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**Estimating technological spillover
effects in presence of knowledge
heterogeneous foreign
subsidiaries: Evidence from
Colombia.**

Nadia Albis
Isabel Álvarez
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Abstract

This paper analyses the effects of heterogeneous foreign subsidiaries in the generation of knowledge spillovers beneficial for domestic owned firms. The empirical analysis uses firm-level panel data for manufacturing firms in Colombia for the period 2003-2012. We identify two different types of subsidiaries according to their technological responsibilities and mandates, to empirically test the existence of differential effects on domestic firms' productivity. Our results confirm that only those subsidiaries oriented to creative technological activities exert significant and positive effects, while those subsidiaries oriented to exploitative technological activities do not generate knowledge spillover effects. These findings contribute to arguments in the existing literature supporting the distinctive role and relevance of heterogeneous foreign subsidiaries in developing host contexts.

JEL Codes: F23, L6, O19, O33

Keywords: technological spillovers, multinational, subsidiaries, firms, heterogeneity

Instituto Complutense de Estudios Internacionales, Universidad Complutense de Madrid. Campus de Somosaguas, Finca Mas Ferré. 28223, Pozuelo de Alarcón, Madrid, Spain.

© Nadia Albis e Isabel Álvarez.

Nadia Albis, Instituto Complutense de Estudios Internacionales and Observatorio Colombiano de Ciencia y Tecnología (OCyT).

Isabel Álvarez, Instituto Complutense de Estudios Internacionales (ICEI), Universidad Complutense de Madrid.

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1. Introduction

Technology spillovers from foreign direct investment (FDI) is a topic that has long been studied as a way to assess the role of multinational enterprises (MNE) in the economic development of countries. Beyond direct benefits in terms of job creation, levels of capital and national spending on innovation, FDI could contribute to enhancing productivity and the competitiveness of domestic owned firms through the generation of positive externalities, including technology dissemination. Regarding developing countries, foreign subsidiaries have the potential to permit not only greater access to technological skills generated abroad, but also the possibility of deeper connections to the global process of creation and dissemination of knowledge (A. Marin & Arza, 2010; Pietrobelli & Rabellotti, 2010). At the same time, under certain circumstances, inward FDI may exacerbate the problems caused by technological dependence in developing countries and generate unwanted effects, such as crowding off the demand of local firms (Aitken & Harrison, 1999).

Despite this being a widely studied subject, empirical evidence on the existence of knowledge spillovers from FDI remains contradictory and inconclusive, revealing remarkable differences among countries¹. One reason that may explain the weakness of the evidence is the basic assumptions underlying the classic model about spillovers (Carlsson, 2006; Todo & Miyamoto, 2006; A. Marin & Arza, 2010; A. Marin & Costa, 2010). In this line, a recent branch of literature has emphasized that foreign subsidiaries do not exhibit homogeneous technological behaviour, and that their differences can determine the generation of differing spillover effects on the domestic economy (Castellani & Zanfei, 2005; Anabel Marin & Bell, 2006; A. Marin & Sasidharan, 2010; Giroud et al., 2012; Ha & Giroud, 2015)².

¹ See the surveys by Gorg & Greenaway (2004), Crespo & Fontoura (2007), Smeets (2008), Meyer & Sinani and Knell & Rojec (2011).

² Other sources of heterogeneity evaluated in the literature are the influence of the structure of foreign ownership (Javorcik & Spatareanu, 2008), the nationality of parent companies (Abraham et al., 2006; Buckley et al.,

The international business (IB) contributions (Birkinshaw & Hood, 1998; Nobel & Birkinshaw, 1998; Cantwell & Mudambi, 2005) have argued that technological spillovers depend on the strategies or mandates, in terms of knowledge creation, that MNEs have granted to their subsidiaries, or on the evolution of affiliates toward more active innovative behaviour. The above contrasts with the traditional approach, in which subsidiaries assume a passive role in the process of generation and transfer of knowledge from the parent to domestic firms – i.e., their technological activities are only a reflection of decisions of the MNE's parent company abroad (Vernon, 1966; Stopford & Wells Jr, 1972).

Following these arguments and previous empirical evidence, this paper empirically explores the effect of the technological heterogeneity of foreign subsidiaries in the generation of intra-industry knowledge spillovers beneficial to domestic owned firms in Colombia. The identification of types of subsidiaries according to their technological responsibilities is our first step. Secondly, we estimate the differential effect on the total productivity of domestic firms using firm-level panel data covering the period 2003 to 2012.

Colombia is a country with a long history of inward FDI attraction policies; however, further technological learning from foreign companies has not been a major concern. Until now, political attention has been concentrated on the amount of inward FDI in the national economy, supported in horizontal policies, rather than on the kind of MNEs that valued added activities attracted³. In addition, although Colombia is not among those countries actively involved in the process of international generation of (2007), the entry modes of FDI (Alvarez et al., 2015), and the export orientation of the subsidiaries (Girma et al., 2008).

³ In Colombia, FDI flows have increased considerably over recent decades as a result of institutional changes and long-term effects of structural reforms developed in the early 1990s (market liberalization and elimination of restrictions on FDI), along with policy reforms made in 2002 for attracting higher FDI (improved regulation, better business environment, and greater incentives for FDI) and an improvement of security conditions in the country (Garay, 1998; Fedesarrollo, 2007; Kalin, 2009).

technology, the contribution by foreign subsidiaries to innovation investment in Colombian manufacturing sectors is significant (Albis & Alvarez, 2014). Therefore, this country provides an interesting case study that can contribute to the present state of knowledge about the effects that foreign owned firms may generate on local innovation capabilities in less developed contexts.

The remainder of this paper is structured as follows. The second section presents the theoretical framework, and the development of our hypothesis. The third section contains the description of data sources, the empirical model, and the research method. A discussion of results is presented in fourth section, and the fifth section includes some concluding remarks and basic implications.

2. Theory and hypothesis

2.1 The classic approach on technological spillovers

Since the pioneering research developed in the 1970s (e.g. Caves, 1974; Globerman, 1979), the study of knowledge spillover effects has been subject to extensive attention in the literature, in both developed and developing economies. The concept of spillover effects involves the idea that the technology of MNEs, including product technologies, processing and distribution, management and marketing skills, might be transmitted to domestic firms and, therefore, lead to increases in levels of productivity (Blomström & Kokko, 1998). The general assumption has been the existence of knowledge and technological development gains that multinational companies cannot appropriate abroad, and that are transmitted to the host economy. The channels through which the presence of foreign subsidiaries might affect the technological and productive performance of domestic-owned firms have been identified as diverse: involuntary technology transfer through imitation and demonstration effects, the mobility of qualified personnel, and the transfer of knowledge to domestic firms via their connection to the subsidiaries' value

chain, as well as competition effects that induce the efficiency or technological improvement of domestic firms (Blomström & Kokko, 1998; Crespo & Fontoura, 2007).

Despite the widespread attention to the issue, there is not sufficient evidence around the generation of spillover effects (Crespo & Fontoura, 2007; Greenaway & Kneller, 2007; Smeets, 2008; Meyer & Sinani, 2009; Perri & Peruffo, 2016). While the pioneering studies on the topic based on industrial and cross-section data found that the FDI had positive effects on domestic firms' productivity (e.g. Caves, 1974; Globerman, 1979)⁴, more recent research, using firm and panel data, have not managed to replicate the positive results of previous studies in a wide range of countries⁵. To address this, the literature has turned its attention to certain factors that may affect the generation of spillovers, emphasizing: the importance of the knowledge-absorptive capacities of domestic enterprises as a precondition to capturing the benefits of FDI (Cantwell, 1989; Girma, 2005); the different channels that lead to the transfer of knowledge, particularly forward and backward linkages (Javorcik, 2004); and the role of spatial dimension on knowledge spillovers (Driffield, 2006).

While these contributions to the general model have permitted a better understanding of the subject, little attention has been given to restrictive assumptions about the technological behavior of foreign subsidiaries for underling the assessment of spillover effects (Castellani & Zanfei, 2005; Anabel Marin & Bell, 2006; A. Marin & Sasidharan, 2010). In the main approach, MNEs have by definition the potential to generate positive impacts on indigenous technological capabilities, based on three ba-

⁴ This is because positive results from this type of research design may result from MNEs being located in what are already relatively high-productivity sectors in the host economy (Aitken & Harrison, 1999).

⁵ The explanation for results might be that negative competition effects tend to weigh heavier than positive externalities from foreign subsidiaries, because foreign firms have strong incentives to prevent knowledge leaks, and "they may well push domestic firms out of the market by stealing their market share and forcing them to produce at higher unit costs" (Castellani & Zanfei, 2005).

sic assumptions. First, the technological superiority of multinational companies, derived from the possession of unique intangible assets (e.g. technology, management skills) that partly explain the *raison d'être* of multinationals (Hymer, 1976; Dunning, 1988), it being assumed that these intangibles be automatically replicated in the subsidiaries and represent a potential source of positive effects for domestic firms. Second, that technological assets are generated centrally in MNEs and that the role of foreign subsidiaries consists merely in the adoption and diffusion of the technology generated in the parent companies (Cantwell, 1995; Zanfei, 2000). This view is consistent with the earlier theory of the product cycle model of Vernon (1966), according to which strategic decisions, including the R&D activities, are strongly centralized in the home country, and the aim of foreign investment is to facilitate the implementation of less beneficial stages of the product life cycle, incorporating more accessible and standardized technology in the MNE (Cantwell & Janne, 1999; Zanfei, 2000). Finally, the third assumption is that knowledge is a public good easily transferable between MNE units (Marin & Arza, 2010), it being generally assumed that foreign subsidiaries faced homogeneous conditions and similar absorptive capacities to assimilate and transmit the knowledge of the parent companies in host economies.

2.2 The changing role of foreign subsidiaries

Competitive pressures derived from the globalization of markets and production, and deep changes to the generation of technology on an international scale, are challenging the validity of conventional assumptions about the innovative behavior of foreign subsidiaries and their role in the creation of value inside the MNE (Archibugi & Michie, 1995; Carlsson, 2006; Dunning & Lundan, 2009; Belderbos et al., 2013). Although many technological activities are still located at home⁶, MNEs have

⁶ The concentration of innovative activities in the home country can be justified by its strategic nature, by the existence of strong scale and scope economies in R&D, by the high coordination costs of international innovation

evolved toward less hierarchical organizational structures that are based on integrated technology networks, which allows them to more efficiently coordinate their diversified and geographically disperse innovation activities and capacities, both within the organization and with other actors at a global scale (Ghoshal & Bartlett, 1990; Hedlund, 1994; Cantwell, 1995; Cantwell & Janne, 1999; Zander, 2002)

Following the above arguments, several studies have found a variety of patterns of technological innovative activities in foreign subsidiaries, observable both in developed countries (Florida, 1997; Pearce, 1999; Bas & Sierra, 2002; Cantwell & Mudambi, 2005; Álvarez & Cantwell, 2011) and in the developing world (P. Figueiredo & Vedovello, 2005; Sargent & Matthews, 2006; Hobday & Rush, 2007; M. Bell et al., 2008; A. Marin & Bell, 2010; Galina et al., 2011). This stream in the literature finds that technological active subsidiaries in host countries, beyond those generated centrally in the MNE' headquarter, could make important contributions to the MNE competitive advantages.

Subsidiaries might specifically pursue different strategies or mandates, either in the creation or exploitation of competences, alluding to the allocation of responsibilities in the value chain and, particularly, in the generation of new knowledge (Cantwell & Mudambi, 2005). Competence-exploiting (CE) subsidiaries are associated to the classic view of these type of organizations, innovative activities being mainly directed toward the adaptation of products and processes to local market conditions. In this category, it is also possible to find subsidiaries with little or no commitment to innovation, especially in least developed countries (Balcet & Evangelista, 2005; A. Marin & Bell, 2010)⁷. In contrast, competence-creating (CC) subsidiaries have a more active role in the generation of new products and services in international markets, and a stronger connections across national borders, and by the role of the home innovation system in supporting the generation and dissemination of knowledge (Cantwell, 1995; Pavitt & Patel, 1999).

⁷ In general, competence-exploiting subsidiaries are more frequent in developing countries (Kummerle, 1999; Cantwell & Santangelo, 2000; UNCTAD, 2005).

tion between local and global knowledge bases to develop their innovation activities.

Three main drivers in the configuration of a more strategic role for subsidiaries are identified in the related literature: (i) local environment factors in the host country, such as their technological dynamism, industrial specialization, and changes in economic conditions (Florida, 1997; Frost et al., 2002; Cantwell, 2009); (ii) the assignment by headquarters as part of a strategy to maintain or increase the corporation's competitive advantages (Dunning & Narula, 1995; Papanastasslou & Pearce, 1997; Kuemmerle, 1999; Cantwell & Mudambi, 2005); or (iii) the choice or evolution of the subsidiaries toward the development of specialized skills (Birkinshaw & Hood, 1998; Nobel & Birkinshaw, 1998). These factors interact with each other and their configuration can determine the progress or decline of the subsidiaries within the corporation; some simply maintain their competence-exploiting mandate (e.g. assembly production), while others may assume a more creative role and thereby increase the level and complexity of their innovative activities (Cantwell & Mudambi, 2005)⁸.

More recent studies highlight that innovation capability building is also the result of a complex processes of interaction, both within the firm and between the firm and external actors (Veugelers & Cassiman, 2004; Iammarino et al., 2008; A. Marin & Bell, 2010; Achcaoucaou et al., 2014). In this context, more creative subsidiaries could play a more prominent role in knowledge transfer processes within the MNE network. In fact, the evidence shows that the level of knowledge-absorptive capacity in subsidiaries – understood as the firm's ability to identify, assimilate, and exploit knowledge from the environment (Cohen & Levinthal, 2015 p.569) – is a key factor to improving knowledge flows between organizational units of the MNE (Gupta & Govindarajan, 2000; Monteiro et al., 2008; Lee & Wu, 2010).

⁸ Evidence about the subsidiary evolution in developing countries is provided by Ariffin & Bell (1999) in the case of Malaysia, Hodday & Rush (2007) for Thailand, Sargent & Matthews (2006) for Mexico and Collison & Wang (2012) for Taiwan.

2.3 Spillovers and technological heterogeneity of subsidiaries

In the presence of subsidiaries with heterogeneous technological capabilities, it is necessary to review the conditions and channels that lead to knowledge spillovers from foreign firms in host economies. This has given rise to the emergence of a new body of spillover literature centered on subsidiaries, in opposition to the traditional conceptualization focused on the headquarters (A. Marin & Arza, 2010; Ha & Giroud, 2015). The general approach of these studies is that the quality and the level of the subsidiaries' technological activities would have different knowledge externalities beneficial for domestic firms.

In the presence of more creative foreign subsidiaries, stronger knowledge spillovers on domestic-owned firms can be generated thanks to the potential for knowledge diffusion, through the qualified personal linked to subsidiaries' innovation activities. Scientists and engineers in competence-creating subsidiaries have higher employment and learning opportunities compared to workers in subsidiaries with less innovative activities (Kuemmerle, 1999), and this may be a diffusion source of knowledge via formal and informal contacts with local engineers or scientists, or via labor mobility toward domestic firms (Todo & Miyamoto, 2006).

On the other hand, when foreign subsidiaries are engaged in innovation activities, there are greater opportunities for imitation and learning, not only in terms of knowledge developed elsewhere by the MNE, but also in the sense of new knowledge generated by themselves (Castellani & Zanfei, 2005). It is also argued that in host economies which have achieved a certain level of development (i.e., that have a smaller technology gap with respect to MNEs), creative subsidiaries can spread valuable technologies that may not have been present in these economies previously; meanwhile, exploiting subsidiaries (with a smaller technology gap) may create competitive pressures that displace the domestic demand (A. Marin & Sasidharan,

2010). The competition effect created by creative subsidiaries may force domestic firms to improve their competitive advantages through imitation or through development of their own technologies in order to compete in local and global markets (Ha & Giroud, 2015).

Finally, innovation activities might require the introduction of R&D inputs or induce technological cooperation with domestic counterparts. Evidence shows that competence-creating subsidiaries are more connected to the local economy, where knowledge transfer between the subsidiary and domestic firms can be more intense, than is the case with supply of less-knowledge-intensive intermediate goods (Castellani & Zanfei, 2005; Ha & Giroud, 2015).

Previous empirical evidence also shows that active technological subsidiaries generate higher positive technological externalities than those with lower innovation capacities (i.e., FDI spillovers are influenced by the strategic role of the subsidiaries in the MNE's network). Todo & Miyamoto (2006) found that in Indonesia, only subsidiary companies that conducted R&D and training generated positive effects on domestic firms' productivity. In a similar way, Marin & Costa (2010) found that FDI positive effects were visible when subsidiaries in Brazil were active in the production of knowledge and showed higher human capital levels. In Argentina, Marin & Bell (2006) found that positive knowledge spillovers from foreign firms could be only observed in manufacturing sectors where foreign subsidiaries exhibited high technological activity. In Italy, Castellani and Zanfei (2005) concluded that positive spillovers to domestic firms were produced when foreign affiliates carried out knowledge-intensive activities and when they were long established in the host country. Marin & Sasidharan (2010) provide evidence that only creative-competence subsidiaries produce positive spillover effects to domestic firms in India, while subsidiaries that exploit competences, or that are not involved in any technological activity, have negative spillover effects. Similarly, Ha & Giroud (2015) have found in Korea that the activities of competence-creating subsidiaries generate significantly different hori-

zontal and vertical spillovers, compared with competence-exploiting activities.

Foreign subsidiaries are, in sum, technologically heterogeneous, and they are not passive actors within MNEs. Therefore, they do not provide homogeneous opportunities for the generation of knowledge spillovers in host economies. A minimal innovation capacity is required to be an effective channel for transfer and adaptation of the knowledge generated in the MNE network, or to generate novel innovation activities and disseminate them to domestic firms. Subsidiaries can also evolve to develop new technological skills. Given this, our research objective is to empirically test the hypothesis that *more creative subsidiaries generate greater positive host country spillover effects, in the same sector, than subsidiaries that only exploit the competences centrally generated in the multinational corporation.*

3. Methodology

3.1 Data

The empirical analysis presented in this study is based on a firm-level panel data resulting from the intersection of two sources collected by the National Statistics Department of Colombia (DANE)⁹: the Annual Manufacturing Survey (*Encuesta Anual Manufacturera*, henceforth EAM) and the Development and Technological Innovation Industrial Survey (EDIT, for its acronym in Spanish), in versions II to VI¹⁰. The former is a survey that can be considered a census of the Colombian manufacturing sector, and it provides general economic data on firm characteristics and performance variables such as sector of activity¹¹, legal organization,

⁹ The firm-level data provided by this agency are subject to strict regulation of the statistical reserve. Hence, the data were worked directly at DANE's offices through the signing of a specific agreement of collaboration.

¹⁰ The pilot version of the survey was conducted in 1996. In this research, we use the following versions of the survey: EDIT II (2003–2004), EDIT III (2005–2006), EDIT IV (2007–2008), EDIT IV (2009–2010) and EDIT VI (2011–2012).

¹¹ The survey uses the International Standard Industrial Classification (ISIC Rev. 3) adapted to Colombia by DANE.

Table 1. Panel data characteristics

Time: 2003-2012	Foreign subsidiaries	Domestic firms	All firms
Observations	4,051	60,761	64,812
Firms	540	8,003	8,543
Consecutive observations by firm (average)	7.5	7.6	7.4

Source: Own calculation based on DANE - EDIT and EAM

sales, added value, employment, expenditures, fixed assets, and trade, among others. The EAM includes information from industrial establishments with ten or more employees, or with a level of production higher than the specific value stipulated for each year as a reference¹².

The second dataset, based on the Oslo and Bogotá Manuals, collect two-year information about innovation activities undertaken by industrial firms according to the directory of firm establishments in the EAM. By merging the EDIT and EAM surveys, we added the information of variables related to the investment in innovation activities, which are registered for each year¹³.

After a process of cleaning the database to correct for inconsistencies, missing values, and errors in the collection of information, we obtained an unbalanced panel with 64,812 observations and 8,543 firms for the period 2003-2012¹⁴. Table 1 shows the main characteristics of the database, distinguishing between MNE subsidiaries and domestic firms. The set of MNE subsidiaries in the database is composed of 540 firms, with the domestic firms being around 8,003. Regarding the definition of foreign firms in our dataset, the cutting-off point is delimited at a level of 25 percent foreign

ownership of the firm.

3.2 Identifying types of subsidiaries

Prior to specification of the spillover evaluation model, we identified types of affiliates according to their technological responsibilities, i.e., whether they can be classed as creating or exploiting FDI. Literature contributions allowed us to identify various elements that define creative subsidiaries (CC subsidiaries), including: (i) the development of innovation activities that generate new technological assets and capabilities that will allow the MNE to acquire or maintain competitive advantages (Dunning & Narula, 1995; Florida, 1997; Kueggerle, 1999); (ii) the subsidiary connections with external markets (Cantwell & Mudambi, 2005; Álvarez & Cantwell, 2011); and (iii) greater links with the host innovation system and with other units of the international corporation, i.e. dual-network embeddedness (A. Marin & Bell, 2010; P. N. Figueiredo & Brito, 2011; Achcaoucaou et al., 2014)¹⁵. Based on these specific features, the identification of subsidiary types has been based on the following four indicators (See Appendix 1 for more details)¹⁶:

¹⁵ Other factors, not considered here, are the technological intensity of the sector where the subsidiaries are located (Narula, 2002), or where the recipient countries have already achieved considerable technological competences (Bell & Marín, 2004; Molero & Garcia, 2008).

¹⁶ We are aware that the innovation database used displays significant error measure problems in the levels of innovation expenditures across years, due to methodological changes in the survey between 2003 and 2007. Hence, we do not distinguish between levels of expenditures. Instead, we use a discrete measure that equals 1 if the firm spent any amount on R&D. We also found important errors in the levels of export, causing us to ignore the factor of export intensity (export/sales).

¹² For example, for 2012 this value was \$120 million in constant pesos (approximately US\$68,000).

¹³ The two databases have common firm identifiers which allow their combination for research purposes.

¹⁴ In cleaning the database, several aspects have been taken into account: (i) to exclude firms with missing or zero values in any of the main variables of interest during the observation period; (ii) data imputation using the Hot Deck method in the case of missing, zero, or extreme values between two years; and (iii) to exclude sectors with zero or low and discontinuous foreign presence (ISIC 16, 20, 23, 32 and 33).

Table 2. Clusters of subsidiaries and classification variables (on average), 2003-2012

Indicator	Competence creating (CC)	Competence exploiting (CE)
Firms	176	364
1. R&D engagement (1/0)	0.27	0.08
2. Export engagement (1/0)	0.78	0.68
3. MNE embeddedness index	0.40	-0.16
- Headquarters (1/0)	0.56	0.24
- Other enterprises within the MNE group (1/0)	0.46	0.20
4. Local embeddedness index	0.59	-0.24
- Clients (1/0)	0.70	0.28
- Suppliers (1/0)	0.62	0.27
- Competitors (1/0)	0.68	0.28
- R&D organizations	0.51	0.21

Source: Own calculation based on DANE - EDIT and EAM

- *R&D engagement*: dichotomous indicator that measures the existence of research and innovation capabilities within subsidiaries.
- *Export engagement*: dichotomous variable that attempts to measure the subsidiaries' connection with global markets.
- *Local embeddedness index*: using factor analysis, we construct an index that takes into account the local sources of information to innovate (such as suppliers, clients, competitors, and R&D organizations (i.e. universities and R&D centers). Here, the firms' sources of information for innovation activities can be seen as a proxy of knowledge flows within and across organizations (Criscuolo *et al.*, 2010).
- *MNE embeddedness index*: seeks to measure knowledge flows between subsidiaries and their multinational groups (headquarters and other units within the multinational). The index is obtained by applying a factor analysis.

In order to identify types of foreign subsidiaries, we use Ward's hierarchical classification methodology to generate two clusters of subsidiaries with homogeneous characteristics

and with 'distances' between them as wide as possible¹⁷. Table 1 shows the distribution of competence-creating (CC) and competence-exploiting subsidiaries (CE), as well as the average value of the variables used in the classification.

3.3 Model and method

To assess the presence of FDI knowledge spillovers from multinationals firms, we follow a two-step procedure. First, we estimate total factor productivity (TFP) for each manufacturing sector and the sample of domestic firms¹⁸. Second, we examine the relationship between the productivity of domestic firms and the foreign presence, distinguishing the effect of types of foreign subsidiaries, as established in the previous section.

In the first stage, the productivity of each firm is estimated using a production function approach. We assume a log-linear transformation of a Cobb-Douglas function, of the follow-

¹⁷ In general, the cluster method uses different measurements for determining the proximity between two clusters. Ward's method, also known as the method of the minimum variance, considers in each step the heterogeneity or deviance (sum of the squares of the distance of an object from the baricentre of the cluster) of every possible cluster that can be created by linking two existing clusters.

¹⁸ This is intended to prevent the dynamics of estimated TFP to be influenced by the productivity of foreign subsidiaries (Castellani & Zanfei, 2005).

ing type:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \varepsilon_{it} \quad (1)$$

where lower-case letters in Eq. (1) refer to natural logarithms, and subscripts i and t refer to firm and year, respectively. Here y_{it} represents the real output of the firm; l_{it} , k_{it} and m_{it} are inputs of labor, capital and raw materials, respectively. The term ω_{it} represents total factor productivity (TFP) and ε_{it} is an i.i.d. component, representing unexpected deviations from the mean due to measurement error, unexpected delays or other external circumstances.

The firm's output is defined as valued added deflated by industry-specific producer price indices at the two-digit ISIC classification. We distinguish two types of labour: (1) unqualified personnel corresponding to the blue-collar workers and operators, and (2) qualified personnel, defined as the sum of professionals, technicians and sales and administrative staff. The material input is defined as the consumption of raw materials deflated by the producer price index of materials. The stock capital is defined as the value of fixed assets at the beginning of the year deflated by the simple average of the price deflators for terrains, buildings and structures, machinery and equipment, transport equipment and office equipment.

To estimate TFP we follow the semi-parametric method introduced by Levinsohn and Petrin (2003). This approach uses intermediate inputs as proxy for unobserved productivity shocks to take account of possible endogeneity problems resulting from the high correlation between these shocks and the levels of inputs used in production¹⁹. In the second stage, we started by defining a general model for the determinants of total factor productivity of domestic firms in function to a measure of foreign investment. The model takes the following form:

¹⁹ To estimate productivity, we use the Stata routine *levpet* developed by Petrin *et al.* (2004) and estimate firm-level production functions separately for 22 manufacturing sectors. In the interest of brevity, the results of this estimation are not included here, but are available upon request.

$$\ln TFP_{ijt}^d = \alpha_0 + \alpha_1 \ln FDI_{jt} + \alpha_2 X_{ijt} + \mu_t + \varepsilon_{it} \quad (2)$$

Where the subscripts i , j and t in Eq. (2) refer to firm, sector and year, respectively. The variable $\ln TFP_{ijt}^d$ is the logarithm of the multifactorial productivity of domestic firms; FDI_{jt} captures the extent of foreign presence in sector j at time t , and X_{ijt} is a vector of relevant control variables. Whereas parameter α_1 captures the effect of spillovers from foreign firms, μ_t denotes unobservable time-invariant firm-specific effects, and ε_{it} is the error term.

The hypothesis that technologically active foreign subsidiaries have a higher spillover potential is tested by estimating a further modification of Eq. (2), including a measure of the effect of different types of FDI (different types of subsidiaries) on domestic industry productivity. The model that we estimate adopts the following form:

$$\ln TFP_{ijt}^d = \alpha_0 + \alpha_1 CC_FDI_{jt} + \alpha_2 CE_FDI_{jt} + \alpha_3 X_{ijt} + \mu_t + \varepsilon_{it} \quad (3)$$

In Eq. (3), α_1 and α_2 capture the external effect on domestic-owned firms of foreign competence and exploiting subsidiaries, respectively. We calculate creating and exploiting FDI as follows:

$$CC_FDI_{jt} = [\sum_{vi \in j} Foreign\ Share * Y_{it} * CC\ dummy] / \sum_{vi \in j} Y_{it} \quad (4)$$

$$CE_FDI_{jt} = [\sum_{vi \in j} Foreign\ Share * Y_{it} * CE\ dummy] / \sum_{vi \in j} Y_{it} \quad (5)$$

Three control variables are included in vector X . The first is the Herfindahl index, calculated as the sum of squares of firms' turnover shares in each 2-digit industry. This allows us to control for the effect of technological changes generated by domestic firms in response to increased competition from FDI, rather than from technology flows. The second is the knowledge domestic firm's absorptive capacities, a dummy variable which seeks to take into account the hypothesis that the foreign presence is more likely to generate spillover effects when domestic firms have strong innovation competences and consequently higher knowledge-absorptive capabilities. Finally, we included firm size and export engagement as control variables.

The estimation of equation (3) is made with the GMM System estimator, proposed by Blundell and Bond (2000) with robust estimation of covariance matrices. This method allowed us to control for unobserved heterogeneity, simultaneity and possible measurement errors. We also estimate the spillover model with Pooled Ordinary Least Squares (OLS) and Random Effects (RE) econometric specification, and then compare the results to those obtained with GMM model. We use random effects estimation because it is more efficient than a fixed effects estimator in the presence of independent variables that do not vary much over time (Beck, 2001; Plümper & Troeger, 2007).

4. Discussion of the results

The empirical results obtained under different specifications are shown in this section. The outcomes to the conventional spillover model in which FDI is simply treated as a homogeneous block are reported in Table 3. In each

case, we use alternative estimation methods: OLS, System GMM, and Random Effects. Appendix 2 presents the descriptive statistics and the correlation matrix for the regression variables, based on the full sample of domestic-year observations.

In the first round of estimations, across all the econometric specifications, the results show no statistically significant relationships between foreign presence and domestic productivity of Colombian firms in the same sector. These results do not confirm the existence of horizontal spillovers according to the conventional model. This is consistent with previous evidence for Colombia (Kugler, 2006; Hyman, 2011) as well as for other less development countries (Haddad & Harrison, 1993; Aitken & Harrison, 1999). Regarding the controls, it is notable that the variables for R&D engagement, export links, market concentration, and the size of domestic-owned firms are significant, and the signs of the estimated coefficients are coincident with the theoretical expectations.

Table 3. Results of conventional spillover model

Dependent variable: TFP (log)	(1)	(2)	(3)
TFP t-1	0.602*** 0.003	0.449*** (0.007)	- -
Conventional FDI	-0.010 (0.010)	-0.003 (0.006)	-0.068 (0.001)
Market concentration	0.004** (0.002)	0.006** (0.002)	0.004 (0.003)
R&D engagement	0.056*** (0.011)	0.066*** (0.011)	0.076*** (0.012)
Export engagement	0.088* (0.008)	0.116*** (0.010)	0.150*** (0.009)
Size (Log employment)	0.364** (0.004)	0.494*** (0.008)	0.769*** (0.005)
Observations	52,248	52,248	60,761
Firms	7,953	7,953	8,003
Method	OLS	GMM	Random effects

Standard errors in brackets. * p<0.1, ** p<0.05, *** p<0.01. We use the one-year lag for FDI-related regressors.

The second round of estimations of the model, in Table 4, show that results differ when considering the presence of heterogeneous subsidiaries; that is to say, distinguishing between creating and exploiting inward FDI. Only competence-creating FDI in Colombia has a consistent positive productivity effect in all the econometric estimations, while competence-exploiting FDI does not have any statistically significant effect. Meanwhile, the negative and significant sign of the estimated coefficient of CE FDI in column 6 can be related to the competition effects and the fact that these subsidiaries are more market-oriented, as opposed to creative activities as is the case with CC subsidiaries.

These results are consistent with previous evidence (shown in section 2.3) but also allow us to confirm our hypothesis, according to which creative subsidiaries in Colombia imply a higher potential for the generation of spillovers within industries –an argument that can be easily extended to the case of other developing host countries. On the other hand, the variables of R&D and export engagement, as well

as of market concentration and size, are also statistically significant and adopt the expected signs. These are in line with the hypothesis that spillovers are more likely in presence of higher absorptive capacities, in this case reflected by the R&D engagement of firms according to the original definition provided by the seminal contribution of Cohen and Levinthal (1989), as well as by export engagement, which may induce learning by exporting opportunities, as affirmed in a recent paper by Albis and Alvarez (2014).

5. Concluding remarks

A large number of studies have considered whether the presence of foreign investment leads to the generation of horizontal technological spillovers toward domestic firms. However, until now the evidence has not led to full consensus on the subject. One possible reason for these inconclusive results may be the rigid assumptions that underlie the classic model for evaluating spillover effects, where subsidiaries are considered passive actors in the

Table 4. Results of subsidiary heterogeneity model of productivity spillovers

Dependent variable: TFP (log)	(4)	(5)	(6)
TFP t-1	0.608*** (0.003)	0.457*** (0.007)	- -
Competence creating FDI	0.041*** (0.003)	0.052*** (0.004)	0.056*** (0.005)
Competence exploiting FDI	-0.003 (0.006)	-0.006 (0.008)	-0.018* (0.010)
Market concentration	0.006*** (0.002)	0.008*** (0.002)	0.006* (0.003)
R&D engagement	0.057*** (0.011)	0.067*** (0.011)	0.075*** (0.012)
Export engagement	0.077*** (0.008)	0.099*** (0.010)	0.153 (0.009)
Size (Log employment)	0.352*** (0.004)	0.492** (0.008)	0.769*** (0.005)
Observations	52,248	52,248	60,761
Firms	7,953	7,953	8,003
Method	OLS	GMM	Random effects

Standard errors in brackets. * p<0.1, ** p<0.05, *** p<0.01. We use the one-year lag for FDI-related regressors.

processes of generation and transfer of knowledge. Recent evidence from IB literature suggest that foreign subsidiaries can develop distinctive capabilities by combining resources and capabilities via host-country endowments and internal MNE networks, and that these distinctive capabilities determine the possibility of generation of technological spillover to host economies.

Based on these arguments, this paper explores empirically the differential intra-industry spillover effects of technologically heterogeneous foreign subsidiaries on total factor productivity of domestic owned firms, using firm-level panel data for manufacturing firms in Colombia for the period 2003-2012. We propose a specific typology of subsidiaries according to their innovation, export, and networking capabilities, then analyze the importance of each in explaining knowledge spillover effects.

The empirical results confirm our hypothesis that competence-creating subsidiaries generate greater positive productivity effects on domestic manufacturing firms, in the same sector, than do units identified as competence-exploiting. In fact, subsidiaries oriented mostly to technologically exploitative activities do not generate knowledge spillover effects. In contrast, when we estimate the conventional model of spillover effects, where foreign investment is treated as a homogenous block in terms of technological capabilities, the empirical analysis does not yield statistically significant results. These findings also reveal the limitations of considering subsidiaries as a homogeneous group with passive technological behavior, for the purposes of both research and public policy.

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Appendix 1

Table 5. Definition of variables (Firs step)

Variable	Definition
<i>Dependent variable</i>	
Added value	Logarithm of added value deflated by the producer price index
<i>Independent variables</i>	
Capital stock	Logarithm of book value of the capital of the firms deflated by the price index of terrain, buildings and structures, machinery and equipment, transport equipment and office equipment.
Blue collar workers	Logarithm of the sum of workers and operators
White collar workers	Logarithm of the sum of professionals, technicians and sales and administration staff
Materials	Consumption of raw materials deflated by the producer price index of raw materials

Table 6. Definition of variables (Second step)

Variable	Definition
<i>Dependent variable</i>	
Total Factor Productivity	Natural logarithm of Total Factor Productivity
<i>Independent variables</i>	
Conventional FDI	Share of total sales in an industry j accounted for by foreign firms.
Competence creating FDI	Share of total sales in an industry j accounted for by foreign firms defined as competence creating subsidiaries.
Competence exploiting FDI	Share of total sales in an industry j accounted for by foreign firms defined as competence exploiting subsidiaries
Market concentration	Sum of squares of firms' turnover shares in each 2-digit industry
R&D engagement	Dummy equal to 1 if the firm has made investments in R&D and equal to 0 in another case.
Export engagement	Dummy equal to 1 if the firm has exported and equal to 0 in another case.
Size	Logarithm of employment

Table 7. Definition of variables (Types of subsidiaries)

	Variable	Definition
<i>MNE knowledge flows</i>	Headquarter	Dummy equal to 1 if the firm use headquarters as source of information for innovation activities and equal to 0 in another case.
	Other enterprises within the MNE group	Dummy equal to 1 if the firm use other enterprises within the MNE group as source of information for innovation activities and equal to 0 in another case
<i>Local knowledge flows</i>	Clients	Dummy equal to 1 if the firm use clients as source of information for innovation activities and equal to 0 in another case
	Suppliers	Dummy equal to 1 if the firm use suppliers as source of information for innovation activities and equal to 0 in another case
	Competitors	Dummy equal to 1 if the firm use competitors as source of information for innovation activities and equal to 0 in another case
	R&D organizations	Dummy equal to 1 if the firm use R&D organizations (e.g. universities and R&D centers) as source of information for innovation activities and equal to 0 in another case

Appendix 2

Table 8. Descriptive statistics and pairwise correlations

	1.	2.	3.	4.	5.	6.	7.
1.Total Factor Productivity (TFP)	1.00						
2.Market concentration	0.06	1.00					
3.Export engagement	0.35	0.00	1.00				
4.R&D engagement	0.19	-0.02	0.13	1.00			
5.Size (Log employment)	0.78	0.06	0.38	0.19	1.00		
6.Competence creating FDI	0.13	0.01	-0.01	0.08	0.08	1.00	
7.Competence exploiting FDI	-0.01	0.06	0.05	0.05	-0.01	0.10	1.00
Mean	10.9	-4.4	0.2	0.1	3.3	-2.8	-2.1
SD.	1.4	1.9	0.4	0.2	1.2	1.1	0.6

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