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Microeconomic dynamics of FDI and local innovation: A firm level estimation of Chilean firms

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Abstract:

Globalization has significantly influenced economic policy in Latin America. After the debt crisis of the 1980s, capital controls were removed leading to a substantial increase in Foreign Direct Investment (FDI) to the region. Chile, in particular, has extensively promoted free international integration, with the import of technology through FDI playing a major role in its economic development. During the 1990s, Chile experienced a period of rapid GDP growth, increased exports, and higher productivity. However, its productive dynamism has since stalled, trapping the country in an income plateau. Insights from evolutionary economics provide a framework for understanding this phenomenon, where neoclassical theory falls short. This study seeks to provide empirical evidence on whether FDI has promoted or hindered the innovative performance of domestic firms in Chile. Using firm-level data, the research employs the well-known CDM model to address selection bias in innovation efforts. The econometric analysis measures the impact of foreign competition on local innovation, specifically examining how foreign ownership and competition within economic sectors influence innovation outputs in local firms. The findings indicate that firms facing higher levels of foreign competition are less likely to implement new processes or products. These results offer valuable policy implications, highlighting the nuanced effects of FDI on host economies. The impact of FDI varies depending on the type of investment, the economic sector, and the technology introduced. Consequently, strategies aimed at leveraging FDI for economic catch-up must account for these variances and focus on fostering local innovation and technological advancement.

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I. Introduction

The process of globalization in the economic sphere has been characterized by a steady increase in trade, migration, and capital flows (O'Brien & Williams, 2003). This process has been particularly relevant for countries in the global South as they have begun to play a more prominent role since increasing their participation in international capital flows while, in line with their increased participation on the international stage, this process has defined their development strategies and specialization patterns (Lall, 1993; Ahumada & Torres, 2022). As shown by UNCTAD (2023), developing countries surpassed developed countries in World FDI inflows since 2019, while also experiencing lower volatility in these flows compared to developed countries. This recent experience can be understood within the framework of the implementation of the Washington Consensus, where developing countries have incorporated market-oriented policies, which has meant formulating productive development policies based on attracting FDI to import technology and promote technological development (Lall, 1993).

There is extensive development in the literature concerning the effects of FDI on developing countries. In the macroeconomic sphere, this has included growth (Borensztein et al., 1998; Basu & Guariglia, 2007; Bénétrix et al., 2023) and inequality (Murphy et al., 1989; Herzer et al., 2014; Doh, 2019). The microeconomic literature has focused on FDI spillovers, particularly concerning productivity (Barba-Navarreti & Venables, 2004; Crespo & Fontoura, 2007; Rojec & Knell, 2018). This literature aims to explain how multinational enterprises (MNEs) benefit local firms through their interactions, since MNEs might possess greater knowledge and skills such as advanced technologies, management techniques, and marketing strategies, among others (Barba-Navarreti & Venables, 2004). Regarding the latter, the literature has identified several channels through which MNEs could transmit technological gains to local firms, including demonstration effects, labor rotation, foreign market access, and vertical and horizontal linkages (Spencer, 2008). Empirical studies on this issue have been abundant, and while previous research found positive spillovers, recent results have become mixed, as these studies vary in terms of the country studied and the econometric techniques implemented (Keller, 2018; Santos, 2023).

Despite extensive research on productivity spillovers, the impact of MNEs on innovative behavior remains less explored and inconclusive. In this context, some authors argue that innovation spillovers may be considered non-pecuniary (Santos, 2023), as they can be identified through their effects on the production function of local firms. This is in contrast to pecuniary spillovers, that are influenced by changes in prices, which in turn affect the profit function. In this sense, Khachoo and Sharma (2016) argue that prioritizing the evaluation of innovation over productivity proves more effective, as it better captures technological progress, particularly in discussing productive development processes in developing countries. Additionally, assessing innovation allows for the observation of capability development, a central aspect in bridging technological gaps with developed countries (Cimoli et al., 2009).

This paper seeks to evaluate empirically how FDI encourages, or undermines, local innovation, through econometric analysis using a Chilean innovation survey at firm level between 2017 and 2019. Chile serves as an interesting case study in this regard, given its widely recognized success following the implementation of policies promoted by the Washington Consensus, positioning it as one of the earliest adopters in the region. Consequently, Chile has become one of the leading recipients of FDI in Latin America, ranking only behind Brazil and Mexico. Despite this initial success, reflected in high growth rates during the 1990s and dynamic development in the export sector (Ffrench-Davis, 2018), more recent economic outcomes have shown significant signs of

productive stagnation, lack of export dynamism, and limited innovative development (Palma, 2022; Agosín, 2023).

GDP growth rates went from averaging over 7% annually between 1990 and 1998, to a constant decline, reaching 4.3% between 1999 and 2008, and 2.9% between 2009 and 2022. Within this framework, limited innovative development can also be observed, as evidenced by gross R&D expenditure reaching 0.36% of GDP between 2007 and 2020, which can be crucial in expressing a country's capacity to receive, adapt, adopt, and absorb foreign knowledge (Crespo & Fontoura, 2007). Additionally, Klerkx et al. (2015) identify the Chilean national innovation system as "immature" and with low coordination levels, which, coupled with low private R&D expenditure, hampers firms' ability to build technological capabilities.

This paper further aims to estimate the role that FDI has played in fostering innovative capacity among local firms, to provide novel insights to both understand the impact of MNEs on local firms and to support evidence-based policy development. To achieve this, the Crépon, Duguet, and Mairesse (CDM) model (Crépon et al., 1998), is implemented, which allows for estimating three stages of the innovation process: from the decision to invest, through estimating innovation effort (measured as R&D expenditure), to finally estimating the probability of firms implementing a new product or process. This model has been widely recognized for correcting endogeneity due to selection bias resulting from differences in unreported information effort, which is not taken into account when using innovation expenditure surveys (Lööf et al., 2017). Thus, this methodology allows the use of a predicted value of R&D to capture the real effort on innovation and not only the reported R&D expenditure. This methodology can thus be used to study the innovation output of local firms, including the effect of FDI competition. While there are some studies that estimate the innovation function of local firms (Benavente, 2005; Crespi & Zuñiga, 2012), the novelty of this paper is the inclusion of the amount of FDI in the economic sector where firms operate, thus providing new evidence for Chile and providing a discussion of the link between FDI and innovation performance.

The results obtained indicate mixed evidence. While for the year 2017, it was found that higher investment flows decrease the probability of innovation in local firms, no significant results are found for the year 2019. To explain these findings, it may be insightful to understand the nature of the knowledge creation process, which is costly, risky, and path-dependent. Therefore, a plausible explanation for understanding a negative result may lie in the more intensive competitiveness conditions faced by local firms when competing predominantly with foreign firms in the industry, which could impair their ability to undertake riskier innovative efforts (Caves, 1974; Annique & Cuervo-Cazurra, 2008). Furthermore, a non-positive relationship may align with the literature suggesting that the adoption of foreign knowledge requires significant effort to adapt, integrate, and successfully implement it (Nelson, 2004).

The present paper is structured as follows. The next section describes the theoretical and empirical literature in this field. Section III outlines the methodology, followed by Section IV, which describes the empirical findings. Finally, Section V concludes.

II. Literature review

There are several approaches in the literature to understanding FDI dynamics. For example, there are studies that focus on the motivation of MNEs to carry out activities overseas. Much of the literature can be linked to the earlier contributions of Dunning (1993, 1998), such as market seeking, resource seeking, and efficiency seeking. New scholars in the international business literature propose a critical theoretical revision (Cuervo-Cazurra et al., 2015), while other research concentrates on the economic effects of MNEs operation in the host economies, both at the firm level, e.g., firm productivity, and at the macroeconomic level, e.g., GDP growth (Barba-Navarreti & Venables, 2004; Santos, 2023). While studies on the motivations of MNEs are useful for understanding why some companies decide to operate overseas, the literature on the FDI effects in the host economy is valuable for examining the economic processes and consequences in the host country and is therefore useful for supporting public policies.

The discussion of FDI policies implemented in the host economy has thus become particularly relevant for developing economies fostering 'catch-up' (Lall, 1993). After the implementation of the policies suggested by the Washington Consensus, FDI has been intensively promoted by developing economies with the assumption that MNEs bring new knowledge, managerial skills, new practices, and new technologies that could increase productivity (Dunning & Lundan, 2008). FDI furthermore can generate positive spillovers to local firms (Caves, 1974), while promoting investment, thus increasing domestic savings in balance-of-payment constraint contexts (Narula, 2014). Hence, in recent decades, FDI has played a major role in developing countries, as they have based their development strategies on FDI attraction policies (Khachoo & Sharma, 2016). As a result, FDI inflows have significantly increased to developing countries, attracting more than developed countries in recent years (UNCTAD, 2023).

Some controversial insights have been discussed in terms of catching up possibilities using FDI, particularly in terms of competitive advantage analysis. Some authors argue that FDI enhances productivity and drives positive structural changes in both the home and host countries (Kojima & Ozawa, 1984). In the home country, firms with a comparative disadvantage may engage in overseas activities where they possess a comparative advantage. This shift leads to better resource allocation and improved trade dynamics in both the home and host countries (Kojima, 2000; Lin & Monga, 2011). On the other hand, some authors argue that the unequal international distribution of competitive advantage allows high-income countries to reinforce their specialization in technological advancements, thereby widening the technological gap with developing economies (Cimoli & Porcile, 2009; Cimoli et al., 2009; Chang & Andreoni, 2016; Dosi & Tranchero, 2018).

Despite the increasing importance of FDI inflows into developing countries, several effects of FDI on the host economy remain controversial or unexplored. Therefore, more evidence is needed to support local policies (Khachoo & Sharma, 2016). Nowadays, one of the main areas of research is the productivity spillover of FDI on local economies (Barba-Navarreti & Venables, 2004; Kopiński, 2023). While part of the literature is focused on the macroeconomic growth effects of FDI (Borensztein, De Gregorio & Lee, 1998; Basu & Guariglia, 2007; Chowdhury & Mavrotas, 2006), and inequality (Murphy, Shleifer & Vishny, 1989; Herzer, Hühne & Nunnenkamp, 2014; Doh, 2019). In contrast, the microeconomic literature is focused on FDI spillovers on local firms, mainly, in productivity (Barba-Navarreti & Venables, 2004; Crespo & Fontoura, 2007; Rojec & Knell, 2018).

The productivity spillover of FDI is a widely studied topic, supported by abundant firm-level empirical evidence. In earlier literature, the evidence supported the idea that foreign subsidiaries increased the productivity of local firms, however, further econometric developments and the

higher country variety of studies shows mixed results (Barba-Navarreti & Venables, 2004). Although in recent years, studies have incorporated increased firm heterogeneity with better differentiation between horizontal and vertical spillover, and absorptive capacity, the results are still mixed (Rojec & Knell, 2018). On the theoretical side, the channels through which these effects transpire are well identified. With the horizontal or intra-industry spillovers, there are the demonstration effects, labor mobility, and competition effects, while with vertical or inter-industry spillovers, there are the linkage effects[1]. However, the empirical evidence has not clearly distinguished these effects (Demena & Murshed, 2018), and therefore, has not considered how these mechanisms may counteract each other (Pineli, Narula & Belderbos, 2021).

Rojec and Knell (2018) address the distinction between productivity and knowledge spillovers, a topic not well covered in the literature. Thus, studying productivity as an effect of the presence of foreign firms suffers from endogeneity due to the multitude of factors that can determine productivity, especially, since it can be measured in a broad way (i.e., sales per worker) and could not capture the knowledge spillover. At the same time, there are factors that prevent the conversion from knowledge to productivity, such as institutional factors and absorptive capacity. In this framework, a more appropriate way to measure knowledge spillover would be to observe the effect on the innovation capacity of local firms, which is more difficult to measure and less addressed in the literature (Rojec & Knell, 2018).

The effect on innovation instead of productivity has been less covered (Stiebale & Reize, 2011; Fu, Pietrobelli & Soete, 2011) and, for several reasons, is more appropriately considered. First, concerning the research question, productivity could be a manner to measure technological improvement since value added (used as a productivity indicator) does not imply new products or processes because of a learning process in the presence of FDI. In this respect, innovation could be the more effective path, when the research question is to evaluate technological progress (Stiebale & Reize, 2011; Khachoo & Sharma, 2016).

Second, a methodological issue exists and studying innovation may offer a clearer perspective on knowledge spillovers since the measure used is more precise compared to productivity. Essentially, knowledge spillover is difficult to capture, as Krugman stated (1991: 53), "knowledge flows . . . leave no paper trail". For this reason, productivity, being a broad measure, can be influenced by many other factors than new knowledge. For example, higher market demand can increase prices, and productivity (measured as sales per worker) can appear to increase, even if the production process remains unchanged. Innovation instead of productivity might be a more precise measure because, using innovation survey data, innovation can be measured as the implementation of a new product process implemented by the firm.

In the context of this research, if the presence of foreign firms promotes the flow of knowledge to local enterprises, it may be clearer to study the effect on innovation before productivity, assuming that the first step is the innovation process, followed by an increased in productivity (Crépon et al., 1998). This approach aligns with the productivity methodology proposed by Crépon et al. (1998), which outlines the steps required to estimate a productivity equation, from R&D efforts and innovation results to productivity improvement. This estimation has been widely recognized and implemented in the literature for firm-level productivity estimations (Lööf et al., 2017) and will be applied in this paper.

[1] An abundant size of literature can be found in this respect. The seminal papers that identify horizontal spillovers are Blomström and Kokko (1998), Kokko (1992), Görg and Strobl (2001), and Görg and Greenaway (2004).

Third, when considering policy implications, focusing on innovation rather than productivity may be more interesting for addressing the catching-up process in developing countries, where capability creation is a central axis. From an evolutionary and structuralist perspective (Cimoli & Porcile, 2009; Cimoli et al., 2009), the catching-up process for developing countries requires innovative efforts that build new capabilities with higher technological content, where an evolutionary process also develops based on specific institutional conditions, norms, and trajectories. For this reason, understanding how FDI can impact capability creation, rather than productivity, can be useful for designing public policies that focus on attracting FDI aimed at developing specific local capabilities.

In addressing the question of how foreign presence might affect local innovation, the nature of the innovation process must be considered. Knowledge creation and the innovation process is path-dependent, tacit, risky, and costly, and at the same time, fundamental for developing countries to catch-up (Fu, Pietrobelli & Soete, 2011; Lall, 1993). For this reason, importing technology that uses FDI is not a straightforward or easy process, either for developing and developed economies. Imitation is not an automatic process since knowledge is "tacit, difficult to codify in manuals and textbooks, and hard to acquire without direct investigation" (Griffith, Redding & Van Reenen, 2003: p. 99-100). At the same time, technical progress is localized and place-specific, therefore, it is necessary to consider the relevance of the learning-by-doing process to promote an innovation process (Atkinson & Stiglitz, 1969; Nelson, 2004). Pillai (1979) showed how Japan promoted a rapid catching-up process incorporating foreign technology, however, the investment in local innovation was seven times bigger than that imported. In this sense, considering the nature of knowledge creation, the implementation of foreign knowledge might require, as a necessary condition, important adaptation efforts in order to convert foreign innovation into the creation of new processes or products locally (Nelson, 2004).

Evolutionary literature is particularly focused on this issue (Cimoli & Dosi, 1995; Nelson, 2004; Cimoli & Porcile, 2009). Under this framework, industrial policy is a necessary condition for catching up in developing countries, and with this purpose, the creation of local capabilities must incorporate the local condition required for the capability creation. In one of the foundations of this framework, Nelson and Winter (1985) provided a new perspective on the neoclassical firm theory. These authors incorporate firm heterogeneity, institutional and cultural context, and the accumulative learning process, in order to explain the dynamic production process and technological change. For these authors, knowledge creation is cumulative, and each firm has their own path to incorporate an innovation, corresponding with the idea that knowledge is tacit. In essence, the innovation process will not be a direct process obtained by simple imitation, but it will require institutional coordination efforts and the generation of internal capabilities that allow the adaptation of foreign technology (Cimoli & Porcile, 2009).

Empirical literature on innovation and FDI

The empirical evidence in this respect is restricted and further research is needed to explore the advantages or disadvantages of FDI in the development of local innovation and the following capability creation (Fu et al., 2011; Álvarez et al., 2019). The results found in the literature vary mainly depending on which part of the innovation process is being studied, and how innovation is measured. However, as suggested by Crépon et al. (1998), innovation can be understood as a process that starts from the decision to innovate, the intensity of that effort, and finally, the result of the process (i.e., new products, patents, new processes, among others).

For instance, regarding the first steps of the decision and intensity of innovation, most of the empirical studies consider the R&D expenditure by firms (Kinoshita, 2000; Kinoshita, 2001;

Annique & Cuervo-Cazurra, 2008). In this context, we can find firm-level R&D estimations aimed at explaining what motivates firms to invest in R&D and how FDI could play a role in that process. Within this, two relevant aspects emerge when considering MNEs in this process. First, the R&D expenditure by MNE subsidiaries allows for a comparison of whether they spend more or less than local firms (Annique & Cuervo-Cazurra, 2008). Second, the literature considering potential spillover effects of the MNEs on local firms' R&D activities examines R&D activities. While the literature on the former question is more extensive, the latter is less explored (Kathuria, 2008; Wu et al., 2023).

Regarding the investment in R&D by MNEs, Annique and Cuervo-Cazurra (2008) summarize possible explanations for the differences in R&D investment level compared to local firms. While foreign affiliates could invest less because they received the technology from the parent company, on the contrary, they could invest more because they have cheaper access to capital. This study implements a Tobit estimation in two steps to estimate, first, the decision to invest in R&D and second, the intensity (measured as total R&D expenditure as a share of total sales). The result shows that subsidiaries invest less in R&D than local firms and find a negative spillover effect. Following this research question, studies carried out for India (Kathuria, 2008; Sasidharan & Kathuria, 2011; Khachoo & Sharma, 2016) follow a similar approach, using a Heckman in two steps to avoid selection bias. The results found are mixed, without a clear conclusion on the empirical evidence on the spillover. Fan and Hu (2007) study this issue for China, performing an OLS estimation that shows that the ownership has a negative effect on R&D investment, however, no significant result was found concerning the spillovers.

In a more recent paper for China (Wu et al., 2023), the relation between FDI and R&D, including a geographical component, is explored. In this study, the authors examine the interrelationship between local and foreign firms through the number of transactions, geographic distances, and the level of competition to understand their effect on the intensity of R&D expenditure. The results indicate that both foreign-owned firms and spillover effects to local companies have a positive impact on innovation spending.

There are a set of studies that analyze innovation output, measured mainly as the implementation of process improvement, development of new products and/or patents records. The results of these studies are mixed and depend on the country where this is implemented and the econometric technique applied (Álvarez et al., 2019).

However, one aspect that has not been widely covered in the literature, including in the case of Chile, is the spillover effect of MNEs on domestic firms' innovation performance. While some studies consider the presence of FDI in the industry (Kathuria, 2008; Sasidharan & Kathuria, 2011; Jin et al., 2019), the evidence for the Chilean case is scarce (Álvarez et al., 2019) and generally does not consider the spillover effect of innovation activities on local firms (Álvarez & Robertson, 2004; Benavente, 2005; Crespi & Zuñiga, 2012; Montégu et al., 2022). Table 1 shows an overview of the literature concerning the effect of FDI on the innovation output.

Table 1: Empirical evidence on FDI and innovation

Authors	Countries	Period	Dependent variable	Method	Results
Jin, García and Salomon (2018)	Spain	1993-2009	Number of patents and number or new products	Dynamic negative binomial model	Positive for technological leaders
Álvarez and Robertson (2004)	Chile and Mexico	1993-1995	New product implementation	Probit (no panel)	Not significant for Chile and positive for Mexico
Khachoo & Sharma (2016)	India		Number of patents	Binomial model	Positive
Alvarez et al., (2019)	Six latinamerican countries	2003-2017	Introduction of one product or process	OLS with IV	Mixed
Liu et al. (2010)	China	2006	Number of patents	GMM	negative relation
Wang & Wu (2015)	China	2009 and 2013	New product implementation	OLS	Positive
Lin & Lin (2010)	Taiwan		Decision on conducting product innovation Number of valid patents	Logit and Negative Binomial	Positive
Stieblae & Reize (2011)	Germany	2002-2007	innovation implemented (sales, product or process)	CDM estimation: tobit and probit	non significant
Cheung & Ping (2004)	China	1995-2000	Number of patents	OLS and panel analysis	Positive
Vujanovic, Radosevic, Stojcic, Hisarciklilar & Hashi (2022)	Serbia	2010-2012	Sales from new products	3SLS and tobit	
Ha & Giroud (2014)	South Korea	2002-2005	Number of patents	Poisson model	mixed

Source: own elaboration

Jin et al. (2019) study the spillover effects for Spanish firms, performing a dynamic negative binomial model, measuring innovation as patents and implementation of new products. The results show that the spillovers are positive only for leaders' firms. Khachoo and Sharma (2016) and Lin and Lin (2010) also perform a binomial model for India and Taiwan. While the former found a positive spillover only for manufacturing firms, the latter showed positive results for all firms.

Stieblae and Reize (2011) estimate the model using German firms, without finding significant effects on spillovers. In the case of Latin American countries, the above studies usually include an ownership variable (foreign or domestic) when estimating innovation equations, without exploring the spillover effect of MNEs on local firms[2]. Benavente (2005) estimated the implementation of new products using a generalized Tobit model, in the context of the CDM model, and found no significant results for foreign ownership. Crespi and Zuñiga (2012) applied the four steps of the CDM model to estimate the effects for six Latin American countries and found that for Chile, foreign ownership has a positive and significant effect on the probability of implementing new

[2] Alvarez et al. (2019) stand as the sole exception employing instrumental variable approaches. However, their study does not directly consider FDI inflows to the country; instead utilizing a business survey to gauge perceptions of foreign competition, which is then used as a proxy to estimate spillover effects.

products, a result not observed in the other countries studied. For Argentina, Colombia, and Panama, the authors found negative effects of foreign ownership.

Finally, in more recent work, Montégu et al. (2022) study the innovation performance of Chilean firms in order to explain the effect of firm import activity. This estimation also includes the ownership variable, allowing for knowing the probability of a MNE subsidiary to innovate; the spillover effect on local firms is not explored. The result presented shows that foreign owned firms spend more on innovation, while having a lower probability of innovation. Thus, Acevedo and Díaz-Molina (2021) utilized a CDM model to study the effect of absorptive capacity on the innovation and productivity of Chilean firms. They distinguish between operational and strategic absorptive capacity, finding that both positively impact innovation expenditure and the likelihood of innovation. However, this paper does not include any further analysis of foreign ownership or the presence of FDI.

The estimations in this paper aim to generate new evidence for the Chilean case, enhancing our understanding of its current economic performance and contributing to the general understanding of the spillover effects of FDI on innovation activities within the framework of capability creation.

III. Data and Methodolgy

Data

Innovation data are obtained from the Survey on Expenditures and Personnel in Research and Development (EGPID), conducted by the Ministry of Economy of Chile, following the Frascati Manual guidelines to produce results comparable with OECD countries. This survey collects information at the firm level, where a questionnaire is administered to characterize their productive activity (e.g., sales, exports, size, etc.), followed by a characterization of their R&D activities, including spending on intramural and extramural R&D activities, as well as the results of their innovation efforts. To classify innovation activity according to economic activity, the survey uses the International Standard Industrial Classification of All Economic Activities (ISIC).

In this paper, we use the survey versions for the reference years 2017 and 2019. Additionally, to obtain information regarding the amount of Foreign Direct Investment (FDI) in each economic sector, we use data published by the Central Bank of Chile. This FDI data is combined with the EGPID firm-level data in order to include the presence of FDI in the industry where the firm operates. The sources and the period of the data are described in the following Table 2:

Table 2: Data Sources

Data	**Source**	**Period**
Survey on Expenditures and Personnel in Research and Development (EGPID)	Ministry of Economy, Development and Tourism of Chile	2017 and 2019
Statistics Database	Central Bank of Chile	2012-2019

Table 3 shows the number of firms surveyed in each industry, the average innovation ratio (defined as the portion of firms that have executed an innovation in processes or products) and foreign ownership in each industry considered in this estimation.

Table 3: Description of the firm per industry

Industry	Number of firms	Innovation ratio	Foreign Ownership
Agriculture and fishing	1,556	14%	3%
Mining	151	24%	38%
Manufacture	2,511	24%	8%
Electricity, water and gas	210	27%	22%
Construction	1,126	16%	3%
Trade	1,702	16%	6%
Transport and communication	1,302	21%	8%
Real state, finance and business services	1,309	15%	6%
Other services	1,970	19%	5%

Source: Survey on Expenditures and Personnel in Research and Development (EGPID), 2017-2019

The number of firms across the industry is relatively homogeneous and representative at this level within the sample, which allow us to perform an industry-level analysis. Furthermore, the column "foreign ownership" shows the proportion of firms that have more of 10% of foreign capital, and indicates that foreign participation is more concentrated in firms within the mining, electricity, water, and gas sectors. In terms of innovation output, the innovation ratio indicates the proportion of firms that have implemented a new product or process during the survey period. It is evident that sectors such as agriculture, construction, and trade exhibit lower rates of innovation, whereas sectors such as electricity, water, gas, manufacturing, and mining demonstrate a higher proportion of firms that have implemented innovations; a tendency that is expected given the nature of those economic activities and their capital intensity.

Methodology

Within this set of studies, a relevant part of them used the CDM model, which aims to estimate the complete process of innovation (as was mentioned before) to explain productivity effect after the implementation of an innovation. A firm-level estimation will be presented in order to assess the microeconomics dynamics in the FDI on local firms. The goal of this estimation is to understand the firm-level determinants of innovation and how foreign presence could promote or undermine local innovation.

To assess innovation accurately, we employ a methodological approach based on the structural CDM model, as it was explained above, following previous research on productivity and innovation (Crespi & Zuñiga, 2012; Montégu et al., 2022). This model has garnered significant recognition for estimating innovation and productivity, primarily due to its adept handling of the bias correction related to innovation efforts. While the CDM model has been utilized in various contexts such as financing innovation, employment, or trade (Lööf et al., 2017), this paper aims to extend its application to FDI investment.

When estimating innovation outcomes, the CDM model offers methodological advantages over other models, considering the entire innovation process, from firms' decision to innovate, through estimating the intensity of innovation expenditure, to ultimately examining the probability of innovating and the resulting productivity outcomes. In contrast, due to its comprehensive approach, it allows for the correction of endogeneity and selection bias present in innovation estimates. This endogeneity occurs because, although many companies pursue innovation, these

are not necessarily reflected in the amount of money spent on R&D when they are non-monetary in nature.

With their methodological procedure, the CDM model involves a four-step process for estimating productivity: (I) firms deciding on innovation, (II) firms determining the investment amount, (III) executing the innovation, and (IV) observing changes in productivity resulting from the innovation. In our current research, we will focus on the initial three steps to formulate the ultimate innovation equation (step III).

In the first step, we identify the investment decision equations, which use a dummy variable indicating whether the firm participates in innovation activities or not. Firms are defined by $i = 1, \dots, n$:

$$D_i = \begin{cases} 1 \; if \; D_i^* = \sum_{j=1}^{n} \beta_j X_j + \; \varepsilon_i > c \\ 0 \; if \; D_i^* = \sum_{j=1}^{n} \beta_j X_j + \; \varepsilon_i \leq c \end{cases} \quad (1)$$

D_i represents the observable decision on firm participation in innovative activities, that takes a value of 1 when the company decides to engage in innovation activities and 0 otherwise, where *i* denotes the firm. The value for individual firms is determined based on a latent variable D*, which express the decision of participating in innovation activities (reported or not reported) determined by a set of explanatory variables. When D* exceeds a threshold c, the company decides to participate in innovation activities, whereas when below c, it would not engage in such activities.

The second step is the effort equation, the total innovation effort made by each firm i, measured as the expenditure in R&D per worker. However, as for the decision of innovation, the real effort (monetary or non-monetary innovative effort) made by each firm is a latent variable, called E_i^*.

$$E_i = \begin{cases} E_i^* = \sum_{j=1}^{n} \beta_j Z_j + \; \mu_i \;\; if \; D_i = 1 \\ 0 \; if \; D_i = 0 \end{cases} \quad (2)$$

In equation (2), it is shown that the observed effort in innovation, E_i, will be equal to the latent effort in innovation, E_i^*, when the firm has decided to make innovation efforts ($D_i = 1$). Otherwise, when $D_i = 0$, the reported effort will be zero. Assuming that the errors terms μ_i and ε_i are normally distributed and homoscedastic, and $\rho_{\mu,\varepsilon}$ is the correction term, a generalized Tobit estimation is applied to equations (1) and (2) to address the issue of selection bias arising from the decision to innovate, determined by unobservable variables (Crespi & Zuñiga, 2012; Montégu et al., 2022).

In the third and last step the innovation output is developed, measured as the implementation of a new process or product, which is estimated to provide an answer to the research question: is there any presence of innovation spillovers from MNEs to local firms? In this manner, the innovation output shows the probability of implementing an innovation, using the dummy variable I_i (1 if the firm has performed an innovation and 0 if not). Furthermore, in this step, the FDI variable is included in order to capture the effect of foreign ownership in the innovation results of local firms. The estimation is described as follows:

$$I_i = \; \gamma E_i^* + \sum_{j=1}^{n} \beta_j K_j + \; \upsilon_i \quad (3)$$

The variable I_i is assessed based on the implementation of new products or processes within firm i, aligning with extensive use of this variable in the innovation literature (Crespi & Zuñiga, 2012; Griffith et al., 2003). As part of the procedure of the CDM model, we are applying a correction to the pecuniary efforts in innovation included in I_i with the variable E_i^* as an explanatory variable. This inclusion, as described in the previous steps, is based on the idea that not all the firms have pecuniary efforts in innovation, measured as R&D expenditure; however, they might implement non-monetary efforts that are not captured in the variable R&D. Therefore, the equation (3) includes the predicted value of R&D per firm based on the observable characteristics estimated in equation (2).

In this model, we aim to extend our analysis by incorporating foreign activity, measured by an FDI variable. This extension involves including total FDI inflows into the economic sector, enabling us to assess the FDI spillover effect on local firms. Unfortunately, the inclusion of FDI may introduce an endogeneity issue, as the level of local innovation in the sector could potentially influence the level of FDI entering that sector. Caves (1996) elucidates that foreign firms enter new markets through acquisitions based on productivity and innovativeness in the industry. To address this endogeneity problem, we are adopting the approach outlined by García et al. (2019), which entails using the three, two, and one year lags of FDI inflows in the place of current FDI. Although past FDI may be correlated with current FDI, the current level of R&D cannot explain previous FDI inflows.

This analysis requires the estimation of three equations conducted in recursive order using the methodology outlined above. The description of the variables used in this estimation is provided in the following Table 4:

Table 4: Variables description

Dependent Variables	**Definition**	**Excepted sign**
Innovation decision	Dummy = 1 if the firm has reported in-house research and development expenditure	
Innovation efforts	Log of total CLP in house research and development expenditure per worker made by the firm in the reported period.	
Innovation output	Dummy = 1 if the firm has implemented a new product or service in the previous 2 years	
Independent variables		
FDI inflow in the industry	Total FDI inflows of the previous 3, 2, and 1 year as a share of the gross domestic product´s industry	+/-
Foreign ownership	Dummy = 1 if the firm has foreign capital (> 10%)	+/-
Control vars		
Size	Log of average sales of the previous 2 years	+
Exporter	Dummy = 1 if the firm exports in the previous 2 years	+
Age	Number of years since incorporation of the firm	+/-
Public finance support	Dummy = 1 if firm has received funding by public institutions in the previous 2 years	+
Firm Cooperation	Dummy = 1 if firm i has cooperate with other firm in any innovation effort	+
National cooperation	Dummy = 1 if firm i has cooperate with other national firm in any innovation effort	+
Foreign cooperation	Dummy = 1 if firm i has cooperate with other foreign firm in any innovation effort	+/-
Predicted R&D	Predicted value of the Log of total CLP in house research and development expenditure per worker obtained in equation 2	+
Mills ratio	Inverse of the Mills ratio	+

IV. Results

The main findings will be described in this section, based on the previously explained estimations. The solutions to equations (1) and (2) are presented in the following Table 5. This estimation corresponds to steps 1 and 2 of the model which express the decision equation, followed by the effort equation.

Table 5[3]: Results for decision equation and expenditure in R&D (Equations 1 and 2)

	2017		2019	
VARIABLES	Decision	Effort	Decision	Effort
Foreign ownership	0.05***	2.34***	0.25**	1.23***
	-0.09	(0.27)	(0.09)	(0.28)
Exporter	0.08***	3.53***	0.09***	4.15***
	(0.06)	(0.26)	(0.06)	(0.29)
Public finance support		0.77***		1.10***
		(0.24)		(0.23)
Cooperation		1.23***		0.75**
		(0.31)		(0.36)
Size	0.00***		0.00***	
	(0.00)		(0.00)	
Mills ratio		5.97***		6.25***
		(0.21)		(0.27)
Constant	-1.75***	-7.34***	-1.70***	-7.38***
	(0.03)	(0.48)	(0.03)	(0.53)
Observations	5,961	5,724	5,961	5,727

Standard errors in parentheses
Coefficients are reported as marginal effects
*** p<0.01, ** p<0.05, * p<0.1

The results obtained from the Generalized Tobit specification allow us to correct the bias problem in reporting innovation activity participation, as we assumed that only companies making a certain effort report their participation, expressed in R&D expenditure per worker. Furthermore, this estimation is carried out for the two years, corresponding to the 2017 and 2019 survey results. In the first step, we find that foreign-owned companies have a higher probability of participating in innovation activities, which is consistent for both periods. While Crespi and Zuñiga (2012) did not find this variable significant for the year 2005, they did find this positive relationship for other countries studied, such as Argentina, Panama, and Uruguay. The same results were found with export activity, meaning that firms that have exported experienced a higher probability to participate in innovation activity, and to invest a higher amount of R&D per worker (Crespi & Zuñiga, 2012). Regarding the size of the firm, this variable shows a significant positive explanation on the decision to innovate, where the bigger the firm is, measured as the log of the total sales, the

[3] Following Crespi and Zuñiga (2012), selected variables were incorporated into the first and second steps of the estimation to ensure a more consistent analysis, in line with the current literature, and to lay the groundwork for subsequent steps.

higher the probability of participating in innovation activities (Crespi & Zuñiga, 2012; Montegú et al., 2022).

One variable included in the equation measuring innovation efforts is collaboration, determined by asking firms whether they have engaged in cooperative research activities with other firms. As expected, firms that have collaborated with others tend to exhibit higher expenditures on R&D (Fitjar & Rodríguez-Pose, 2013). A plausible hypothesis for this outcome could be that companies seeking collaboration with other firms exhibit a positive bias towards greater innovation expenditures given the nature of that relationship, whereby the motivation for collaborating on innovation is associated with a desire to spend more on innovative efforts.

The relevant estimation results are reported in Table 6. The innovation outcomes, measured as the implementation of new products and processes for both years 2017 and 2019, are reported.

Table 6: Result for all firms, survey 2017 and 2019

	Dependent variable: innovation					
VARIABLES	2017			2019		
Foreign ownership	-0.05**	-0.05**	-0.05**	-0.05**	-0.05***	-0.05**
	(0.08)	(0.09)	(0.09)	(0.10)	(0.09)	(0.10)
FDI inflow Lag-1	-1.20***			-0.01		
	(1.43)			(1.05)		
FDI inflow Lag-2		-0.95***			-0.01	
		(1.24)			(1.01)	
FDI inflow Lag-3			-0.48***			-0.01
			(0.67)			(1.19)
Predicted R&D	0.11***	0.02***	0.03***	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Sales	0.02***	0.02***	0.02***	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exporter	-0.04***	-0.04***	-0.04**	-0.10***	-0.10***	-0.10***
	(0.07)	(0.06)	(0.08)	(0.07)	(0.07)	(0.08)
Age	0.00	0.00	0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Public finance support	0.10***	0.10***	0.11***	0.15***	0.15***	0.15***
	(0.12)	(0.13)	(0.14)	(0.15)	(0.15)	(0.15)
Cooperation with national	0.27***	0.27***	0.27***	0.36***	0.36***	0.36***
	(0.26)	(0.27)	(0.23)	(0.43)	(0.37)	(0.41)
Cooperation with foreign	-0.17**	-0.19**	-0.19**			
	(0.36)	(0.40)	(0.40)			
Constant	-1.51***	-1.54***	-1.57***	-1.49***	-1.49***	-1.49***
	(0.18)	(0.16)	(0.19)	(0.19)	(0.21)	(0.17)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,872	5,872	5,872	5,946	5,946	5,946

Standard errors in parentheses
Coefficients are reported as marginal effects
*** p<0.01, ** p<0.05, * p<0.1

Regarding the main objective of this paper, in particular the spillover effect on innovation from foreign to domestic firms, the innovation outcomes equation incorporates elements of foreign

competition to assess the question posed here. To do this, a dummy variable measuring whether the company has carried out any innovations in product or process is used as the dependent variable. Regarding the independent variable to evaluate the intensity of FDI, two alternative variables are used as robustness checks. The lag of FDI inflows over the past 3, 2 and 1 years as a share of the industry's GDP was tested. The use of the lag is taken from Jin et al. (2019), which allows for correcting the endogeneity problem due to double causality, as the amount of FDI present during the period studied may be determined by how innovative the economic sector is in which the MNEs invest.

The results obtained from the FDI variables show consistent results. It can be observed that only for the year 2017 is there a significant negative effect of the amount of sectoral FDI on the probability of firms innovating. However, for the year 2019, no significant effects are observed. This finding contrasts with the evidence presented by Alvarez et al. (2019), which, while studying these spillovers with Chilean firms, reaches opposite results. Nevertheless, this paper employs a more robust measure of FDI as it considers the actual flows of FDI rather than firms' perception of foreign competition.

Additionally, Jin et al. (2019), in the case of Spain, and Stieblae and Reize (2011), in Germany, find similar results as this paper for the year 2019, where no relationship between FDI and innovation outcomes is observed. Finally, for the year 2017, a significant negative relationship is observed, suggesting that a higher amount of FDI in the sector could affect the innovation capacity of local firms. As a robustness check, Table 7 below presents a new estimation of the innovation equation using a subsample of only local firms. The results obtained exhibit the same outcomes as previously, indicating a significant negative FDI spillover effect on local firms' innovation.

Table 7: Result for national firms, survey 2017 and 2019 for local firms

	Dependent variable: innovation					
VARIABLES	2017			2019		
FDI inflow Lag-1	-1.27***			-0.04		
	(1.69)			(1.39)		
FDI inflow Lag-2		-1.01***			-0.04	
		(1.2)			(1.36)	
FDI inflow Lag-3			-0.51***			-0.05
			(0.61)			(0.84)
Predicted R&D	0.02***	0.02***	0.02***	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Sales	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exporter	-0.04**	-0.04***	-0.04**	-0.09***	-0.09***	-0.09***
	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)
Age	0.00	0.00	0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Public finance support	0.10***	0.10***	0.10***	0.15***	0.15***	0.15***
	(0.13)	(0.12)	(0.15)	(0.15)	(0.17)	(0.15)
Cooperation with national	0.27***	0.27***	0.27***	0.35***	0.35***	0.35***
	(0.30)	(0.26)	(0.26)	(0.46)	(0.42)	(0.45)
Cooperation with foreign	-0.18*	-0.18**	-0.18			
	(0.53)	(0.51)	(0.47)			
Constant	-1.51***	-1.54***	-1.58***	-1.52***	-1.52***	-1.52***
	(0.20)	(0.16)	(0.19)	(0.20)	(0.18)	(0.17)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,497	5,497	5,497	5,569	5,569	5,569

Standard errors in parentheses
Coefficients are reported as marginal effects
*** p<0.01, ** p<0.05, * p<0.1

The results obtained indicate that FDI industry inflows decrease the probability of innovation by local firms for the year 2017. This can be partly explained by the challenges firms experienced due to increased competition from MNEs. As the competitive environment becomes more hostile for local firms, they may have reduced capacity to take risks on innovation activities, which are inherently riskier and more uncertain in nature (Caves, 1974; Annique & Cuervo-Cazurra, 2008).

Including the remaining control variables yields results consistent with expectations based on prior empirical research (Crespi & Zuñiga, 2012; Stieblae & Reize, 2011; Jin, García & Salomon, 2019). The firm size, measured as the logarithm of sales, is included as a control variable, and demonstrates a positive and significant effect on the probability of innovating. Similarly, a positive relationship is observed for the predicted value of R&D expenditure per worker, where a higher predicted expenditure in R&D increases the likelihood of implementing innovation. The dummy variable for exporting firms also shows a positive and significant result in each estimation, consistent with previous literature. Finally, public financing is included in the estimation as a

control variable, revealing that firms receiving public monetary support have a significantly higher probability of innovating.

A novel addition is the inclusion of cooperation as an independent variable. The findings indicate that companies claiming to have collaborated with other domestic firms show a higher likelihood of innovating, both in 2017 and 2019, which aligns with the literature emphasizing the importance of collaboration in the knowledge production process (Almudi et al., 2013; Fitjar & Rodríguez-Pose, 2013). A distinction made in this analysis is the origin country of collaboration; while there is a positive and significant effect of collaborating with a local firm, there is a negative effect of collaboration with a foreign company. A plausible explanation for this result may lie in localized knowledge production, as explained in evolutionary literature, which suggests that knowledge is place-specific and path-dependent (Nelson, 2004).

V. Conclusions

This paper presents econometric evidence on innovation spillovers from MNEs to local firms in Chile. Using microeconomic data from the 2017 and 2019 survey EGPID, the well-known CDM model was applied to estimate the effect of FDI presence in the industry on the innovation performance of local firms. The results for the 2017 sample show a significant and negative relationship: the greater the presence of FDI in the industry, the lower the probability that local firms will generate innovations, measured by the implementation of a new product or process. For the 2019 survey, no significant results were found. As a robustness check, the same estimation was performed using only local firms, yielding consistent results.

While productivity spillovers have been widely studied, this paper provides novel evidence on a less explored type of spillover: innovation. In this context, focusing on innovation allows us to concentrate on the effects of MNEs on the technical capabilities of local firms, such as changes in their production functions and their ability to generate new products or processes. This approach promotes a deeper understanding of how increased interaction with foreign companies can enhance the potential for local firms to generate new knowledge.

As the results illustrate, a greater presence of foreign firms does not necessarily ensure improved innovation capacities in local companies. Following the knowledge-generation dynamics outlined by several authors (Nelson, 2004; Cimoli & Porcile, 2009), new knowledge cannot be absorbed through mere interaction, as its nature is path-dependent, tacit, and place-specific. Thus, only the explicit effort of local firms can facilitate the absorption and adaptation of new knowledge, and even then, these conditions are not always guaranteed. Additionally, the results show a negative effect, which may suggest that less favorable conditions for generating innovation arise due to more adverse competitive environments driven by increased foreign competition (Caves, 1974; Annique & Cuervo-Cazurra, 2008).

Finally, the limited access to detailed information on foreign companies, particularly the ability to disaggregate by its characteristics, presents a limitation for studies of this kind. Given the significant heterogeneity among foreign firms (e.g., greenfield vs. mergers and acquisitions, country of origin, among others), it is likely that their relationship with local firms has a distinct nature. Therefore, advancing in this direction would be valuable for future research.

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