 50-99, 100-199, 200-499 or 500+. We choose the size band 100-199 as the omitted category such that all marginal effects are calculated relative to that group. We also include a set of regional dummies to control for any agglomeration effects and industry dummies.

Finally we consider the possibility of transfer pricing by MNEs in order to move profits to low-tax jurisdictions, a factor that may be particularly relevant given the difficulty of pricing flows of intangible assets between countries (Devereux and Griffith, 2002). To control for this possibility we follow Branstetter et al. (2006) and include in the regressions a measure of *relative corporate taxes* between Spain and the country of origin of the acquiring MNE. We construct the ratio of corporate income taxes of a given country to the corporate income taxes of Spain. The data come from the from the OECD tax database. If corporate taxes are higher in Spain than in the other country, MNEs might be expected acquire domestic firms in order to increase their innovation expenditures in Spain, thereby reducing taxable profits in the high-tax country. If transfer pricing were a relevant source of differences in behaviour between MNEs from different countries we would expect a negative relationship between our measure of *relative corporate taxes* and probability of acquisition.

From the non-R&D characteristics we find evidence of selection of the best firms for acquisition. From column (i) in Table A3, we find that the probability of acquisition by a foreign MNE is increasing in the labour productivity and size of the firm. Conditional on size and labour productivity acquired firms have lower capital investment per employee and lower sales growth. We also find strong evidence of transfer pricing as a motive for acquisition. The regression shows that the probability of acquisition is 5.4% higher from countries with lower corporate taxes than Spain.

[33] Our assumption is that the dummy variable will capture whether being a MNE (in R&D and/or possibly production) matters or not for acquisition and that the intensity variable reflects more clearly the effects of the type of knowledge inputs the firm uses.

The regressions reveal that the probability of acquisition is increasing in the technological intensity of the firm, given by the innovation expenditure/total turnover of the firm, but is unaffected by total innovation expenditure. From this it would appear that the mix of R&D expenditures is more important than the total in determining the likelihood of acquisition. The marginal effects reported in the table suggest that the effect of innovation intensity is similar in magnitude to that estimated for labour productivity. In column (ii) we find evidence that the relationship between total innovation spending and acquisition is explained by the multinational R&D status of the firm. Firms with R&D facilities abroad are 2.6% more likely to be acquired. This result might indicate that foreign multinationals view the knowledge assets of Spanish owned MNEs to be superior to those of non-MNEs, or perhaps more likely given the insignificance of the R&D intensity variables, that foreign-MNEs view Spanish MNEs as more attractive targets for acquisition than non-MNEs.

In regression (ii) of Table A3 we continue to find no effect on the probability of acquisition from the ratio of external/internal R&D intensity, a result consistent with the summary statistics in Table 1. However, when we replace this intensity with the (logged) level of internal and external R&D expenditures (columns iii and iv) we find a significant effect. Interestingly the level of internal and external R&D have oppositely signed effects on the probability of being acquired. The fact that firms that have greater expenditures on external knowledge are less likely to be acquired whereas those with higher internal R&D expenditures are more likely, is consistent with the view that foreign MNEs value highly the internally generated aspects of new knowledge.[34] A more general conclusion that one might draw from the results is that in addition to standard measures of performance such as size, R&D inputs also play a role in determining which firms are targeted for acquisition FDI.[35]

In the remaining regressions in Table A3 we explore whether there are differences between acquisitions made by MNEs from Germany, Japan and the US as our MNEs from the technological frontier and those made by MNEs from other countries. In these regressions we use the specification used to generate the results in regression (iv) as the relevant comparison. In regression (v) we include only acquisitions made by MNEs from Germany, Japan and the US, and column (vi) we only include acquisitions by MNEs from elsewhere. There is one noticeable difference between the results in these two columns. The estimated

[34] Upon further investigation we found that this negative effect is attributable to external domestic R&D expenditures.

[35] As additional controls, not reported here, we include patent output in the regressions and the results do not change significantly.

marginal effect on the dummy indicating expenditures on R&D from other subsidiaries abroad is larger in column (vi) compared to when we use acquisitions from Germany, Japan and the US only (column v). This would seem to suggest that MNEs from less technologically intensive countries place the greatest value on the knowledge generated internally by the firm. However, when we test for differences between the firms that are acquired by MNEs from Germany, Japan and the US compared to MNEs from other countries in column (vii) we find that none of these differences are statistically significant at conventional levels with the exception of the ratio of external/internal R&D intensity variable.

Table A3: Characteristics of Acquired firms

Sample	All firms	All firms	All firms	All firms	JUG vs. non-acquired	Non-JUG vs. non-acquired	JUG vs. non-JUG
Regression No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**	**(vii)**
Log(Total innovation expenditure)	-0.0001	0.0005					
	(0.000)	(0.000)					
Log(Total innovation /turnover)	0.0028*	-0.0003					
	(0.001)	(0.002)					
External R&D/internal R&D		-0.0000					
		(0.000)					
Log(internal R&D)			0.0001*	0.0001*	0.0000	0.0001	-0.0008
			(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Log(external R&D)			-0.0003***	-0.0003***	-0.0001***	-0.0002**	-0.0062***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
External R&D same		0.0000	0.0000				
business group/external R&D		(0.000)	(0.000)				
External R&D same		0.0263**	0.0611***	0.0618***	0.0154*	0.0654***	-0.0011
business group dummy		(0.012)	(0.020)	(0.016)	(0.009)	(0.016)	(0.032)
Labour productivity	0.0024***	0.0020***	0.0022***	0.0022***	0.0007***	0.0014***	0.0025
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.012)
Physical investment	-0.0002*	-0.0003***	-0.0001	-0.0001	-0.0000	-0.0001**	-0.0009
per employee	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)
Sales growth	-0.0015**	-0.0016	-0.0016**	-0.0016**	-0.0004	-0.0011*	0.0155
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.029)
Size <50 employees	-0.0107***	-0.0089***	-0.0094***	-0.0094***	-0.0022***	-0.0066***	-0.0127
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.032)
Size: 50-99 employees	-0.0032***	-0.0029***	-0.0028***	-0.0028***	-0.0002	-0.0025***	0.0310
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.041)
Size: 200-499 employees	0.0009	-0.0011	0.0011	0.0011	0.0011	-0.0001	0.0318
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.033)
Size: >=500 employees	0.0054***	-0.0017	0.0053***	0.0053***	0.0019*	0.0030**	-0.0039
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.034)
Relative corporate taxes	-0.0541***	-0.0458***	-0.0491***	-0.0491***	-0.0160***	-0.0369***	-0.0915**
	(0.005)	(0.007)	(0.005)	(0.005)	(0.003)	(0.005)	(0.040)
Observations	34,948	18,109	34,948	34,948	34,308	34,567	1,021

Note: In columns (i) to (vi), the dependent variable is a dummy variable that takes the value one if the firm is acquired in year t, and zero otherwise. In column (vii), the dependent variable is a dummy variable that takes the value one if the firm is acquired by a MNE from either Germany, Japan or the US (JUG) in year t, and zero if the acquisition is by a MNE from a non-JUG country. All estimations use a probit model. The coefficients refer to marginal effects calculated at sample means. Estimated standard errors are clustered at the firm level and shown in parenthesis. All independent variables are lagged one period and are in logarithms except dummy variables. All regressions include region and year dummies. * Significant at 10%. ** significant at 5%. *** significant at 1%

Table A4: Test of balancing hypothesis.

	Sample of all firms				Sample of non-stoppers			
	Treated	Control	t-test	p-value	Treated	Control	t-tes	p-value
Log(internal R&D)	12.03	12.07	-0.29	0.77	5.87	6.53	-1.04	0.30
Log(external R&D)	6.72	6.55	0.41	0.68	2.43	3.45	-2.04	0.04
External same business group dummy	0.04	0.08	-0.80	0.43	0.04	0.08	-1.62	0.11
Labour productivity	0.28	0.36	-1.31	0.19	12.03	12.15	-1.11	0.27
Physical investment per employee	0.19	0.20	-0.31	0.76	6.31	5.93	0.99	0.33
Sales growth	0.19	0.13	1.16	0.25	0.06	0.04	0.61	0.54
Size <50 employees	0.13	0.12	0.19	0.85	0.16	0.18	-0.52	0.60
Size: 50-99 employees	1.02	1.00	1.70	0.09	0.14	0.17	-1.09	0.28
Size: 200-499 employees	12.03	12.07	-0.29	0.77	0.27	0.16	2.64	0.01
Size: >=500 employees	6.72	6.55	0.41	0.68	0.27	0.32	-1.29	0.20
Relative corporate taxes	0.04	0.08	-0.80	0.43	0.99	1.00	-1.25	0.21

Table A5: The Effect of Foreign Acquisition on Innovation Expenditures Based on the Randomized Sample

	Dependent variable: Log(Innovation Expenditure)		
Innovation Expenditure Measure	**Non-R&D**	**External Foreign Other Private**	**External Foreign Non-private**
Regression No.	**(i)**	**(ii)**	**(iii)**
Panel A			
Year of acquisition	-1.038***	0.012	0.013
	(0.284)	(0.083)	(0.014)
One year after acquisition	-0.343	-0.163	0.053
	(0.424)	(0.105)	(0.066)
	1,926	1,926	1,926
Observations	(0.424)	(0.105)	(0.066)
R-squared	1,926	1,926	1,926
Number of firms	0.044	0.013	0.032
Panel B			
JUG countries			
Year of acquisition	-1.246**	-0.232	-0.011
	(0.487)	(0.146)	(0.012)
One year after acquisition	0.410	-0.166	-0.065
	(0.690)	(0.134)	(0.060)
Non-JUG countries			
Year of acquisition	-0.957***	0.104	0.022
	(0.310)	(0.094)	(0.017)
One year after acquisition	-0.563	-0.159	0.089
	(0.571)	(0.135)	(0.065)
Observations	1,926	1,926	1,926
R-squared	0.045	0.014	0.033
Number of firms	399	399	399

Note: OLS estimates. Estimated standard errors are clustered at the country level and shown in parenthesis. All regressions include firm-fixed effects, lagged size, sector, region, and year dummies. * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table A6: The Effect of Foreign Acquisition on Innovation Expenditures: Alternative Definitions of Technologically Intensive Countries

Innovation Expenditure Regression No.	Non-R&D (i)	External Foreign Other Private (ii)	External Foreign Non-private (iii)
Panel A: Top 10 and non-top 10 in terms of BERD as percentage of GDP[b)]			
Top 10			
Year of acquisition	-1.272**	-0.107	-0.005
	(0.448)	(0.183)	(0.008)
One year after acquisition	-0.431	-0.363	-0.041
	(0.681)	(0.221)	(0.055)
Not Top 10			
Year of acquisition	-0.915**	0.074	0.022
	(0.320)	(0.073)	(0.017)
One year after acquisition	-0.301	-0.071	0.097
	(0.557)	(0.114)	(0.072)
Panel B: Technological leaders and non-leaders (Source European Commission)[c)]			
Technological Leader			
Year of acquisition	-1.109***	-0.047	0.001
	(0.368)	(0.133)	(0.006)
One year after acquisition	0.381	-0.198	-0.025
	(0.669)	(0.132)	(0.044)
Not Techno. Leader			
Year of acquisition	-0.973**	0.066	0.024
	(0.405)	(0.091)	(0.020)
One year after acquisition	-0.956*	-0.134	0.120
	(0.544)	(0.162)	(0.081)
Panel C: 5 least technologically intensive countries			
More Techno. Intensive			
Year of acquisition	-1.058***	0.030	0.016
	(0.290)	(0.083)	(0.013)
One year after acquisition	-0.378	-0.148	0.058
	(0.436)	(0.098)	(0.067)
Least Techno Intensive			
Year of acquisition	-0.482	-0.510	-0.077
	(1.205)	(0.527)	(0.069)
One year after acquisition	0.992	-0.764	-0.128
	(2.469)	(0.895)	(0.105)

Note: OLS estimates. Estimated standard errors are clustered at the country level and shown in parenthesis. All regressions include firm-fixed effects, lagged size, sector, region, and year dummies. For classification of countries a), b) and c) see Table 2. * Significant at 10%;** Significant at 5%; *** significant at 1%.

Table A7: Determinants of Acquisitions by a Foreign MNE: Comparing Country Samples

Sample Regression No.	JUG vs. Techno. Similar (i)	JUG vs.5 Least Techno Intensive (ii)	Techno similar vs. 5 Least Techno Intensive (iii)
Log(internal R&D)	-0.0013	-0.0015	0.0002
	(0.002)	(0.006)	(0.005)
Log(external R&D)	-0.0062**	-0.0068	-0.0032
	(0.003)	(0.007)	(0.005)
External R&D same	-0.0118	-0.0171	-0.0458
business group dummy	(0.032)	(0.086)	(0.071)
Labour productivity	0.0030	-0.0102	-0.0163
	(0.013)	(0.035)	(0.021)
Physical investment	-0.0008	-0.0080	-0.0145**
per employee	(0.003)	(0.008)	(0.006)
Sales growth	0.0181	-0.0002	0.0324
	(0.031)	(0.076)	(0.055)
Size <50 employees	-0.0191	-0.0486	-0.0706
	(0.032)	(0.095)	(0.078)
Size: 50-99 employees	0.0249	0.0336	-0.1246
	(0.042)	(0.101)	(0.077)
Size: 200-499 employees	0.0255	0.0337	0.0013
	(0.034)	(0.091)	(0.076)
Size: >=500 employees	-0.0088	0.0571	-0.0537
	(0.035)	(0.099)	(0.076)
Relative corporate taxes	-0.0969**	-0.0606	-0.1899
	(0.042)	(0.119)	(0.122)
Observations	976	426	640

Note: In columns (i) the dependent variable is a dummy variable that takes the value one if the firm is acquired by a MNE from either Germany, Japan or the US (JUG) in year t, and zero if acquired from a Technologically Similar Country. In columns (ii) the dependent variable equals one if the firm is acquired by a MNE from either Germany, Japan or the US (JUG) in year t, and zero if acquired from one of the 5 Least Technologically Intensive Countries. In columns (iii) the dependent variable equals one if the firm is acquired by a MNE from A Technologically Similar Country in year t, and zero if acquired from one of the 5 Least Technologically Intensive Countries. All estimations use a probit model. The coefficients refer to marginal effects calculated at sample means. Estimated standard errors are clustered at the firm level and shown in parenthesis. All independent variables are lagged one period and are in logarithms except dummy variables. All regressions include region and year dummies. * Significant at 10%. ** significant at 5%. *** significant at 1%.