DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 12-11

Does Licensing Induce Technological Spillovers to Domestic Firms?

Luis Castro
University of Colorado at Boulder

November 2012

Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

Does Licensing Induce Technological Spillovers to Domestic Firms?*

Luis Castro†

Department of Economics
University of Colorado at Boulder

This Draft: November 2012

*I would like to thank my advisor, Keith Maskus, for all his support and guidance. I would also like to thank the rest of my committee, Wolfgang Keller, Scott Savage, and Thibault Fally, for invaluable comments and advice. I am grateful to Joze Damijan, and Ricardo Lopez for helpful comments; and to various participants at the Third Bolivian Conference on Development Economics, the Eastern Economic Association, and the Empirical Investigations in Trade and Investment (EITI) for constructive remarks.

†Department of Economics. University of Colorado at Boulder, Boulder, Colorado 80309-0256.
E-mail address: Luis.Castropenarrieta@colorado.edu
Phone: +1(305)905-1139
Website: http://luiscastroecon.weebly.com

Abstract

Productivity differences can explain differences in economic growth across countries. It has been demonstrated that the presence of a foreign-owned multinational enterprise (MNE) in a developing country is one of the most important methods through which technology transfer occurs. This presence could be in the form of foreign direct investment (FDI), licensing, or imports from the developing country. However, it is still unclear by what means and how effectively each type of foreign presence affects domestic productivity.

In this paper, I study licensing as one of the channels through which foreign technology is transferred to domestic plants. This technology transfer can occur in one industry and also in related industries, which results in technology spillovers that can affect both intra- and inter-industry productivity. Moreover, the institutional framework of the country can affect the type of foreign presence adopted by MNEs in the host country. Therefore, it is important to analyze the effect of a change in the institutional framework on technology spillovers. This can be achieved by analyzing a set of new and stronger intellectual property rights (IPR).

Using Chilean firm level data for the 2001–2007 period I find that there are positive inter-industry spillover effects when licensing occurs in downstream sectors which result in higher productivity for domestic plants in upstream sectors (backward spillovers).

When evaluating the effect of the IPR measure, I find that stronger IPR measures decrease the backward spillover effect. I also find that the change in policy has a stronger effect on firms that are, on average, smaller and have low productivity.

Moreover, there is a crowding-out effect between licensing and FDI since, with better IPR, MNEs prefer doing licensing than incurring higher costs of FDI. This is consistent with the literature arguing that licensing becomes the preferred mode of technology transfer, replacing FDI, once a certain threshold of IPR is reached.

JEL Codes: F14, O54, O3.

Keywords: Spillovers; Technology transfer; Intellectual Property Rights; Chile.

1 Introduction

Many economists have recognized that productivity differences can explain differences in economic growth across countries. Numerous studies have demonstrated the importance of technology transfer to reduce the productivity gap between developed and developing nations.

As Montalvo and Yafeh (1994) note:

> "*Japan's economic growth in the postwar period has been characterized by a very rapid growth in productivity, achieved, to a great extent, through massive borrowing of technology from more advanced countries.*"

The main channels to transfer technology from a multinational enterprise (MNE) are foreign direct investment (FDI), licensing, and imports by the host country. The importance of FDI for economic growth due to the technology transfer it brings has been shown in many studies (see for example Blalock and Gertler (2008), and Alfaro et al. (2006)).[1]

Licensing also constitutes an important source of technology transfer. Studies related to this topic have mostly dealt with FDI exclusively. When thinking about imports as a source of technology transfer, it is important to note that this could be a major channel as shown by Acharya and Keller (2009).

In this paper, I will focus on the first two channels (FDI and licensing) for technology transfer since in a recent trend, developing countries have introduced different measures to attract foreign presence. As Zanatta et al. (2008) point out, a clear example of this trend is the recent economic opening of China and also the amendment to the Indian Law of Patents in 2002 and the liberalization of most aspects of FDI in India.

Note that to attract foreign presence, the institutional framework in developing countries is crucial. Factors that affect the level of foreign presence are: political stability, labor market regulations, infrastructure, human capital, and market size, which could attract or deter MNEs.

With the increasing importance of intangible assets in the current state of economic globalization,

[1] Throughout the paper I will refer to FDI as inward FDI, that is the investment by an MNE on a subsidiary in a host country.

intellectual property rights (IPR) play an important role in the decision of MNEs when entering a market abroad through FDI or licensing.[2] The awareness of the importance of IPR has increased in the last fifteen years due to the implementation of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) in 1995 by members of the World Trade Organization (WTO). As stated by the WTO, *"it (the agreement) establishes minimum levels of protection that each government has to give to the intellectual property of fellow WTO members."*[3]

Nevertheless, there is still some controversy as to the effect of IPR strengthening on the welfare of the host economy. On one side, stronger IPR provides the necessary protection in order for production to shift and increase in a developing country *("market effect")* and thus release resources in the developed countries to push the technological frontier further. On the other side, stronger IPR reduce the ability of local firms in the host economy to imitate new technologies, and create a *"monopoly effect"* that would reduce the incentive for investing or licensing in the foreign affiliate.

I use Chilean manufacturing data for the 2001–2007 period to evaluate the effect of stronger IPR since there was a reform in 2005. Two different effects of a change in IPR are worth examining. First, the effect of IPR changes on the productivity of domestic firms, which will be the pivotal point for this study. Second, the effect of IPR changes on entry mode decisions for MNEs. It is important to note that these effects have not been fully studied in the context of a developing country with in interaction with an IPR reform.[4]

When analyzing the effect on productivity, it is important to note that there could be productivity externalities from foreign presence in the domestic economy. These externalities or *"spillovers"* could happen horizontally (within the same industry) or vertically (across different industries). If there is a large positive effect for either upstream or downstream industries, this can provide the grounds for a more open policy toward foreign presence (either through FDI or licensing). However, if the effect on other industries is negative, the country might be more restrictive in pursuing foreign presence since that might hurt domestic firms more than help them. This issue is crucial to inform economic policy about the impacts of foreign presence in the country.[5]

Figure 1 can be used to better understand the concept of having licenses in one sector and productivity spillovers in another.

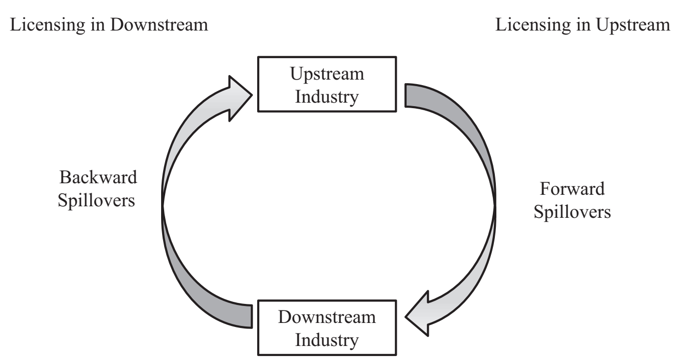
[2] Branstetter et al. (2006) and Branstetter et al. (2007) analyze the effect of IPR reforms in different countries.
[3] For more information see the WTO website.
[4] The second effect is examined in more detail in Castro (2012).
[5] This could be true when the market structure is such that foreign firms have overwhelming market power.

One example of spillovers for the Chilean economy is the US MNE *Burger King*, which produces fast food. This MNE has been in Chile for 11 years, with 22 different licensees. In this case, it is likely that licensee firms in Chile use intermediates from Chilean providers, such as food and beverages from a local providers, packing containers of a given quality and so forth. This could create backward spillovers in the economy.[6]

Thus, looking at the left side of Figure 1, if licenses are in the downstream industry (fast food), it is plausible to think about transfer of technology to the upstream sector (such as containers, tables, chairs, and so on), resulting in backward spillovers.

If licensing is in upstream sectors, downstream sectors could benefit through lower prices or higher quality. The MNE *Crown Aluminio* from Taiwan, for example, is the licensor for the production of glass and aluminum. Therefore, it is possible to think about licensees providing intermediate goods at a lower price or a better quality, which could result in forward spillovers.

Figure 1: Spillover Effects of Licensing



Many studies have analyzed foreign presence and the technology externalities that could affect the productivity of domestic firms (spillover effects). Most of these studies focus on FDI as a form of foreign presence. Among the most important firm level studies that analyze spillover effects are Aitken and Harrison (1999), which uses data from Venezuela, and Javorcik and Spatareanu (2008), which looks at Romania. An influential study is Javorcik (2004b), in which she analyzes spillover effects of FDI on productivity through backward and forward linkages in Eastern Europe. Another important study is that by Damijan et al. (2008); they analyze spillover effects across different transition economies in Europe. More recently, Keller (2009) examines spillovers to US firms through two channels: imports and FDI. The closest study to this one is Lopez (2008), who

[6] For more examples see www.franquicia.cl/nacionales.html

studies if plants benefit from licensing foreign technology. He finds that licensing has positive forward spillover effects and negative backward spillover effects.[7]

There are four important contributions made in the current study. First, the time frame of this study is more recent, which is important since Chile has been growing steadily in the last decade. Second, Lopez (2008) could not include the change in IPR that occurred in 2005, which might affect the choice of entry mode of MNEs and thus, affect the level of licensing. Third, there have been new developments in the field of productivity measurement. This study uses a different and more accurate productivity estimation technique compared to earlier studies. Fourth, it is possible to determine different magnitudes of spillover effects depending on the productivity level of the firm as in Damijan et al. (2008).

The current paper also addresses the effect of stronger IPR on the decision between FDI and licensing as a form of entry. Empirical studies shed some light into the effect of stronger IPR on trade flows and FDI.[8] Lee and Mansfield (1996); Braga and Fink (1998); Nunnenkamp and Spatz (2004); Javorcik (2004a) find that weaker IPR perception leads to lower levels of FDI in different settings.

Branstetter et al. (2006) analyze the effect of IPR reforms in sixteen countries during the 1982–1999 period. A more complete study followed (Branstetter et al., 2007). They find that MNEs increase their capital stock and employment compensation, while royalties paid are reduced after IPR reforms.[9] This study is the closest in spirit to the hypothesis to examine whether there is an increase in FDI or licensing as a result of the IPR reform.[10]

I find that increasing the strength of patent laws in Chile led to smaller backward spillover effects in the economy. This may be due mainly to the fact that more strict and better enforced laws reduce incentives for people to copy foreign technology when they may face a stronger penalty for doing so. Moreover, the IPR policy seemed to *"harm"* firms with lower productivity, and smaller firms, which may have benefited more from spillover effects.

I also find that there is a substitution effect into licensing and away from FDI since with stronger IPR, MNEs prefer to license rather than incur the higher costs related to FDI. This is consistent with the literature arguing that licensing displaces FDI once a certain threshold of IPR is reached.

[7] For a survey on spillover effects see Görg and Greenaway (2004).
[8] For a discussion between the relation between trade and IPR, see Maskus and Penubarti (1995).
[9] Hereafter referred to as BFFS.
[10] Park (2008) reviews issues behind IPR strength and innovation.

The remainder of the paper is structured as follows. Section 2 describes a theoretical model in order to motivate the empirical study. Details about the data used are explained in section 3, while the empirical analysis is in sections 4 and 5, while section 6 concludes.

2 Theory Model

The model is based on Maskus et al. (2005). Their original model deals with the choice of entry of a multinational (either through FDI or licensing). In equilibrium, an MNE has to be indifferent between FDI and licensing. Thus, after the choice of entry has been made, there are two types of firms in the host economy that have a direct link with the MNE: FDI firms and licensees.

Moreover, it is necessary to introduce linkages that can produce backward spillovers in the host economy. Bringing in such linkages, and thus the possibility of intra-industry spillovers, requires an intermediate good industry. Following Markusen and Venables (1999), I assume that there are four types of firms. In the host country, there are three types of firms: domestic suppliers of intermediate goods, foreign firms that undertake FDI, and domestic firms that receive licenses. There are also firms located abroad that produce intermediate goods, that can be used in the host economy but only through either FDI or licensing. Thus, the four types of firms can be summarized as follows, noting variables for prices and outputs:

- Domestic firms in the intermediate goods industry p_i, x_i
- Foreign firms in the intermediate goods industry p_i^*, x_i^*
- Licensing firms in the final goods industry p_L, x_L
- FDI firms in the final goods industry p_F, x_F

Following Maskus et al. (2005), the fixed cost of production for firms in the final goods industry has the form:

$$F_j = K_j + c_j(k) \qquad \text{for } j = F, L$$

Where K_j are production-related costs (independent of IPR), and $c_j(k)$ is a contractual cost that depends on the strength of IPR (k). Since it is plausible to think that MNEs incur higher fixed costs through the need to establish distribution channels, gaining knowledge of the market, and the like; it is assumed that $F_F > F_L$.

Moreover, following Yang and Maskus (2001) assume that the contractual costs of both FDI and licensing decline with the level of IPR, that is: $\frac{dc_j}{dk} < 0$. However, it is reasonable to suppose that these costs decline with k faster for licensing than for FDI:

$$\left|\frac{dc_F(k)}{dk}\right| < \left|\frac{dc_L(k)}{dk}\right|$$

This is a plausible assumption because licensees have a comparative advantage relative to FDI firms since they have a greater knowledge of the contracting enforcement mechanisms in the host country.

2.1 The technology

Let FDI and licensing firms have a constant returns to scale (CRS) Cobb-Douglas production function, using labor and intermediate goods in the host country as inputs:

$$x_j = l_j^{1-\alpha} q_j^{\alpha} \qquad \text{for } j = L, F$$

Where l_j is labor and q_j is a composite intermediate input that also requires labor (following Dixit and Stiglitz (1977), and Ethier (1982)). The production function of intermediate goods is assumed to be a CES function that uses intermediate goods from the domestic economy as well as from abroad.

$$q_j = \left[\mu_j(k)x_{ij}^{\theta} + (1-\mu_j(k)){x_{ij}^*}^{\theta}\right]^{1/\theta}$$

Where θ is the elasticity of substitution between intermediate goods, x_{ij} is the amount of intermediate goods (either domestic or imported) needed to produce a unit good j, and there is an efficiency parameter $\mu(k)$ that represents the efficiency of domestic inputs. The crucial link between IPR strength and the efficiency parameter is that when there is stronger IPR, it is plausible that both FDI and licensing firms have access to greater varieties of intermediate inputs (maybe even better in terms of quality); thus, the relative efficiency of domestic intermediate goods is reduced.

It is also plausible to assume that FDI firms have higher access to intermediates from the home country. That is, $\mu_F < \mu_L$. Also, an increase in IPR strength affects the requirement for domestic goods negatively as explained above (firms will transfer more goods from abroad); thus $\frac{d\mu_j(k)}{dk} < 0$. Here again it seems likely that an IPR increase will affect FDI firms more than licensing firms, perhaps because MNEs access a greater range of intermediate goods that could be sent to the host country. Thus I assume that:

$$\left|\frac{d\mu_F(k)}{dk}\right| > \left|\frac{d\mu_L(k)}{dk}\right|$$

The operating profit function is given by:

$$\begin{aligned} \pi_j =& p_j x_j - p_i x_{ij} - p_i^* x_{ij}^* - w l_j \qquad \text{for } j = L, F \\ \pi_j =& p_j l_j^{1-\alpha} \left[\mu_j(k) x_{ij}^{\theta} + (1-\mu_j(k)) {x_{ij}^*}^{\theta}\right]^{\alpha/\theta} - p_i x_{ij} - p_i^* x_{ij}^* - w l_j \end{aligned} \tag{1}$$

2.2 Decision between FDI and licensing, and spillover effects

As Maskus et al. (2005) note, new technology brought into the country either by FDI or licensing has two inherent risks. First, any technology could be supplanted by a newer technology through innovation competition. In particular, if there is a large pool of potential innovators and their innovation incentives are unchanged by changes in IPR in the host country, then it is appropriate to assume that successful innovation follows a Poisson process with arrival parameter i. Second, technology can be imitated in the host country. This is equally likely for FDI and licensing. I assume that successful imitation also follows a Poisson process with arrival parameter $m(k)$, where $\frac{dm}{dk} < 0$. That is, stronger IPR reduce the rate of imitation.

MNEs choose between FDI and licensing, which means a firm must be indifferent in equilibrium between these alternatives. Thus, the operating profits from FDI are higher than from licensing to compensate for the higher fixed cost of FDI. Thus, $\pi_F > \pi_L$. To show this equilibrium more carefully, we need to compare discounted value of assets in the two cases. With a discount rate equal to r then:

$$V_F = \frac{\pi_F}{i + m(k) + r} - F_F \qquad \text{and} \qquad V_L = \frac{\pi_L}{i + m(k) + r} - F_L$$

The firm will engage in FDI if $V_F > V_L$. Then the indifference point occurs where $V_F - V_L = 0$:

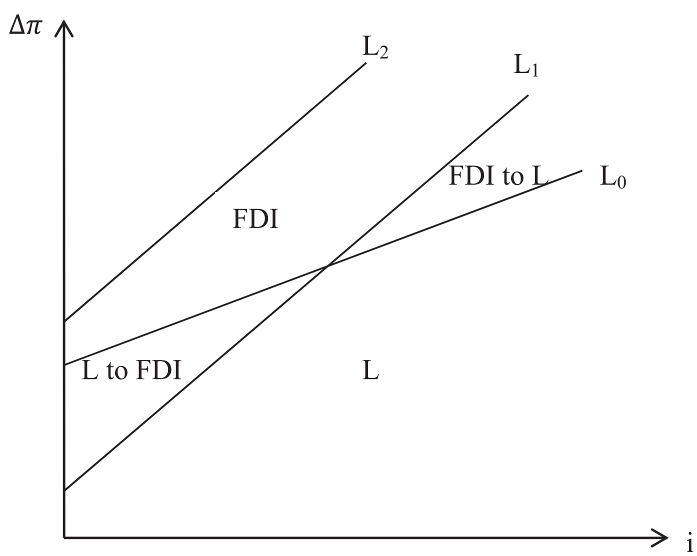
$$\frac{\pi_F}{i + m(k) + r} - F_F = \frac{\pi_L}{i + m(k) + r} - F_L \tag{2}$$

Equation (2) can be written as:

$$\Delta\pi = (i + m(k) + r)\Delta F(k) = (m(k) + r)\Delta F(k) + i\Delta F(k) \tag{3}$$

Where $\Delta\pi = \pi_F - \pi_L > 0$ and $\Delta F(k) = F_F(k) - F_L(k) > 0$. Note that equation (3) is a straight line in the $\Delta\pi, i$ plane with intercept $(m(k) + r)\Delta F(k)$ and slope $\Delta F(k)$. This line is shown as L_0 in Figure 2.

Figure 2: FDI and Licensing Decision
with Variable Innovation



Source: Maskus et al. (2005).

Consider a point above L_0, that is $\delta\pi > 0$. Thus, $\pi_F > \pi_L$ and it is more profitable for the MNE to enter the host economy through FDI. That is, if the firm is above L_0 then it will choose FDI over licensing. On the other hand if the firm is below L_0 it will choose licensing over FDI.

Now consider the impact of a strengthening of IPR on the decision between FDI and licensing. In this case, Maskus et al. (2005) have two direct effects. First, it will affect the slope of the line L_0 and second, it will affect its intercept. However, in the current model there will be a third effect due to the presence of IPR in the operational profit function:

$$\frac{d(\pi_F - \pi_L)}{dk} = \frac{d((m(k) + r)\Delta F(k))}{dk} + \frac{id\Delta F(k)}{dk} \tag{4}$$

First, the cost of imitation increases and the rate of imitation $m(k)$ would decline. Second, the fixed costs of both FDI and licensing would decline. However, the reduction would be greater for licensing since it is assumed that:

$$\left|\frac{dc_F(k)}{dk}\right| < \left|\frac{dc_L(k)}{dk}\right| \qquad \Rightarrow \qquad \frac{d\Delta F}{dk} = \frac{dc_F}{dk} - \frac{dc_L}{dk} > 0$$

Third, for the LHS of (1) we have:

$$\frac{d(\pi_F - \pi_L)}{dk} = \frac{d\pi_F}{dk} - \frac{d\pi_L}{dk}$$

Since the only terms included here that have (k) in it are related to the domestic and foreign intermediate input requirements, $\frac{d(\pi_F - \pi_L)}{dk}$ would give the effect on backward spillovers of a change in IPR. Thus, for $\frac{d\pi_F}{dk}$ we have:

$$\begin{aligned}\frac{d\pi_F}{dk} =& p_F l_F^{(1-\alpha)} \frac{\alpha}{\theta} \left[\mu_F(k) x_{iF}^{\theta} + (1-\mu_F(k)) {x_{iF}^{*}}^{\theta}\right]^{(\alpha-\theta)/\theta} \frac{d\mu_F(k)}{dk} x_{iF}^{\theta} - \frac{d\mu_F(k)}{dk} {x_{iF}^{*}}^{\theta} \\ =& \Omega_F \frac{d\mu_F(k)}{dk} \left(x_{iF}^{\theta} - {x_{iF}^{*}}^{\theta}\right)\end{aligned}$$

Where:

$$\Omega_F = p_F l_F^{(1-\alpha)} \frac{\alpha}{\theta} \left[\mu_F(k) x_{iF}^{\theta} + (1-\mu_F(k)) {x_{iF}^{*}}^{\theta}\right]^{(\alpha-\theta)/\theta} > 0$$

Therefore:

$$\frac{d\pi_F}{dk} = \Omega_F \frac{d\mu_F(k)}{dk} \left(x_{iF}^{\theta} - {x_{iF}^{*}}^{\theta}\right) \gtrless 0 \qquad \text{and} \qquad \frac{d\pi_L}{dk} = \Omega_L \frac{d\mu_L(k)}{dk} \left(x_{iL}^{\theta} - {x_{iL}^{*}}^{\theta}\right) \gtrless 0$$

The term $\frac{d(\pi_F - \pi_L)}{dk}$ could therefore be either positive or negative. The intuition is as follows. If this term is positive, it would mean that stronger IPR lead to an increase in $\Delta\pi = \pi_F - \pi_L$. Then it is more profitable to engage in FDI over licensing. As a result, there will be a strongly negative effect on the demand for domestic intermediate goods, since FDI firms now demand lower levels of domestic intermediate inputs. In turn, there would be lower backward spillovers.

If $\frac{d(\pi_F - \pi_L)}{dk}$ is negative, FDI would be less profitable than licensing and the latter would rise. Still, this outcome would also imply a negative effect on the demand for domestic intermediate goods, which leads to lower backward spillovers. However, the effect would be smaller than in the previous case.

Moreover, the sign also depends on the change of equilibrium quantities of intermediates used. In this case it is possible to assume that the equilibrium quantity of domestic intermediates decreases with stronger IPR and the quantity of foreign intermediates increases.

In order to know the sign of the LHS of (4) it is possible to see that:

$$sign\left(\frac{d(\pi_F - \pi_L)}{dk}\right) = sign\left(\frac{d((m(k)+r)\Delta F(k) + i\Delta F(k))}{dk}\right) \tag{5}$$

Note that the RHS of (4) can be decomposed into the effect on the slope and the effect on the intercept. The effect on the slope is clear:

$$\frac{id\Delta F(k)}{dk} = i\left(\frac{dc_F}{dk} - \frac{dc_L}{dk}\right) > 0$$

Thus an increase in IPR would unambiguously increase the slope of the line L_0 depicted in Figure 2, say to that shown in line L_1.

When looking at the effect on the intercept, we need to consider two cases. It is possible that the decline in costs is dominated by the reduction in imitation:

$$\frac{d((m+r)\Delta F)}{dk} = \frac{dm}{dk} + (m+r)\frac{d\Delta F}{dk} < 0$$

As noted in Maskus et al. (2005), in this case the indifference line between FDI and licensing would shift downward and would also be steeper. Thus, the new line lies below the old line for low rates of innovation (low tech industries) and above the line for high rates of innovation (high tech industries).

The result is that increasing IPR converts licensing to FDI for low innovation rates but shifts FDI to licensing for high innovation rates (L_1 line in Figure 2).

In the second case, it is possible that the decline in relative costs dominate the reduction in imitation:

$$\frac{d((m+r)\Delta F)}{dk} > 0$$

Here the line shifts up and it is steeper (line L_2 in Figure 2). Therefore, increasing IPR induce firms to increase licensing unambiguously, regardless of the rate of innovation.

Therefore, there will be two hypotheses to be tested regarding impacts of an increase in IPR. First, there is the effect on backward spillovers to domestic firms through licensing. Initially, licensing implies higher demand for domestic intermediate inputs, which should result in higher productivity. However, as a result of stronger IPR, there should be a decrease on backward spillovers.

Second, stronger IPR should shift the entry mode from FDI to licensing, depending on the level of innovation or technology (high-tech vs. low-tech) in each industry. In this paper I will dwell on the first hypothesis, while the second hypothesis is tested less rigorously.[11]

3 Data

3.1 Firm level data

The plant-level data used in this study comes from the Chilean *Encuesta Nacional Industrial Anual* (ENIA).[12] This survey is conducted by the Chilean National Statistics Institute (INE) and it covers all the establishments (plants) with ten or more workers. Previous versions of this census have been used by Pavcnik (2002), and Lopez (2008), among others. One study that uses this census for the 2001–2006 period is Gibson and Graciano (2011). The years covered by this study are 2001–2007.

The unit of observation is the "establishment" (plant). There are firms that only have one plant; however there are firms that have more than one plant and that are integrated either vertically or horizontally (multi-plant and also multi-activity).

[11] For a more detailed treatment of the second hypothesis see Castro (2012).
[12] This is a national survey of the manufacturing sector.

In the case of multiple plants that belong to a firm, the survey includes each plant of the firm. Even though each plant has its own identification number (ID), due to statistical confidentiality purposes, it is not possible to identify which plants belong to a given firm.[13] Thus, each plant has a unique ID number that allows one to follow its performance throughout time, permitting longitudinal studies. In the present paper, the terms plant and firm will be used interchangeably. However, I will refer to establishments mostly as firms.

Regarding the activity of firms, in order to classify the economic activity of the plant, I use the *International Standard Industrial Classification of All Economic Activities* (ISIC) revision 3 from the United Nations classification system. The level of disaggregation of economic activities is at the four-digit level; however, due to data constraints this study focuses on two-digit aggregation.[14,15]

3.1.1 Data cleaning

The original dataset contains 37,307 firm-year observations. The first thing to note about the dataset is that starting in 1974 Chile was divided into 13 regions. However, in 2007 two regions were split, *Tarapacá* became *Arica y Parinacota* and *Tarapacá*; and *Los Rios* became *Los Rios* and *Los Lagos*. In order to maintain the consistency of the dataset, the 1974 division is maintained throughout the sample.

Next, since all the monetary variables in the dataset are in current pesos, it is necessary to deflate them into real pesos. Two different deflators are used in this case. This study undertakes estimation of Total Factor Productivity (TFP) as a central analytical element. Thus, for all the variables that enter TFP estimation, such as value added and capital stock, I use a four-digit deflator specifically designed by the INE for this survey. For variables, such as the value of licenses paid or wages, that have a more macroeconomic meaning and where it makes more sense to use a wider deflator, I use the more encompassing GDP deflator, provided by the Central Bank of Chile.

Some observations were purged in the data cleaning process. First, firms with negative value added have been purged from the study. Second, there are three different industries that have been

[13] This could present a problem if the majority of firms are multi-plant; however, as noted by Pavcnik (2002), using a previous version of this dataset, around 90% of the firms have a single plant. For the 2001–2007 period, this figure is around 89%.

[14] See: http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=2 for more detail.

[15] The covered industries are, in terms of ISIC (Rev.3) codes, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36. ISIC (Rev.3) codes of the manufacturing sector ranges from 15 to 36. Industries 16 (tobacco) and 23 (coke, refined petroleum products and nuclear fuel) have no observations in the dataset.

excluded. Industry 27 at the two-digit level ISIC level (Manufacture of Basic Metals) has been dropped from the study because the prices for these products are guided mainly by international prices. This implies that such variables as value added and sales for these products do not reflect the relation between inputs and output. Industries 30 and 32 (Manufacture of office, accounting and computing machinery and Manufacture of radio, television and communication equipment, respectively) have been drawn out of the study since there are not enough observations in each case (11 and 51 for the entire sample, respectively) to have enough variation to properly estimate productivity.

As explained above, in order to estimate TFP the data have been grouped at the two-digit ISIC level. To better understand the distribution of the data, it is possible to look at the number of observations and the description of each industry in Table A.1 in the Appendix. Note that except for the Food and Beverages industry, the observations are fairly evenly distributed.

The rest of the observations that are purged are the firms that change either industries or region (location) during the period of the study. Even though it could be argued that there is a loss of information in this case, the counter-argument is twofold. First, the number of observations lost is not high (approximately 6 percent of the original dataset). Second, when estimating a model using fixed effects, these fixed effects will capture all the inherited characteristics of a firm that do not change over time. Thus a change in industry or region would invalidate the interpretation of the results.[16] The final dataset has 33,538 firm-year observations in 17 industries at the two-digit level.

3.1.2 Descriptive statistics

Table 1 shows descriptive statistics of key variables. It is important to note that most of the stock of capital is held by domestic firms, while foreign firms only hold 15 percent of the capital on average. However, this is a very high percentage when compared to the percentage of foreign firms.[17,18]

I will now turn to foreign firms and licensing firms. In order to determine which firms are considered foreign, I used a 10 percent capital rule (i.e., if the capital holding is more than 10 percent the establishment is considered foreign). The resulting differentiation is presented in Table 2a. Moreover, it is also possible to analyze the number of firms, either foreign or domestic, that pay

[16] A more detailed explanation will be provided in the empirical section.
[17] This calculation is not shown in Table 1 but it is available upon request.
[18] The average exchange rate in 2003 was 691.54 pesos per US dollar.

Table 1: Descriptive Statistics for Key Variables (33,538 Obs.)

Variable	Mean	Std. Dev.	Min	Max
Capital Stock	1,946	15,532.6	0	953,000
% Domesic Capital	96	19.3	0	100
% Foreign Capital	4	19.3	0	100
Value Added	2,342	19,274.8	0	1,720,000
Sales of Production	3,815	29,328.1	0	1,770,000
Total Wages	375	2,148.9	0	275,000
Gross Production Value	5,449	46,237.2	2	3,480,000
Payments for Licenses and Foreign Assistance	8	151.3	0	11,864
Income due to Exports	1,090	8,654.9	0	401,000
Number of Skilled Workers	13	46.4	0	1,554
Skilled/Unskilled Workers Ratio	1	3.5	0	159
Skilled/Total Workers Ratio	0	0.3	0	1

Note: All monetary values are in 2003 Million Pesos.

licensing fees (for royalties and also for foreign assistance) and those that do not. This is depicted in Table 2b.[19]

Table 2: Distribution of Firms

Owner	Freq.	Percent	Cum.
Domestic	31,733	94.62	94.62
Foreign	1,805	5.38	100
Total	33,538	100	

(a) Ownership

Licensing	Freq.	Percent	Cum.
Does Not Pay Licenses	31,897	95.11	95.11
Pays Licenses	1,641	4.89	100
Total	33,538	100	

(b) Licensing

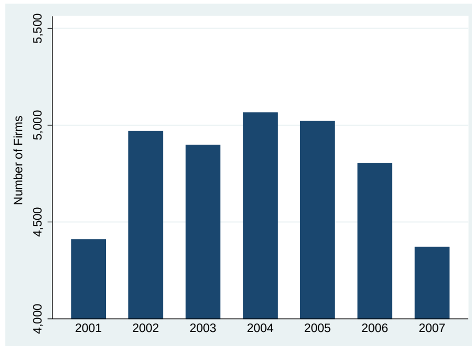
Moreover, when analyzing the dynamics of the number of firms present in Chile, one striking feature is depicted in Figure 3, where the decline in the number of firms after 2005 is extreme, achieving levels in 2007 that were even lower than the ones in 2001. This is not the case solely for domestic firms; it seems that FDI in the manufacturing sector has been decreasing steadily in the last few years. This can be seen in the following figure:

To better analyze the dynamics between domestic and foreign firms, as well as entry and exit, it is possible to construct transition tables where the entry and exit of foreign plants can be quantified. The average transition matrix for any two years within the 2001–2007 period is depicted in Table 3.

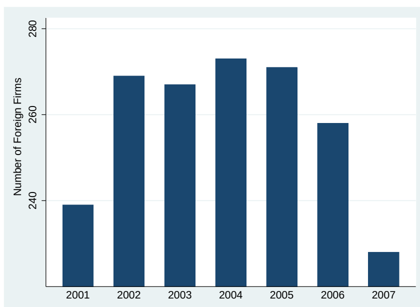
The way to interpret this matrix is as follows. The domestic-domestic cell in the matrix shows that for the entire period, 75.9% of firms were domestic in period t and remained domestic in period $t+1$. The foreign-domestic cell shows the percentage of firms that changed from foreign to domestic,

[19] This Table refers to the expenditure of the firm in licenses. The field in the ENIA survey is *Licenses and Foreign Technical Assistance*.

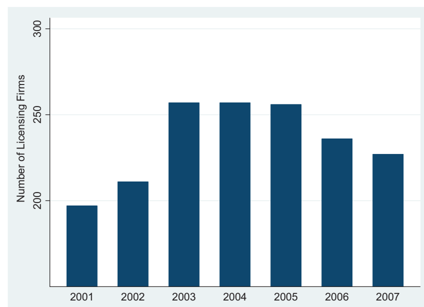
Figure 3: Number of Firms



(a) Total



(b) Foreign



(c) Licensing

Table 3: Transition Matrix for 2001–2007

			2001-2007		
			Period t+1		
		Domestic	Foreign	Exit	Total
Period t	Domestic	75.9%	0.4%	9.3%	85.5%
	Foreign	0.5%	4.0%	0.5%	4.9%
	Enter	9.1%	0.5%	0.0%	9.6%
	Total	85.4%	4.9%	9.7%	100.0%

and so on. The enter row shows the percentage of firms that entered the Chilean market in $t + 1$, while the exit column shows the percentage of firms that exited in period t.[20]

Note, from this transition table, that the number of domestic firms decreased in this period (this is due mostly to a decrease in the number of firms in 2007). Second, the previous point is confirmed when looking at the number of exits for domestic firms (2,985) versus the number of entrants (2,928) between periods t and $t + 1$. At the same time, the number of foreign firms has stayed relatively constant.[21]

It is possible to do the same analysis for firms that undertake licensing. The average transition matrix for any two years within the 2001–2007 period is depicted in Table 4.

Table 4: Transition Matrix for 2001–2007

2001-2007					
			Period t+1		
		No Licensing	Licensing	Exit	Total
Period t	No Licensing	75.2%	1.5%	9.4%	86.0%
	Licensing	1.4%	2.6%	0.4%	4.4%
	Enter	9.2%	0.4%	0.0%	9.6%
	Total	85.8%	4.5%	9.7%	100.0%

In this case, it is clear that the number of firms that do not pay licenses has slightly decreased in this period (again, this is due most likely to a decrease in the number of total firms in 2007). At the same time, the number of firms that pay licenses increased. Again, note the slight increase in the percentage of firms that pay licenses in period $t + 1$, rising from 4.4% to 4.5%.

Moreover, it is possible to decompose the above transition matrices into the periods before and after the IPR reform in 2005. The resulting transition matrices are depicted in Table 5.

[20] As it will be shown in the next section, the decline in the number of foreign firms occurs after 2005, which was also depicted in Figure 3.
[21] The numbers expressed are not shown in Table 3 but are available upon request.

Table 5: Transition Matrices
(Before and After the IPR Reform)

2001-2004 (BEFORE)

		Period t+1			
		Domestic	Foreign	Exit	Total
Period t	Domestic	72.4%	0.4%	8.8%	81.5%
	Foreign	0.5%	3.8%	0.4%	4.7%
	Enter	13.1%	0.7%	0.0%	13.8%
	Total	85.9%	4.9%	9.2%	100.0%

2005-2007 (AFTER)

		Period t+1			
		Domestic	Foreign	Exit	Total
Period t	Domestic	80.5%	0.4%	9.9%	90.8%
	Foreign	0.5%	4.1%	0.6%	5.2%
	Enter	3.9%	0.2%	0.0%	4.1%
	Total	84.8%	4.7%	10.4%	100.0%

(a) Ownership

Table 5: Transition Matrices
(Before and After the IPR Reform)

2001-2004 (BEFORE)

		Period t+1			
		No Licensing	Licensing	Exit	Total
Period t	No Licensing	71.8%	1.5%	8.9%	82.1%
	Licensing	1.3%	2.4%	0.3%	4.1%
	Enter	13.3%	0.5%	0.0%	13.8%
	Total	86.4%	4.4%	9.2%	100.0%

2005-2007 (AFTER)

		Period t+1			
		No Licensing	Licensing	Exit	Total
Period t	No Licensing	79.5%	1.5%	10.0%	91.1%
	Licensing	1.6%	2.8%	0.4%	4.8%
	Enter	3.9%	0.2%	0.0%	4.1%
	Total	85.1%	4.5%	10.4%	100.0%

(b) Licensing

3.1.3 IPR reform in Chile

It is important to understand the concept and differences between intellectual property rights (IPR) and industrial property (IP) in Chile. Intellectual property, in a very broad sense, is everything that is created by the human mind, such as inventions, branding, and literary works. However, in Chile, the term intellectual property is related specifically to one branch of intellectual property, which are copyright laws for authors.

The concept of intellectual property encompasses:

- Industrial property, including patents, commercial branding, origin denominations. In Chile, the National Institute of Industrial Property (INAPI) is responsible for all these aspects.
- Copyright law, relating to artists, and performers regarding their work, recordings, radio and TV shows. In this case, the office in charge is the Office of Intellectual Property Rights.

In this paper, I will focus more on the role of INAPI since it is the *"...technical and legislative office in charge of the administration and attention of the services of Industrial Property..."* Thus, one of the principal roles of INAPI is to regulate the registry of IP rights.[22]

There were some Laws regarding IP going back to the Chilean constitution, however, Law No. 19.039 published in 1991, which is the actual Law of Industrial Property, gave the INAPI full control over patents and branding.

In 1994, the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) was established within the international agreement that created the World Trade Organization (WTO). In this agreement, there is a set of minimum standards for intellectual property regulations within its members.

This treaty was made official in Chile in 1995. With its adoption, there were some things to improve in the 1991 law. These changes resulted in the Law No. 19,996 of March 11, 2005. The modifications made changes in the concept of brands, the process in order to get patents and brands registered, and the time limit for patents (set to 20 years) and branding. It also included new fees to be paid for patenting and branding.

Moreover, one of the most important changes in the law was the creation of an Industrial Property Tribunal (Art. 17 of Law 19,996). This is an independent special court, subject to the

[22] For more information see Instituto Nacional de Propiedad Industrial .

Supreme Court, whose seat is in the city of Santiago.

The Tribunal consists of six members and four alternates. Each of its members is appointed by the President of Chile, from a list of names proposed by the Supreme Court, made after a public merit competition. Members of the Tribunal must certify the possession of a law degree for a minimum period of five years. In the selection of four members and two alternates, all are required to have expertise in industrial property. The Tribunal should meet normally in two courtrooms where there should be at least two members and they meet at least three days a week.

Resolutions are adopted by simple majority vote. In complex cases, the Court may order an expert report. The court must order the report of one or more experts, in which case they will participate in its deliberations, with voice.

All these changes increased the IPR in Chile. Since there was a specific court created to deal with IP issues, this created a greater enforcement of IP laws and reduced the contracting costs related to technology transfer. Moreover, the increase in the number of years allowed for a patent created an incentive to increase technology transfer to Chile.

3.1.3.1 Measures of IPR

Two different measures of IPR will be used in this study, a dummy variable at the time of the change, and the Fraser Institute measure. The dummy variable takes a value of one, on and after the year of the reform (2005), and a value of zero otherwise. This is the type of measure used by Branstetter et al. (2007).

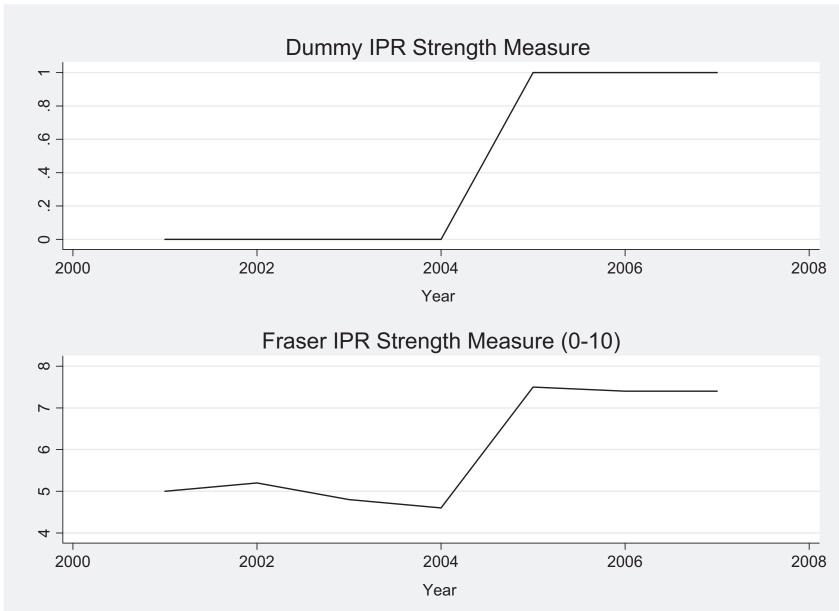
However, since the change cannot happen overnight, it is also useful to take into account a measure that comes from a survey and relates to intellectual property rights and property rights in general. Thus, the second measure of protection comes from the Fraser Institute, in the *Economic Freedom of the World* report. The question asked is if "Property rights, including financial assets are poorly defined and not protected by law (= 0) or are clearly defined and well protected by law (= 10)".[23]

Note that the Fraser Institute measure of IPR, as the survey indicates, includes a wider measure of property rights, not only including a specific intellectual property rights measure but a more general property rights measure, which includes assets as well.

[23] The formula used by the Fraser Institute is based in the index presented by another institution, the World Economic Forum, in its *Global Competitiveness Report*. The relation used is: $EFW_i = [(GCR_i - 1)/6] * 10$.

The two different measures can be viewed in the graph below. Note that the Fraser and the dummy measures follow the same trend so we should not expect much differences when using either of them.

Figure 4: IPR Strength Measures



4 Spillover Effects

4.1 Empirical approach

As stated above, the spirit is very close to the one used by Lopez (2008) and Damijan et al. (2008). In order to estimate the effect of licensing on productivity through spillovers, I use a slight modification of Lopez (2008):

$$log(TFP_{ijrt}) = \alpha + \beta' V_{jt} + \Gamma' X_{ijrt} + \Theta' Z_{jt} + \varepsilon_{ijrt} \tag{6}$$

Where i is the plant, j is the sector, r is the region and t is the year. V_{jt} is a vector that comes in three forms: it measures spillovers through the same industry (horizontal linkages - H_{jt}); spillovers through backward linkages (B_{jt}); and spillovers through forward linkages (F_{jt}). X_{ijrt} is a vector of firm level controls (exporter, foreign owned). Finally, Z_{jt} is a vector of control variables that includes the Herfindahl index to control for concentration, the export to sales ratio of the sector and measures of foreign presence in the same industry as well in downstream industries and upstream industries.

If we rewrite the full specification of this equation we would have:

$$\begin{aligned} log(TFP_{ijrt}) =& \alpha_0 + \alpha_j + \alpha_r + \alpha_t + \beta_1 H_{jt} + \beta_2 B_{jt} + \beta_3 F_{jt} \\ &+ \gamma_1 M_{ijrt} + \gamma_2 O_{ijrt} \\ &+ \theta_1 FDIS_{jt} + \theta_2 FDID_{jt} + \theta_3 FDIU_{jt} \\ &+ \theta_4 Herf_{jt} + \theta_5 Exp_{jt} + \varepsilon_{ijrt} \end{aligned} \tag{7}$$

Where α_j is a set of industry dummies; α_r is a set of region dummies; α_t is a set of time dummies; H_{jt} are horizontal spillovers; B_{jt} are backward spillovers; F_{jt} are forward spillovers; M_{ijrt} is the market presence of the firm (domestic, exporter, or both; O_{ijrt} is the ownership of the firm; $FDIS_{jt}$ is FDI in the same industry; $FDID_{jt}$ is FDI in downstream industries; $FDIU_{jt}$ is FDI in upstream industries; $Herf_{jt}$ is the Herfindahl Index; and Exp_{jt} is the exports to sales ratio by industry.

Moreover, if we want to include the effect of the IPR reform, the full specification becomes:

$$\begin{aligned} log(TFP_{ijrt}) =& \alpha_0 + \alpha_j + \alpha_r + \alpha_t + \beta_1 H_{jt} + \beta_2 B_{jt} + \beta_3 F_{jt} \\ &+ \beta_4 H_{jt} \times IPR_t + \beta_5 B_{jt} \times IPR_t + \beta_6 F_{jt} \times IPR_t \\ &+ \gamma_1 M_{ijrt} + \gamma_2 O_{ijrt} \\ &+ \theta_1 FDIS_{jt} + \theta_2 FDID_{jt} + \theta_3 FDIU_{jt} \\ &+ \theta_4 Herf_{jt} + \theta_5 Exp_{jt} + \varepsilon_{ijrt} \end{aligned} \tag{8}$$

The measurement of each of these variables entails a lot of detail. In order to calculate the vector V_{jt}, I use the value paid by each firm for licenses and technical assistance to calculate these variables.[24] The variable is calculated as:

$$H_{jt} = \frac{\sum_{i \in j} L_{ijt}}{\sum_{i \in j} Sales_{ijt}} \tag{9}$$

Where the assumption is that the larger the share of license payments, the larger the potential

[24] For this variable, Lopez (2008) uses two methods, the stock method and the flow method. The method described here refers to the flow method. For a detailed explanation of both methods, see Lopez (2008).

spillover effect. The backward spillovers and forward spillovers variables are calculated as:

$$B_{jt} = \sum_{k,k\neq j} \alpha_{jk} H_{kt} \tag{10}$$

$$F_{jt} = \sum_{k,k\neq j} \sigma_{jk} H_{kt} \tag{11}$$

Where α_{jk} is the proportion of sector j output supplied to sector k, while σ_{jk} is the share of inputs purchased by sector j from sector k.

Finally, the vector Z_{jt} includes measurements of foreign presence:

$$FDI\ Same\ Sector_{jt} = \frac{\sum_{i\in j} Foreign\ Share_{ijt} * Y_{ijt}}{\sum_{i\in j} Y_{ijt}}$$

$$FDI\ Downstream\ Sector_{jt} = \sum_{k,k\neq j} \alpha_{jk} * FDI\ Same\ Sector_{kt}$$

$$FDI\ Upstream\ Sector_{jt} = \sum_{k,k\neq j} \sigma_{jk} * FDI\ Same\ Sector_{kt}$$

Here, $Foreign\ Share_{ijt}$ is the percentage of foreign ownership and Y_{ijt} is the output (value added) of plant i, in industry j, and year t. The results obtained by Lopez (2008) are reported in the Appendix. He discovered that licensing to upstream sectors increases productivity of plants that purchase intermediate inputs from them (downstream sectors); while, as explained above, licensing to downstream sectors generates a negative effect on the productivity of suppliers (upstream sectors). The latter result goes against previous results, such as those in Javorcik (2004b) and Blalock and Gertler (2008). This is another reason why it is important to validate the results. Moreover, it is key to take into account the strengthening in IPR that occurred in 2005.

The first step is to estimate TFP in order to evaluate changes in productivity due to licensing. In order to measure TFP, it is possible to employ the semi-parametric method proposed by Olley and Pakes (1996), as used in Damijan et al. (2008). Since the data contain many zeros for investment, it is preferred to use the modification proposed by Levinsohn and Petrin (2003) in order to overcome the investment problem and also to correct the bias that is created.[25]

Nevertheless, a new development in TFP estimation has been proposed by Ackerberg et al. (2006). They show that there is a collinearity problem when using either of the methods described

[25] This refers to the simultaneity bias that is created due to the fact that not all inputs are exogenous to the firm's productivity. For a more detailed explanation see Appendix C.

above. Therefore, for this study I will use their proposed method of estimation and perform robustness checks with the previous estimation methods.

4.1.1 Total Factor Productivity (TFP) estimation

Total Factor Productivity (TFP) measurement has been an elusive issue in economics. At least for the past half a century there have been attempts to analyze TFP either at the aggregate level and more recently at the firm level.

As Van Beveren (2012) points out, firm level TFP assumes output to be a function of different inputs and productivity. Thus, in essence, in order to analyze TFP it should be possible to determine the functional form between output (either sales or value added) and inputs and then assume that the residual is a good measure of TFP.

Therefore, it is crucial to take into account the new developments of TFP estimation and use the most appropriate estimation technique in order to obtain TFP. In this study I use the Ackerberg, Caves, and Fraser (ACF) methodology to properly estimate TFP (see Appendix C for an overview of different estimation methods).

In order to estimate equation (22) using the Ackerberg et al. (2006) method and using skilled and unskilled labor and the value of purchased electricity as a proxy for unobservable productivity shocks. It is important to note that the results obtained are robust to different methods of TFP estimation. The coefficients from the different estimation methods are depicted in Table C.1 in the Appendix.

Note that I will only present the results of IPR changes on spillover effects using the ACF method. It is important to note that using any other method described in the Appendix provides qualitatively similar results. The reason for choosing the ACF TFP estimator is that it conveys a more reliable estimation since it does not assume the exogeneity of any of the firm's decisions regarding labor as previous estimators do.[26]

A couple of important issues regarding TFP estimation is that data is grouped into two-digit sector codes (see Table A.1 in Appendix). This is done due to the fact that there are not enough observations at the four-digit or even at the three-digit level to properly estimate TFP.

Moreover, as explained in the data section, industry 27 (Manufacture of Basic Metals) has

[26] Since there would be an excessive amount of results to present for different TFP estimators, only the ACF results are presented. Other results are available from the author upon request.

been excluded from the sample since the price (international prices) and thus the value added of basic metals do not reflect realistically the conversion from inputs into an output. Moreover, two other industries have been excluded from the TFP estimation, industry 30 (Manufacture of Office, Accounting and Computing Machinery) and industry 32 (Manufacture of Radio, Television and Communication Equipment), because in both industries, the number of observations is very small in the entire sample (11 and 51, respectively) impeding reliable TFP estimation due to the lack of variation.

4.2 Econometric issues

After estimating TFP, as noted by Javorcik (2004b) and Lopez (2008), there are a few econometric issues that have to be taken into account when estimating equation (6). First, there could be firm level time-invariant characteristics that are not captured in the model and make some firms more productive (the most widely used example is managerial ability). Thus, it is necessary to estimate the equation in first-differences. The resulting equation is equation (12).

$$\Delta log(TFP_{ijrt}) = \alpha_1 + \beta' \Delta V_{jt} + \Gamma' \Delta X_{ijrt} + \Theta' \Delta Z_{jt} + \Delta \varepsilon_{ijrt} \tag{12}$$

Which, in the full specification translates to:

$$\begin{aligned} \Delta log(TFP_{ijrt}) = & \alpha_1 + \beta_1 \Delta H_{jt} + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_4 \Delta (H_{jt} \times IPR_t) \\ & + \beta_5 \Delta (B_{jt} \times IPR_t) + \beta_6 \Delta (F_{jt} \times IPR_t) + \gamma_1 \Delta M_{ijrt} \\ & + \gamma_2 \Delta O_{ijrt} + \theta_1 \Delta FDIS_{jt} + \theta_2 \Delta FDID_{jt} \\ & + \theta_3 \Delta FDIU_{jt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt} \end{aligned} \tag{13}$$

The second issue is that, there could be shocks at the industry or region level that affect the productivity of only one group of firms; therefore, it is necessary to include a set of two-digit ISIC sector and region dummies, as well as a set of time dummies.[27]

The third issue is simultaneity (more productive sectors could spend more on licensing). Thus,

[27] An important thing to note here is that due to econometric constraints, it is not possible to include so many dummies and at the same time calculate the standard errors using clustering at the industry-year level, thus one way to overcome this is to drop all the firms that changed either region or industry, which was explained previously.

the entire vector Θ in equation (12) can be correlated with the error term. As discussed in Lopez (2008) this can be accounted for by using instrumental variables. In order to overcome this problem, the three licensing variables are instrumented with their second and third lags. This is also an important difference with Lopez (2008) since the first lag of the licensing variables is not a valid instrument due to the model being estimated in first-differences.[28]

The final issue is that we have to correct the standard errors because of the possibility of underestimating standard errors due to the estimation with firm level data but including sector varying variables as shown by Moulton (1990). In this case we have to cluster the standard errors at the industry-year level.

It is important to note that there are crucial differences in the estimation when compared to Lopez (2008). First, the estimation of productivity is done for each two-digit industry instead of each three-digit industry. Second, the input-output table used in the calculation of the backward and forward coefficients is the 2003 input-output table.

4.3 Identification

The first step in order to identify the model was taken by checking the underidentification test and the overidentification test for the main three estimations of equation (13).

Another important aspect to check is the first stage of the main three estimations. The summary results for the first stage regressions are presented in Table 6, 7, and 8.

Table 6: First Stage Results No IPR Measure

Summary results for first-stage regressions				
Variable	**Shea Partial R2**	**Partial R2**	**F(6, 16)**	**P-value**
Horizontal Spillovers	0.3667	0.4581	36.59	0.0000
Backward Spillovers	0.6260	0.3892	35.28	0.0000
Forward Spillovers	0.4177	0.3847	32.48	0.0000

[28] For a more detailed discussion see Cameron and Trivedi (2005) p.754.

Table 7: First Stage Results Fraser IPR Measure

Summary results for first-stage regressions				
Variable	**Shea Partial R2**	**Partial R2**	**F(12, 50)**	**P-value**
Horizontal Spillovers	0.7079	0.5639	27.68	0.0000
Backward Spillovers	0.8040	0.4627	16.78	0.0000
Forward Spillovers	0.7016	0.4392	31.87	0.0000
IPR Fraser x Horizontal Spillovers	0.9190	0.5524	25.53	0.0000
IPR Fraser x Backward Spillovers	0.9320	0.4536	21.84	0.0000
IPR Fraser x Forward Spillovers	0.9025	0.4204	20.62	0.0000

Table 8: First Stage Results Dummy IPR Measure

Summary results for first-stage regressions				
Variable	**Shea Partial R2**	**Partial R2**	**F(12, 50)**	**P-value**
Horizontal Spillovers	0.5520	0.5707	26.25	0.0000
Backward Spillovers	0.6540	0.4655	15.66	0.0000
Forward Spillovers	0.5005	0.4484	32.69	0.0000
Dummy IPR x Horizontal Spillovers	0.9250	0.6726	61.61	0.0000
Dummy IPR x Backward Spillovers	0.9314	0.6144	72.69	0.0000
Dummy IPR x Forward Spillovers	0.8982	0.6072	31.86	0.0000

There are a few results presented in those tables: Shea's (1997) partial R-squared, which takes into account the correlation between instruments; the regular R-squared between the instruments and the endogenous regressors; and the F test of the excluded instruments in the first stage corresponding regression.

The "rule of thumb" is that the F test should be greater than 10 if the instruments are "strong."[29] This is the case in all the first stage regressions for this study, which is a very reassuring result when thinking about the number of instruments needed in each regression. Since all the first stage regressions seem to work reasonably well, it is possible to think about the estimation of the second stage in the next section.

4.4 Results

In the estimated model for equation (13), for each case (no IPR measure, Fraser measure, and dummy variable measure) there are four estimation methods. The first method uses Ordinary Least Squares –OLS– over the entire sample (Pooled OLS). The second method, takes into account the firm time-invariant characteristics and it is estimated using OLS in first differences (OLS FD). The third method takes into account the simultaneity problem, using Instrumental Variables (IV)

[29] This was motivated initially by Staiger and Stock (1997) and updated by Stock and Yogo (2002).

in order to estimate the coefficients (Panel IV). The last method takes into account all the different issues and estimates the model using instrumental variables in first differences (Panel IV FD). Since the Panel IV in first differences estimation is the appropriate estimation method, the results provided in this paper correspond to this estimation method.[30]

Moreover, note that in every specification of the model without the IPR reform, the sample is reduced because if I use the entire sample it would be misspecified since there was an IPR reform in 2005. Results are presented in Table 9:

Table 9: Spillover Effects Under Different IPR Measures
(Panel IV in First Differences)

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Horizontal Spillovers	-1.57	0.05	-0.07
	(1.37)	(0.57)	(0.28)
Backward Spillovers	4.85***	2.66***	1.20***
	(1.13)	(0.72)	(0.46)
Forward Spillovers	-0.70	-1.33	-0.19
	(2.24)	(0.81)	(0.48)
IPR Fraser		-0.54**	
		(0.23)	
IPR Fraser x Horizontal Spillovers		-0.02	
		(0.07)	
IPR Fraser x Backward Spillovers		-0.31***	
		(0.10)	
IPR Fraser x Forward Spillovers		0.23**	
		(0.09)	
Dummy IPR			0.11***
			(0.04)
Dummy IPR x Horizontal Spillovers			-0.09
			(0.21)
Dummy IPR x Backward Spillovers			-0.87***
			(0.29)
Dummy IPR x Forward Spillovers			0.71**
			(0.28)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.26	0.38	0.40
Observations	2,884	8,932	8,932
R-squared	0.01	0.00	0.00
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For the estimation without the IPR change, if the estimation is done using the entire sample,

[30] The other estimation methods have been calculated and are available from the author upon request.

this would cause a misspecification issue, since we know that there has been a change in 2005. Therefore, the estimation is done using only the 2001–2004 period. One difference with the results obtained by Lopez (2008) is that there is strong **positive** evidence of backward spillovers, while he finds a negative effect.

This is a very interesting result that can be explained by the fact that these spillovers could be thought of as promoting the use of domestic inputs, which in turn would result in technology transfer to upstream sectors. Moreover, Table 9 shows no significant forward spillovers.

These results are in line with Javorcik (2004b). There might be a few reasons for that. First, Chile has been developing quite rapidly in the past decade, which would change its productive sector (captured by the IO table). Since in this period Chile is similar to the study of Lithuania in Javorcik (2004b), it would seem plausible to infer that the degree of development of the country plays a crucial role in different spillover effects, especially inter-industry.

Second, with Chilean development also comes an increase in imitative/absorptive capacity of domestic firms. Thus, if there is "new" technology in the market, it is easier for a more developed nation to start imitating products that are either coming straight from MNEs through FDI or indirectly through licensing. It is important to note that if there is a high degree of imitation in the host country, then that would create a positive bias in the spillover effect since the spillover effect would not only be capturing spillover effects through any kind of learning from foreign technology (i.e., learning from exporting) and it would result in an overestimation of spillover effects.[31]

Regarding the effect of stronger IPR, the results in Table 9 show that when using the Fraser IPR measure and the Dummy IPR measure, backward spillovers are smaller after the reform. [32]

When comparing the results once the IPR measure is introduced, it is important to note that before the policy change, the increase in productivity was between 2.7% and 1.2%. In the case of the estimation using the Fraser Institute IPR measure, the decline in backward spillovers is around 0.3%. When using the dummy variable, this decline is much higher (0.9%).

Finally, it is important to note that all the tables containing results include the probabilities of rejection (p-values) of two important tests: the Kleibergen-Paap LM statistic, which tests for

[31] At this point, the assumption is that this imitative capacity is not high enough to create a bias, but this could be checked by introducing an interaction term of the spillover effects with skilled labor, like in Damijan et al. (2008).

[32] In order to make this claim it is useful to think about the dummy IPR measure and the Fraser measure as interaction terms that reflect a difference between before and after the reform. However, this is not a Difference-in-Difference estimation since the change in IPR affects each firm in the same way.

underidentification with the null hypothesis being that the model is not identified. The second test is the Hansen J statistic for overidentification, with the null hypothesis that instruments are valid.

Therefore, it is possible to infer that introducing an IPR measure has had a negative effect on backward linkages. Also, there is a positive effect of the policy reform on forward linkages.

The first result can be explained by thinking of stronger IPR as stronger punishments in some sense, and that they will deter firms from passing along new technology into backward industries. The second result can be explained in the case where the market is fairly competitive, since this would mean that introducing stronger IPR measures would induce higher forward linkages, which could be due to lower prices for downstream industries.

Note that this positive effect of the reform on forward spillovers is a very interesting result. In both cases, for the Fraser Institute measure and the dummy variable, this term is positive and significant. This represents the fact that even though initially firms do not have forward spillover effects, after the IPR reform, they tend to induce higher productivity in downstream industries. One example of this could be any industry of intermediate goods that after the IPR reform has a big *"market effect"* and thus increases production and this would decrease the price for inputs in downstream industries. Again, in this case the effect is much stronger under the dummy variable than under the Fraser Institute measure.

4.5 Extensions

4.5.1 Productivity heterogeneity

As Damijan et al. (2008) show, the magnitude of backward spillovers can depend on the productivity of the firm. Thus, since the backward linkage effects from licenses have been established, it is possible to analyze the same effects depending on the productivity of the firm. Following Damijan et al. (2008), it is possible to divide the sample into different quartiles of productivity and estimate equation (13).[33]

It is important to make this distinction, not only to analyze firm characteristics on spillover results, as explained by Damijan et al. (2008), but also because it is important to see the effect of

[33] It is important to note that the decision to split the sample into quartiles makes it possible to estimate the model. If the division were to be at a smaller size there would not be enough observations in each group for the estimation.

a change in the IPR regime and its effect on different productivity level firms.

Results for the model without any IPR effects are reported in Table 10 in the Appendix. In all cases, the estimation was done using Panel IV in first differences estimation. In this case, when looking at the results by quartile, it is possible to see that there are significant backward linkages in firms in the lower quartiles, but not in high productivity firms. One reason for this may be that low productivity firms have room to benefit from new technology, while high productivity firms already have "high end" technology and do not benefit from spillover effects.

Table 10: Spillover Effects by TFP Quartile with no IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	5.71	3.04	-5.22*	-0.71
	(8.00)	(4.30)	(2.68)	(4.99)
Backward Spillovers	19.50*	11.16**	10.84	10.04
	(10.16)	(5.48)	(6.76)	(15.60)
Forward Spillovers	-17.78	-11.39*	3.02	-5.10
	(12.30)	(6.51)	(4.32)	(6.25)
Foreign Ownership	-0.08	-0.04	-0.20**	0.22
	(0.49)	(0.08)	(0.09)	(0.28)
Market presence	-0.00	-0.17**	-0.05	-0.07
	(0.27)	(0.07)	(0.05)	(0.12)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	n/a	n/a	n/a	n/a
Observations	797	828	851	876
R-squared	-0.03	-0.03	0.00	0.03
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The next question is what happens when there is a change in IPR. Table 11 depicts the results by quartile when using the Fraser IPR measure and confirms the results from above in the sense that lower productivity firms benefit more than high productivity firms. Thus, there seems to be stronger backward linkages for low productivity firms.

When looking at the interaction term, it is negative for all quartiles, and significant for all the quartiles except the third. Moreover, the firms that are most affected by the introduction of the IPR reform are again the least productive ones. This is consistent with the results presented in the previous table, since it seems that low productivity firms are highly affected by the IPR reform. Thus, this would be indicative that the IPR reform would impose a restriction on low productivity firms to enable an increase in their productivity. Results using the dummy IPR measure are depicted in Table 12. These results are in line with the main result of positive backward linkages and a negative effect of the IPR reform.

Table 11: Spillover Effects by TFP Quartile with Fraser IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	3.71*	1.20	1.02	-1.93***
	(2.10)	(1.20)	(0.79)	(0.52)
Backward Spillovers	11.20***	6.46***	0.74	5.91***
	(3.81)	(2.08)	(1.36)	(1.17)
Forward Spillovers	-10.85***	-4.68***	-1.96*	-0.54
	(2.55)	(1.75)	(1.12)	(1.15)
IPR Fraser	-1.20	-0.48	-0.19	-1.26*
	(0.92)	(0.42)	(0.42)	(0.66)
IPR Fraser x Horizontal Spillovers	-0.24	0.07	-0.13	0.21***
	(0.23)	(0.12)	(0.08)	(0.05)
IPR Fraser x Backward Spillovers	-1.41**	-0.79**	-0.13	-0.63***
	(0.56)	(0.31)	(0.17)	(0.14)
IPR Fraser x Forward Spillovers	1.15***	0.19	0.26**	0.35***
	(0.22)	(0.16)	(0.12)	(0.13)
Foreign Ownership	-0.04	0.07	0.12	0.04
	(0.19)	(0.10)	(0.18)	(0.06)
Market presence	-0.43**	-0.14**	0.07	-0.03
	(0.17)	(0.07)	(0.05)	(0.05)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.12	0.41	0.81	0.76
Observations	1,818	2,240	2,355	2,519
R-squared	0.03	0.02	0.01	-0.01
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Spillover Effects by TFP Quartile with Dummy IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	2.62*	1.54*	0.48	-0.95***
	(1.37)	(0.82)	(0.50)	(0.36)
Backward Spillovers	4.52**	2.79***	-0.02	3.10**
	(1.94)	(0.94)	(0.98)	(1.23)
Forward Spillovers	-5.35***	-3.73***	-0.81	0.98
	(1.90)	(1.20)	(0.76)	(1.30)
Dummy IPR	0.19	0.20***	0.11	0.12
	(0.16)	(0.08)	(0.08)	(0.09)
Dummy IPR x Horizontal Spillovers	-0.76	0.17	-0.42*	0.62***
	(0.63)	(0.33)	(0.24)	(0.15)
Dummy IPR x Backward Spillovers	-4.07***	-2.23**	-0.37	-1.88***
	(1.57)	(0.89)	(0.49)	(0.40)
Dummy IPR x Forward Spillovers	3.35***	0.59	0.83**	1.03***
	(0.60)	(0.47)	(0.34)	(0.36)
Foreign Ownership	-0.03	0.07	0.13	0.04
	(0.18)	(0.10)	(0.18)	(0.06)
Market presence	-0.44**	-0.14*	0.06	-0.03
	(0.17)	(0.07)	(0.05)	(0.05)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.12	0.50	0.81	0.76
Observations	1,818	2,240	2,355	2,519
R-squared	0.03	0.02	0.01	-0.01
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Another important result when analyzing productivity quartiles is that there is evidence of negative forward linkages in low productivity firms, which was not present in the result for the entire sample. These negative forward linkages for low productivity firms could be explained by the fact that, since those firms do not possess “high end” technology, it might be possible that they are not able to fully reap the benefits of new inputs.

In this case, the interaction term is positive, which would indicate that stronger IPR benefit firms. As explained before, this could be the case when the market is competitive. Thereby, this increase in productivity may be reflected in lower prices for downstream industries. Similar results are obtained when analyzing the dummy IPR measure.

4.5.2 Size heterogeneity

Damijan et al. (2008) also demonstrate the importance of firm size on the magnitude of spillover effects. Thus, it is also possible to analyze spillover effects depending on the size of the firm through the estimation of equation (13) by quartile depending on firm size, given by the total number of workers. The results obtained are very close to the productivity results from the previous section. Results for the model without any IPR effects are reported in Table 13.

Table 13: Spillover Effects by Size Quartile with no IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	0.72	0.71	0.35	1.36
	(0.99)	(1.29)	(4.05)	(9.68)
Backward Spillovers	-5.03	-0.03	12.33*	14.41
	(3.77)	(3.56)	(6.87)	(11.80)
Forward Spillovers	2.12	-2.93	-6.13	-4.04
	(2.55)	(2.62)	(7.57)	(16.68)
Foreign Ownership		0.27***	0.11	0.03
		(0.09)	(0.18)	(0.19)
Market presence		-0.06	0.01	-0.13
		(0.05)	(0.12)	(0.08)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	n/a	n/a	n/a	n/a
Observations	841	771	860	880
R-squared	-0.00	0.01	-0.04	-0.10
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14 depicts the results by quartile when using the Fraser IPR measure. Here we see a very interesting trend regarding spillovers from downstream sectors. In this case, similarly with productivity, all the smaller firms seem to “benefit” more from backward linkages before the IPR strengthening. Also, when looking at the interaction term, it is negative for all quartiles.

Table 14: Spillover Effects by Size Quartile with Fraser IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	-1.48	3.47***	0.67	-1.11
	(1.06)	(0.58)	(1.17)	(0.97)
Backward Spillovers	6.14***	2.03*	-0.54	2.52*
	(1.59)	(1.19)	(1.05)	(1.32)
Forward Spillovers	0.30	-7.48***	-1.09	0.82
	(1.56)	(1.52)	(1.57)	(1.37)
IPR Fraser	-1.01*	-0.06	-0.13	-0.94**
	(0.53)	(0.33)	(0.27)	(0.39)
IPR Fraser x Horizontal Spillovers	0.06	-0.19**	-0.02	0.06
	(0.10)	(0.07)	(0.13)	(0.12)
IPR Fraser x Backward Spillovers	-0.61***	-0.16	-0.02	-0.34*
	(0.22)	(0.17)	(0.15)	(0.17)
IPR Fraser x Forward Spillovers	0.17	0.32	0.19	0.13
	(0.15)	(0.20)	(0.17)	(0.15)
Foreign Ownership	0.20***	0.09	-0.01	0.05
	(0.04)	(0.15)	(0.13)	(0.09)
Market presence	-0.26	-0.13	-0.03	-0.01
	(0.17)	(0.10)	(0.04)	(0.05)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.25	0.41	0.45	0.03
Observations	2,039	2,006	2,273	2,614
R-squared	0.01	0.00	0.00	0.01
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results using the dummy IPR measure are depicted in Table 15. These results are in line with the main result of positive backward linkages, mainly in smaller firms.

4.6 Robustness tests

4.6.1 Issues with firms exiting the market

As depicted in Figure 3, there has been a clear decline in the number of firms in the manufacturing sector in Chile after 2005. The change in the number of firms could be due to a number of reasons, such as: i) Changes in the way firms report themselves (going from manufacturing to service industries, for example); ii) Mergers and acquisitions; and iii) Decline in some activities like textiles and shoe manufacturing, among others.

One main concern might be that this decline is driving the results. In order to check if this is the case, it is possible to do the analysis restricting the sample to a balanced panel, thus we would be looking only at firms that stay in the market for the entire period.

The results are depicted in Table 16. The results obtained confirm previous results. Note that the decline in the total number of manufacturing firms is not affecting the results. Therefore, when taking into account only a balanced panel we get the same qualitative results as Table 9.

Table 15: Spillover Effects by Size Quartile with Dummy IPR Measure

Dependent variable: log (TFP)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Horizontal Spillovers	-1.17	2.59***	0.64	-0.84
	(0.73)	(0.33)	(0.68)	(0.53)
Backward Spillovers	3.27***	1.21*	-0.69	1.10
	(0.96)	(0.69)	(0.61)	(0.86)
Forward Spillovers	1.11	-5.90***	-0.29	1.42*
	(1.28)	(0.74)	(1.04)	(0.79)
Dummy IPR	0.13	0.07	-0.02	0.18***
	(0.09)	(0.06)	(0.04)	(0.07)
Dummy IPR x Horizontal Spillovers	0.14	-0.54**	-0.04	0.13
	(0.29)	(0.21)	(0.38)	(0.35)
Dummy IPR x Backward Spillovers	-1.65**	-0.41	-0.08	-0.93*
	(0.66)	(0.49)	(0.43)	(0.50)
Dummy IPR x Forward Spillovers	0.47	0.89	0.58	0.46
	(0.44)	(0.58)	(0.49)	(0.45)
Foreign Ownership	0.20***	0.10	0.00	0.06
	(0.04)	(0.15)	(0.13)	(0.09)
Market presence	-0.25	-0.13	-0.03	-0.01
	(0.17)	(0.10)	(0.04)	(0.05)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.27	0.35	0.40	0.05
Observations	2,039	2,006	2,273	2,614
R-squared	0.01	0.00	0.00	0.01
Time, Industry and Region Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: Spillover Effects Under Different IPR Measures
Balanced Panel (Panel IV in First Differences)

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Horizontal Spillovers	-3.14***	0.20	0.12
	(1.13)	(0.67)	(0.33)
Backward Spillovers	6.12***	2.28***	0.93*
	(1.58)	(0.85)	(0.51)
Forward Spillovers	0.41	-1.89**	-0.70
	(1.62)	(0.91)	(0.52)
IPR Fraser		-0.48*	
		(0.27)	
IPR Fraser x Horizontal Spillovers		-0.02	
		(0.09)	
IPR Fraser x Backward Spillovers		-0.29**	
		(0.12)	
IPR Fraser x Forward Spillovers		0.25**	
		(0.11)	
Dummy IPR			0.14***
			(0.04)
Dummy IPR x Horizontal Spillovers			-0.07
			(0.25)
Dummy IPR x Backward Spillovers			-0.82**
			(0.36)
Dummy IPR x Forward Spillovers			0.74**
			(0.31)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.11	0.28	0.28
Observations	2,409	7,227	7,227
R-squared	0.01	0.01	0.01
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.6.2 Specification Issues

Since equation (13) has three different terms that are derived essentially from the horizontal linkages equation (9) where H_{jt} depends on the level of licenses paid in one industry. It is possible to think that there is a high correlation between this variable and the backward spillover effects variable B_{jt} and the forward spillover effects variable F_{jt}.[34]

In order to ensure that this plausible correlation does not affect the results, four different specifications will be tested: one where there is no foreign presence; one where there are no horizontal spillover effects; one where there is no foreign presence nor horizontal spillover effects; and finally one where there is a different use of instrumental variables. All the results are depicted in the Appendix. Recall that the original specification was:

$$\begin{aligned}\Delta log(TFP_{ijrt}) =&\alpha_1 + \beta_1 \Delta H_{jt} + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_4 \Delta (H_{jt} \times IPR_t)\\ &+ \beta_5 \Delta (B_{jt} \times IPR_t) + \beta_6 \Delta (F_{jt} \times IPR_t) + \gamma_1 \Delta M_{ijrt}\\ &+ \gamma_2 \Delta O_{ijrt} + \theta_1 \Delta FDIS_{jt} + \theta_2 \Delta FDID_{jt}\\ &+ \theta_3 \Delta FDIU_{jt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt}\end{aligned}$$

Where H_{jt} are Horizontal Spillovers; B_{jt} are Backward Spillovers; F_{jt} are Forward Spillovers; M_{ijrt} is the Market Presence of the firm (domestic, exporter, or both); O_{ijrt} is the Ownership of the firm; $FDIS_{jt}$ is FDI in the same industry; $FDID_{jt}$ is FDI in Downstream industries; $FDIU_{jt}$ is FDI in Upstream industries; $Herf_{jt}$ is the Herfindahl Index; and Exp_{jt} is the exports to sales ratio by industry.

4.6.2.1 No foreign presence

In this case, equation (13) is replaced by:

$$\begin{aligned}\Delta log(TFP_{ijrt}) =&\alpha_1 + \beta_1 \Delta H_{jt} + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_4 \Delta (H_{jt} \times IPR_t)\\ &+ \beta_5 \Delta (B_{jt} \times IPR_t) + \beta_6 \Delta (F_{jt} \times IPR_t) + \gamma_1 \Delta M_{ijrt}\\ &+ \gamma_2 \Delta O_{ijrt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt}\end{aligned} \tag{14}$$

Table C.2 illustrates results for the unbalanced panel. When examining these results, positive

[34] Recall from equations (10) and equation (11) that these two variables are H_{jt} relative to the IO table.

backward spillovers are confirmed. Moreover, the IPR reform depicts a negative impact on those spillovers.

Moreover, when using a balanced panel in this case, depicted in Table C.3, the results regarding the IPR reform are confirmed. However, the coefficient on backward spillovers tends to be non significant, but still positive.

4.6.2.2 No horizontal spillover effects

In this case, equation (13) is replaced by:

$$\begin{aligned}\Delta log(TFP_{ijrt}) =& \alpha_1 + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_5 \Delta(B_{jt} \times IPR_t) + \beta_6 \Delta(F_{jt} \times IPR_t) \\ &+ \gamma_1 \Delta M_{ijrt} + \gamma_2 \Delta O_{ijrt} + \theta_1 \Delta FDIS_{jt} + \theta_2 \Delta FDID_{jt} \\ &+ \theta_3 \Delta FDIU_{jt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt}\end{aligned} \tag{15}$$

Results for the unbalanced panel are depicted in Table C.4. When analyzing these results it is still possible to see positive backward spillovers, plus the fact that the IPR reform had a negative effect on those spillovers.

One important thing to note here is that there seems to be a negative forward spillover effect, which was not present before. Also, there is evidence of a positive effect of the IPR reform on forward spillovers. When using a balanced panel, depicted in Table C.5, the results regarding the IPR reform are confirmed.

4.6.2.3 No foreign presence nor horizontal spillover effects

In this case, equation (13) is replaced by:

$$\begin{aligned}\Delta log(TFP_{ijrt}) =& \alpha_1 + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_5 \Delta(B_{jt} \times IPR_t) + \beta_6 \Delta(F_{jt} \times IPR_t) \\ &+ \gamma_1 \Delta M_{ijrt} + \gamma_2 \Delta O_{ijrt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt}\end{aligned} \tag{16}$$

Table C.6 displays results for the unbalanced panel. Positive backward spillovers are still evident, and one can note that the IPR reform negatively affects these spillovers.

Again, a negative forward spillover effect, which was not present before is now evident. Also, the IPR reform positively affects forward spillovers. When using a balanced panel, depicted in Table C.7, the results regarding the IPR reform are confirmed.

4.6.2.4 Different use of IV

Another check that we can perform is to use the following equation:

$$\begin{aligned}\Delta log(TFP_{ijrt}) =& \alpha_1 + \beta_2 \Delta B_{jt} + \beta_3 \Delta F_{jt} + \beta_5 \Delta(B_{jt} \times IPR_t) + \beta_6 \Delta(F_{jt} \times IPR_t) \\ &+ \gamma_1 \Delta M_{ijrt} + \gamma_2 \Delta O_{ijrt} + \theta_4 \Delta Herf_{jt} + \theta_5 \Delta Exp_{jt} + \Delta \varepsilon_{ijrt}\end{aligned} \tag{17}$$

However, now there is a major difference with the previous case since *Horizontal Linkage* variables are not used as instruments. Results for the unbalanced panel are depicted in Table C.8. When analyzing these results, it is still possible to see positive backward spillovers, plus the fact that the IPR reform had a negative effect on those spillover effects.

Again, an important thing to note here is that there seems to be a negative forward spillover effect, which was not present before. Also, there is evidence of a positive effect of the IPR reform on these spillovers. When using a balanced panel, depicted in Table C.9, the results regarding the IPR reform are confirmed.

5 FDI vs. Licensing

5.1 Empirical approach

Since the change in the IPR law constitutes a treatment-effect type of estimation, I will use a Difference-in-Differences (DD) approach, where the main assumption is that firms that were "technology intensive" before the reform would have the same evolution in inward FDI as firms that were not "technology intensive" in the absence of the reform.

5.1.1 Generating test and comparison groups

In order to have a valid interaction term in equation (18) below, it is crucial to have valid test and comparison groups. Note that this section uses the data at the four-digit level instead of the two-digit level used in the previous section since there are no restrictions in the estimation process.

Thus, it is necessary to divide plants into "technology intensive" vs. "non-technology intensive" firms to form a dummy variable, $Tech_i$. This can be done by letting each plant be "technological intensive" if it belongs to industries that are considered "high-tech" in other countries.

Here, the *Compendium of Patent Statistics* elaborated by the OECD is used to define high-tech industries.[35] The "technology intensive" industries using the ISIC rev 3 classification (at the two-digit level) are: Medical, precision and optical instruments; Radio, television and communication equipment; Office accounting and computing machinery; and Pharmaceuticals.[36]

The descriptive statistics for each group for foreign plants are presented in Table D.1 in the Appendix. The first thing to note is that the stock of capital and the value added are lower for tech-intensive firms. This could be due to a size issue with the plants (i.e. non-tech plants might need more buildings in manufacturing sectors). Nevertheless, it is clear that payments for licenses and the skill intensity as well as the skill ratio are higher for high-tech plants, which is expected. Second, regarding the remaining variables, the values are close for the two groups, which reinforces the assumption of the similarity between the two groups.

5.2 Testable hypothesis

It is important to capture whether or not stronger IPR lead to increased production by foreign firms in Chile when looking at the industry level. Thus, some measure of the foreign presence, such as the capital stock, in the industry is needed. In this sense, an indicator that resembles the spirit of import penetration would be the *"foreign penetration"* in a given industry, which could be constructed for each industry as follows:

$$fdikstock = \frac{\sum_i^f}{\sum^{f+d}} = \frac{\text{Sum of capital stock for foreign plants}}{\text{Sum of capital stock for all plants}}$$

Therefore, the specification that could be used in order to test for changes in the *"fdi penetration"* could take the following form:

$$fdistock_{jt} = \alpha_0 + \alpha_j + t + \beta_0 IPR_t + \beta_1 IPR_t * Tech_j + \beta_2 X_j + \varepsilon_{jt} \quad (18)$$

Where j indexes each industry, t the year, α_i are industry fixed effects, t is a time trend; IPR_t is

[35] It is important to note that the patent classification is not fully compatible with the ISIC industry classification, but the OECD based their classification on the comparison made by Schmoch et al. (2003).

[36] Since there are no Pharmaceuticals as a industry in ISIC 3, this will be replaced by industrial chemicals, and other chemicals.

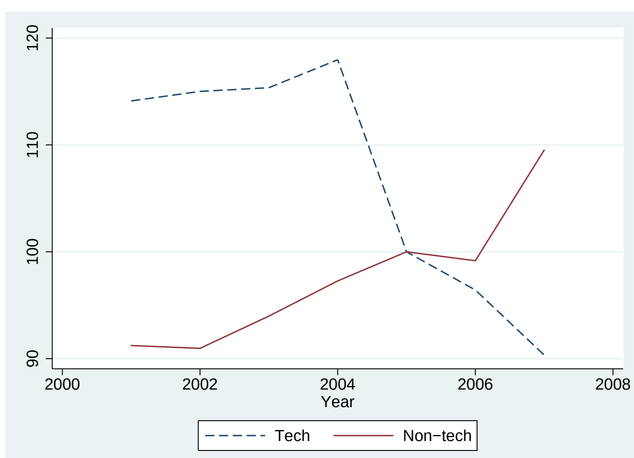
the strength of IPR, $Tech_j$ is a dummy variable that takes the value of one if the firm is "technology intensive" and zero otherwise, and X_j are controls.[37]

Moreover, since there seems to be a decline in the number of FDI firms after 2005, it is possible that foreign presence is being replaced by licensing domestic firms. This can be tested using the following specification:

$$license_{jt} = \alpha_0 + \alpha_j + t + \beta_0 IPR_t + \beta_1 IPR_t * Tech_j + \beta_2 X_j + \varepsilon_{jt} \tag{19}$$

Where the subscripts are similar to the ones in equation (18). In order to see some intuition of the possible results, we can look at the total *"foreign penetration"* as an index (see Figure 5). We observe that foreign presence is decreasing after 2005 in the tech-intensive sectors and it is slightly increasing for the rest of the sectors. This is in line with the hypothesis that foreign plants are being replaced by domestic ones, especially in the tech-intensive industries, which could result in more licensing payments. This should be reflected by a negative coefficient of the interaction term in equation (18).

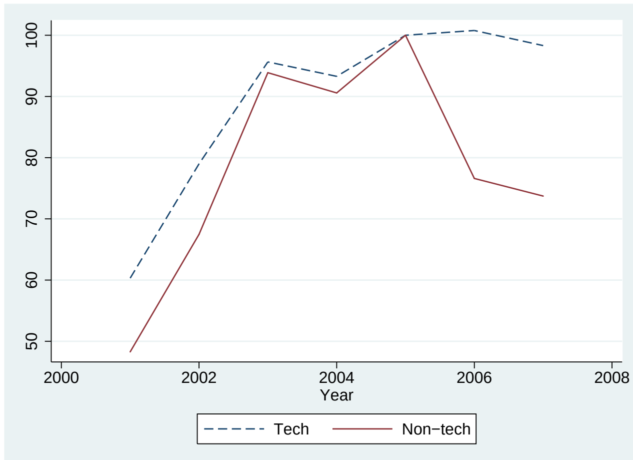
Figure 5: Index of Foreign Presence (fdikstock)
(2005=100)



In a similar fashion, when looking at the Index of License Payments (Figure 6) the upward trend in the technological sector would suggest that there is more licensing after 2005 in the high-tech sectors. Thus, we would expect a positive sign in the interaction term of equation 19.

[37] The controls included are average size and the market where the industry sells its product.

Figure 6: Index Of Payments Of Licenses
(2005=100)



5.3 Results

The results obtained after using specifications (18) and (19) are depicted in Table 17. As expected, the interaction term of IPR has a negative effect on the level of foreign presence. Moreover, the effect on the level of licensing is positive and significant. This would support the hypothesis of a reduction on the number of foreign firms and increased licensing in Chile after the reform.[38]

[38] It is important to note that some controls have been included in this specification even when there are industry dummies and a time trend. Also, the number of observations is not a multiple of the number of industries due to the fact that it is an unbalanced panel so some industries are not present in some years.

Table 17: Foreign Presence Hypothesis

VARIABLES	(1) fdikstock	(2) fdikstock	(3) license	(4) license
Fraser IPR x Tech		-0.03***		122.30**
		(0.01)		(62.16)
Dummy IPR x Tech	-0.09***		346.16**	
	(0.02)		(163.63)	
Exchange Rate	-0.00	-0.00	17.09**	17.54**
	(0.00)	(0.00)	(7.49)	(7.61)
Inflation	0.00	0.00	-41.82*	-44.10*
	(0.01)	(0.01)	(22.18)	(23.51)
Size	0.06***	0.06***	-87.19*	-84.53*
	(0.02)	(0.02)	(49.49)	(49.36)
Market	0.12**	0.13**	-29.32	-34.52
	(0.06)	(0.06)	(115.01)	(116.35)
Dummy IPR	0.01		143.12	
	(0.03)		(97.60)	
Fraser IPR		0.00		49.50
		(0.01)		(34.33)
Observations	714	714	714	714
R-squared	0.80	0.80	0.90	0.90
Time Trend	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6 Conclusions

The importance of FDI for economic growth has been emphasized throughout economic literature. Moreover, developing countries rely on FDI as a source of technology transfer and innovation. Thus, it is important to clarify the most effective channels through which a developing country can benefit from technology advancements in developed countries.

In the present state of globalization, IPR is an important factor that affects the decision of MNEs to invest abroad. This has been shown in previous studies that find that stronger IPR lead to higher and more quality in FDI.

This study sheds some light on the importance of licensing as a technology diffusion mechanism. The present study constitutes a contribution in that sense to the existing literature. Most studies have focused on the effect of Foreign Direct Investment, while somewhat neglecting the potential effect of licensing as a channel for increases in productivity.

Using a dataset that contains more than 33,000 firm-year observations, I provide some empirical evidence of the existence of backward spillover effects from licensing in Chile during the 2001–2007 period.

Moreover, due to the implementation of a stronger IPR reform in Chile in 2005, it is possible to analyze the effect that this change has on how technology is diffused within the same industry as well as intra-industries. In order to do so, I used two different measures of IPR, and I also used the Chilean 2003 input-output table in order to capture the linkages between sectors.

The main contribution of this paper is to show how different economic policies can affect different sectors in the economy. In this case, it was possible to show that increasing the strength of IPR would lead to smaller backward linkages, reducing the spillover effects in the economy. With more strict and better enforced laws, there are less incentives for people to transfer technology when a penalty may be incurred.

Another contribution is to control for firm heterogeneity in productivity and also in size in order to analyze different effects for different subsamples of the survey. The results obtained, at least with the full sample, shed evidence that low productivity and smaller firms, which used to benefit more from spillover effects, now suffer more from the change in IPR policy. This is in line with the results obtained by Keller (2009). The negative impact of stronger IPR in these cases is of greater magnitude than when compared to mid-high productivity firms.

Moreover, the results provided are consistent with the literature arguing that licensing overtakes FDI once a certain threshold of IPR is reached. Stronger IPR leads to lower levels of FDI and increased licensing in Chile during the 2001–2007 period. One of the main causes could be that Chilean firms have changed greatly in the last decade, increasing their imitative capabilities as well as their ability to produce goods that were not produced by local firms before.

References

Acharya, R. C. and Keller, W. (2009). Technology transfer through imports. *Canadian Journal of Economics/Revue canadienne d'conomique*, 42(4):1411–1448.

Ackerberg, D., Caves, K., and Frazer, G. (2006). Structural identification of production functions. *Working Paper*.

Aitken, B. J. and Harrison, A. E. (1999). Do domestic firms benefit from direct foreign investment? evidence from venezuela. *The American Economic Review*, 89(3):605–618.

Alfaro, L., Chanda, A., Kalemli-Ozcan, S., and Sayek, S. (2006). How does foreign direct investment promote economic growth? exploring the effects of financial markets on linkages. Working Paper 12522, National Bureau of Economic Research.

Arnold, J. M. (2005). Productivity estimation at the plant level: A practical guide. *Unpublished manuscript*, 27.

Blalock, G. and Gertler, P. J. (2008). Welfare gains from foreign direct investment through technology transfer to local suppliers. *Journal of International Economics*, 74(2):402–421.

Braga, C. A. and Fink, C. (1998). The relationship between intellectual property rights and foreign direct investment. *Duke J. Comp. & Int'l L.*, 9.

Branstetter, L., Fisman, R., Foley, C. F., and Saggi, K. (2007). Intellectual property rights, imitation, and foreign direct investment: Theory and evidence. Working Paper 13033, National Bureau of Economic Research.

Branstetter, L. G., Fisman, R., and Foley, C. F. (2006). Do stronger intellectual property rights increase international technology transfer? empirical evidence from US firm-level panel data. *Quarterly Journal of Economics*, 121(1):321–349.

Cameron, A. C. and Trivedi, P. K. (2005). *Microeconometrics: Methods and Applications*. Cambridge University Press.

Castro, L. (2012). How does intellectual property rights affect the choice of multinational enterprises entry mode? *Working Paper*.

Damijan, J. P., Rojec, M., Majcen, B., and Knell, M. (2008). Impact of firm heterogeneity on direct and spillover effects of FDI: micro evidence from ten transition countries. LICOS Discussion Paper 21808, LICOS - Centre for Institutions and Economic Performance, K.U.Leuven.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*, 67(3):297–308. ArticleType: research-article / Full publication date: Jun., 1977 / Copyright 1977 American Economic Association.

Ethier, W. J. (1982). National and international returns to scale in the modern theory of international trade. *The American Economic Review*, 72(3):389–405. ArticleType: research-article / Full publication date: Jun., 1982 / Copyright 1982 American Economic Association.

Gibson, M. and Graciano, T. (2011). Costs of starting to trade and costs of continuing to trade. *Washington State University. Working Paper.*

Görg, H. and Greenaway, D. (2004). Much ado about nothing? do domestic firms really benefit from foreign direct investment? *The World Bank Research Observer*, 19(2):171–197.

Instituto Nacional de Propiedad Industrial. www.inapi.cl.

Javorcik, B. S. (2004a). The composition of foreign direct investment and protection of intellectual property rights: Evidence from transition economies. *European Economic Review*, 48(1):39–62.

Javorcik, B. S. (2004b). Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages. *The American Economic Review*, 94(3):605–627.

Javorcik, B. S. and Spatareanu, M. (2008). To share or not to share: Does local participation matter for spillovers from foreign direct investment? *Journal of Development Economics*, 85(1-2):194–217.

Keller, W. (2009). International trade, foreign direct investment, and technology spillovers. *National Bureau of Economic Research Working Paper Series*, 15442.

Lee, J. Y. and Mansfield, E. (1996). Intellectual property protection and US foreign direct investment. *The Review of Economics and Statistics*, 78(2):181–186.

Levinsohn, J. and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70(3):317–341.

Lopez, R. A. (2008). Foreign technology licensing, productivity, and spillovers. *World Development*, 36(4):560–574.

Markusen, J. R. and Venables, A. J. (1999). Foreign direct investment as a catalyst for industrial development. *European economic review*, 43(2):335–356.

Marschak, J. and Andrews, W. H. (1944). Random simultaneous equations and the theory of production. *Econometrica, Journal of the Econometric Society*, pages 143–205.

Maskus, K. E. and Penubarti, M. (1995). How trade-related are intellectual property rights? *Journal of International Economics*, 39(3-4):227–248.

Maskus, K. E., Saggi, K., and Puttitanun, T. (2005). Patent rights and international technology transfer through direct investment and licensing. In *International Public Goods and the Transfer of Technology under a Globalized Intellectual Property Regime*, pages 265–281. Cambridge University Press.

Montalvo, J. G. and Yafeh, Y. (1994). A microeconometric analysis of technology transfer: The case of licensing agreements of japanese firms. *International Journal of Industrial Organization*, 12(2):227–244.

Moulton, B. R. (1990). An illustration of a pitfall in estimating the effects of aggregate variables on micro units. *Review of Economics and Statistics*, 72(2):334–338.

Nunnenkamp, P. and Spatz, J. (2004). Intellectual property rights and foreign direct investment: A disaggregated analysis. *Review of World Economics / Weltwirtschaftliches Archiv*, 140(3):393–414.

Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263–1297.

Park, W. G. (2008). Intellectual property rights and international innovation. *Frontiers of Economics and Globalization*, 2:289–327.

Pavcnik, N. (2002). Trade liberalization, exit, and productivity improvements: Evidence from chilean plants. *The Review of Economic Studies*, 69(1):245–276.

Schmoch, U., Laville, F., Patel, P., and Frietsch, R. (2003). Linking technology areas to industrial sectors. *Final Report to the European Commission, DG Research*.

Staiger, D. and Stock, J. H. (1997). Instrumental variables regression with weak instruments. *Econometrica*, 65(3):557.

Stock, J. H. and Yogo, M. (2002). Testing for weak instruments in linear IV regression. Working Paper 284, National Bureau of Economic Research.

Van Beveren, I. (2012). Total factor productivity estimation: A practical review. *Journal of Economic Surveys*, 26(1):98–128.

Van Biesebroeck, J. (2003). Revisiting some productivity debates. Technical Report 10065, National Bureau of Economic Research.

Van Biesebroeck, J. (2007). Robustness of productivity estimates. *The Journal of Industrial Economics*, 55(3):529–569.

WTO. Intellectual property: protection and enforcement. http://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm7_e.htm.

Yang, G. and Maskus, K. E. (2001). Intellectual property rights, licensing, and innovation in an endogenous product-cycle model. *Journal of International Economics*, 53(1):169–187.

Zanatta, M., Strachman, E., Carvalho, F., Varrichio, P. C., Camillo, E., and Barra, M. (2008). National policies to attract FDI in R&D. an assesment of brazil and selected countries. Technical Report 69, United Nations University - World Institute for Development Economics Research.

Appendices

A Descriptive statistics

Table A.1: Distribution of Firms According to Industry

ISIC rev.3 at 2-digit level	Observations	Description
15	10,764	Manufacture of food products and beverages
17	1,656	Manufacture of textiles
18	1,773	Manufacture of wearing apparel; dressing and dyeing of fur
19	883	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
20	2,320	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
21	1,026	Manufacture of paper and paper products
22	1,716	Publishing, printing and reproduction of recorded media
24	2,033	Manufacture of chemicals and chemical products
25	2,144	Manufacture of rubber and plastics products
26	1,816	Manufacture of other non-metallic mineral products
28	2,473	Manufacture of fabricated metal products, except machinery and equipment
29	1,844	Manufacture of machinery and equipment n.e.c.
31	499	Manufacture of electrical machinery and apparatus n.e.c.
33	205	Manufacture of medical, precision and optical instruments, watches and clocks
34	482	Manufacture of motor vehicles, trailers and semi-trailers
35	296	Manufacture of other transport equipment
36	1,608	Manufacture of furniture; manufacturing n.e.c.

B Spillovers

Table B.1: Results from Lopez (2008).

Table 5. *Productivity spillovers from foreign technology licensing*

	Licenses all plants—stock			Licenses all plants—flow		
	OLS (1)	FD (2)	FD-IV (3)	OLS (4)	FD (5)	FD-IV (6)
Licenses same sector (S)	−0.119	−0.047	−0.035	0.005	−0.012	−0.022
	(3.06)**	(1.66)***	(0.79)	(0.40)	(0.95)	(1.26)
Licenses downstream sectors (D)	−0.133	−0.185	−0.228	0.002	−0.141	−0.248
	(2.84)**	(4.62)**	(5.19)**	(0.05)	(4.65)**	(5.92)**
Licenses upstream sectors (U)	−0.035	0.578	0.764	−0.055	0.237	0.400
	(0.53)	(6.11)**	(6.48)**	(1.44)	(5.63)**	(6.01)**
Herfindahl index	−0.071	−0.277	−0.277	−0.130	−0.275	−0.277
	(1.31)	(6.01)**	(6.13)**	(2.28)*	(5.50)**	(5.64)**
FDI same sector	0.008	−0.003	−0.002	0.012	−0.005	−0.002
	(1.60)	(0.67)	(0.33)	(2.12)*	(1.00)	(0.43)
FDI downstream sectors	0.031	−0.015	0.024	0.030	−0.064	0.023
	(0.78)	(0.38)	(0.59)	(0.67)	(2.20)*	(0.58)
FDI upstream sectors	0.013	0.229	0.177	0.046	0.363	0.327
	(0.34)	(4.11)**	(3.01)**	(1.20)	(6.64)**	(5.46)**
Exports sector	0.032	−0.042	−0.015	−0.004	−0.075	−0.045
	(1.07)	(1.04)	(0.33)	(0.14)	(2.01)*	(1.09)
Exporter dummy	0.462	−0.013	−0.012	0.466	−0.017	−0.016
	(16.43)**	(0.77)	(0.70)	(16.51)**	(0.98)	(0.94)
Foreign ownership dummy	0.259	0.050	0.051	0.278	0.050	0.052
	(9.50)**	(1.28)	(1.31)	(9.97)**	(1.27)	(1.29)
Licenses/sales	1.613	1.345	1.346	3.866	0.494	0.465
	(7.48)**	(2.76)**	(2.77)**	(2.37)*	(1.52)	(1.41)
R-squared	0.517	0.098	0.096	0.515	0.087	0.079
Number of observations	33,821	26,740	26,740	33,821	26,740	26,740

Absolute value of t statistics in parentheses. **, *, ***: significant at 1%, 5%, and 10%. Three-digit sector, region, and year dummy variables were included but not reported. Standard errors were clustered at the sector-year level.

C TFP estimation

Following Van Beveren (2012), the most common functional form for the output is to assume a Cobb-Douglas production function. Thus, the estimating equation, would be:

$$Y_{ijrt} = A_{ijrt} K_{ijrt}^{\beta_k} L^{s\,\beta_{ls}}_{ijrt} L^{u\,\beta_{lu}}_{ijrt} \tag{20}$$

Where Y_{ijrt} is output of the firm i in sector j and region r at time t; K_{ijrt} is the capital stock; while L^s and L^u are the number of skilled and unskilled workers respectively. If we apply logarithms to this equation we get:

$$y_{ijrt} = \beta_0 + \beta_k k_{ijrt} + \beta_{ls} l^s_{ijrt} + \beta_{lu} l^u_{ijrt} + \varepsilon_{ijrt} \tag{21}$$

So that productivity is:

$$ln\ TFP_{ijrt} = y_{ijrt} - \beta_k k_{ijrt} - \beta_{ls} l^s_{ijrt} - \beta_{lu} l^u_{ijrt} \tag{22}$$

Which can also be seen as:

$$ln\ A_{ijrt} = \beta_0 + \varepsilon_{ijrt}$$

It is important to note that ε_{ijrt} is the time-industry-region-producer specific productivity shock, which can be decomposed into an observable part and an unobservable component. Therefore we have:

$$ln\ A_{ijrt} = \beta_0 + \nu_{ijrt} + \eta_{ijrt}$$

So that productivity is $\omega_{ijrt} = \beta_0 + \nu ijrt$ and η_{ijrt} is an i.i.d. error component. It is important to note that ν_{ijrt} is a part of the error term that is observed by the firm but not by the econometrician.

One might be tempted to estimate equation (21) using Ordinary Least Squares (OLS). However, there are several methodological issues that have to be taken into account to estimate equation (21). If we were to specify the issues one by one, we would see possible solutions.

C.1 Endogeneity

If we would estimate equation (21) using OLS, the main assumption would be that all the inputs in the production function are exogenous. However, as noted by Marschak and Andrews (1944) inputs in the production function are not chosen independently. The clearest case is that any firm would determine their labor inputs according to its productivity, and thus creating a correlation between the level of inputs chosen and the productivity shock that is observed by the firm but not by the econometrician.

Thus, if the firm has knowledge of ω_{ijrt}, it would affect the choice of inputs. If there is a positive productivity shock, this would likely increase the use of variable inputs (unskilled and skilled labor), which in turn would introduce an upward bias to the estimates of variable input coefficients and a downward bias on fixed input coefficients (capital).

C.2 Selection bias

The problem of selection bias is introduced when, in an unbalanced panel of firms, the decision on allocation of inputs (especially variable inputs) is not independent of the decision to continue operating in the market. Therefore, the estimation technique has to take into account that the estimates are conditional on the survival of the firm.

There are many theoretical models that predict the importance of productivity on the firm's decision to continue operating in the market. Therefore, if firms have some knowledge of their productivity, this would generate a negative bias on the capital stock coefficient. This bias is due to the fact that firms with higher capital stock and a given productivity are more likely to survive than firms with low capital stock and the same productivity level.[39]

C.3 Estimation

There have been many different ways to approach the problems outlined above. The most important ways to estimate will be explained in turn. This part follows closely the work of Van Biesebroeck (2003), Van Biesebroeck (2007), and Van Beveren (2012).[40]

In the following subsections I will use a typical Cobb-Douglas production function so that there is only one type of labor (this is only a simplification that helps explain the different methods of

[39] Van Beveren (2012) also makes reference to problems related to omitted price bias and multiproduct firms. However, I will focus on the problems outlined here since they have been under study for much longer and also because they are more relevant in this study.

[40] In the following subsections, the production function will be indexed at the firm-time level instead of being at the firm-industry-region-time level.

estimation). Thus, the production process is assumed to be:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} \tag{23}$$

C.3.1 Index numbers

This approach does not rely on a functional form of the production function. It relies on a theoretical approach to estimate the relation between inputs and output without the necessity to specify an exact production function. The basic idea of this approach is to calculate the following formula:

$$\begin{aligned} log\ (A_{it}/A_{it-1}) &= log\,(Y_{it}/Y_{it-1}) \\ &\quad - [\overline{s}_{it}\ log\ \ (L_{it}/L_{it-1}) + (1-\overline{s}_{it})\ log\ \ (K_{it}/K_{it-1})] \end{aligned} \tag{24}$$

Where $\overline{s}_{it}$ is the average cost share of labor between time t and $t-1$.

One of the main advantages of using index numbers is that they are easy to calculate while keeping the technology fairly flexible. Also, as long as there is some data regarding the inputs, it is easy to modify equation (24) in order to include all the inputs.

The biggest drawback of this approach is that it is very sensitive to the quality of the data and, most importantly, a number of assumptions have to be satisfied: constant returns to scale, competitive input and output markets, and profit maximizing firms.

Next, there are some parametric methods that try to overcome the endogeneity and selection bias. However, I will only explain the non-parametric approaches that have been developed recently. For a more detailed explanation on the parametric approaches see Van Biesebroeck (2003).

C.3.2 Olley and Pakes

Olley and Pakes (1996) (OP henceforth) constitutes a major breakthrough in productivity estimation since they take into account both the endogeneity issue and the selection bias problem. As Ackerberg et al. (2006) (ACF henceforth) point out, the main assumption is that capital is a fixed input that depends on an investment process. Therefore, capital in period t depends on capital in $t-1$ and investment i_{t-1}. This timing helps to solve the endogeneity issue with respect to capital since the decision of capital is taken before the knowledge of the productivity shock.

Therefore, Olley and Pakes (1996) introduce a three-step estimation process where the investment of the firm is a monotonically increasing function of productivity and existing capital.

If the relationship is monotonically increasing, as explained in Arnold (2005), the investment decision is a function of the productivity (ω_{it}) and the capital stock:[41]

$$i_{it} = i_t(\omega_{it}, k_{it})$$

This relation can be inverted and we have a function for productivity that depends on investment and capital:

$$\omega_{it} = h_t(i_{it}, k_{it})$$

Then the estimating equation becomes:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + h_t(i_{it}, k_{it}) + \eta_{it}$$

We can define the function:

$$\omega_{it} = \beta_k k_{it} + h_t(i_{it}, k_{it})$$

Thus for the first step, the estimating equation becomes:

$$y_{it} = \beta_0 + \beta_l l_{it} + \phi(i_{it}, k_{it}) + \eta_{it}$$

Since the functional form of $\phi(.)$ is unknown, it can be approximated non-parametrically by a third or fourth degree polynomial. Thus, in the first stage, both $\widehat{\beta_l}$ and $\widehat{\phi}$ can be estimated using regular Ordinary Least Squares (OLS).

In the second step, they introduce a correction for the selection bias (exit decision). Exit is conditional on the realization of productivity, with a given threshold for firms to exit. Both are unknown functions of investment and capital, and they can be estimated through a probit regression for exit. Thus, in the second step, the probability of survival $\widehat{P_{it}}$ is estimated.

Also, since $\widehat{\beta_l}$ has been consistently estimated in the first stage, then it is possible to form a new

[41] For ease of exposition I will only include one variable that represents labor, although in this study I use skilled and unskilled labor as two different inputs.

function $V_{it} = y_{it} - \widehat{\beta}_l l_{it}$ and estimate:

$$V_{it} = \beta_k k_{it} + g(\phi_{it-1} - \beta_k k_{it-1}) + f(\phi_{it-1} - \beta_k k_{it-1})\widehat{P_{it}} + \eta_{it} \tag{25}$$

Where $g(.)$ and $f(.)$ are unknown functions and are therefore estimated using a polynomial approximation as in the first step. However, it is worth noting that in this stage, since there is a given structure for β_k, then this equation has to be estimated using Non Linear Least Squares. Once we have estimates of equation (25) then we obtain consistent estimates of β_l and β_k, enabling the construction of TFP.

However the main limitation of this methodology is that there could be a large number of "zero" investment observations (not all firms invest every single period). Thus a considerable amount of information is potentially lost.

C.3.3 Levinsohn and Petrin

Since Olley and Pakes (1996) assume that there is a monotonic relation between investment and productivity, then, in order to use that method it is necessary that all the observations with zero investment are dropped from the sample.

As explained above, this could imply a significant loss of observations in the dataset (depending on how many firms do not invest). Since investment is not always positive, Levinsohn and Petrin (2003) (LP henceforth) provide an alternative approach.

The estimation is very much in spirit of Olley and Pakes (1996). However, they use intermediate inputs as a proxy for productivity shocks. As Arnold (2005) points out, typically there are significantly less zero- observations in intermediate inputs than in investment.

C.3.4 Ackerberg, Caves, and Fraser

More recently, Ackerberg et al. (2006) have re-examined the estimation methods for production functions. They shed some light into some issues that might hinder the methodology proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003).

They argue that there may be significant problems with the estimation of production functions if the methods mentioned above are used. The most critical issue are collinearity problems that arise in both methods. If the assumptions of the OP and LP methods hold, then it would be possible to identify β_l in the following equation:[42]

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + h_t(i_{it}, k_{it}) + \eta_{it} \tag{26}$$

Where $h_t(i_{it}, k_{it})$ is the productivity shock (ω_{it}) in the OP methodology. In the LP methodology, it is replaced by $h_t(m_{it}, k_{it})$. ACF argue that there are some collinearity issues between β_l and $h_t(.)$.

Regarding the LP methodology, the issue is whether there is any variation of l_{it} that is independent of the non-parametric term $h_t(.)$. They argue three different scenarios where collinearity would be present. In the first scenario, l_{it} and m_{it} are decided at the same time. In this case, if they are both jointly determined, then it is clear that the choice of labor should also be a function of the productivity shock and the stock of capital. Recall that:

$$m_{it} = m_t(\omega_{it}, k_{it}) \qquad \text{then it should be that:} \qquad l_{it} = l_t(\omega_{it}, k_{it})$$

Therefore, since $\omega_{it} = h_t(m_{it}, k_{it})$, then: $l_{it} = l_t(h_t(m_{it}, k_{it}), k_{it}) = g_t(m_{it}, k_{it})$ where l_{it} is some function of m_{it} and k_{it}. Therefore, l_{it} is collinear with the non-parametric function.

In the second scenario, where l_{it} is decided before m_{it}, then the appropriate function determining the level of intermediate inputs would be:

$$m_{it} = m_t(\omega_{it}, k_{it}, l_{it})$$

creating a clear correlation with l_{it} in equation (26). The third scenario is when l_{it} is decided after m_{it}. In this scenario, if the productivity shock ω_{it} occurs in between the decision of buying intermediate inputs and hiring labor, then the collinearity disappears. However, this contradicts the assumption that the inversion of the investment function will solve the endogeneity problem.

For the OP methodology, the reasoning is similar. In order to get proper identification of β_l in equation (26) it is necessary that there is some variation of l_{it}. ACF assume that there could be some potential optimization error or measurement error that could lead to variation of l_{it}. However, these, on average, will approach zero.

They propose an approach that takes into account the possibility of collinearity between l_{it} and

[42] Recall that in the LP methodology, investment is replaced by intermediate inputs m.

$h_t(i_{it}, k_{it})$. Consider the production function in logs:[43]

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \eta_{it} \tag{27}$$

Then, following LP, the intermediate input function is:

$$m_{it} = m_t(\omega_{it}, k_{it})$$

Which is assumed to be monotonic and can be inverted, yielding:

$$\omega_{it} = h_t(m_{it}, k_{it})$$

Now, in order to take into account the collinearity issues discussed above, we should have:

$$l_{it} = l_t(\omega_{it}, k_{it}) = l_t(h_t(m_{it}, k_{it}), k_{it}) = g_t(m_{it}, k_{it})$$

If we substitute this into equation (27):

$$y_{it} = \beta_l g_t(m_{it}, k_{it}) + \beta_k k_{it} + h_t(m_{it}, k_{it}) + \eta_{it}$$

Then the estimating equation becomes:

$$y_{it} = \beta_0 + \phi(m_{it}, k_{it}) + \eta_{it} \tag{28}$$

In this equation, $\phi(m_{it}, k_{it})$ combines all the production function terms, including l_{it}. Moreover, β_l is not identifiable from this equation, however; the $\phi(.)$ function can be estimated non-parametrically following the spirit of OP and LP. Therefore, it is possible to obtain values of $\widehat{\phi(.)}$.

Now, similarly as in OP and LP, in a second stage, the estimating equation is similar to the

[43] In this production function, y_{it} is value added, that is, net of materials.

procedure described in the Olley and Pakes section, equation (25):

$$\begin{aligned} V_{it} &= \beta_l l_{it} + \beta_k k_{it} + g(\phi_{it-1} - \beta_k k_{it-1} - \beta_l l_{it-1}) \\ &\quad + f(\phi_{it-1} - \beta_k k_{it-1} - \beta_l l_{it-1})\widehat{P_{it}} + \eta_{it} \end{aligned} \tag{29}$$

The estimation has to be performed using either non-linear least squares, or an optimization routine.

Table C.1: TFP Estimation

Method	Industry																
	15	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**26**	**28**	**29**	**31**	**33**	**34**	**35**	**36**
OLS																	
No of Obs.	10764	1656	1773	883	2320	1026	1716	2033	2144	1816	2473	1844	499	205	482	296	1608
lnskilled	0.49	0.43	0.40	0.45	0.28	0.63	0.45	0.51	0.36	0.51	0.37	0.48	0.38	0.40	0.64	0.47	0.54
lnunskilled	0.41	0.40	0.41	0.41	0.09	0.29	0.33	0.19	0.30	0.23	0.33	0.37	0.34	0.27	0.48	0.33	0.51
lnkstock	0.30	0.27	0.33	0.39	0.46	0.32	0.38	0.38	0.40	0.24	0.35	0.28	0.30	0.40	0.37	0.33	0.21
RTS	1.20	1.10	1.15	1.25	0.83	1.24	1.16	1.07	1.06	0.97	1.06	1.13	1.02	1.08	1.49	1.13	1.26
TORNQVIST INDEX																	
No. of Obs.	8,400	1,295	1,365	681	1,793	818	1,338	1,598	1,672	1,406	1,903	1,414	388	163	366	222	1,211
lnskilled	0.16	0.13	0.15	0.14	0.08	0.07	0.17	0.08	0.08	0.11	0.14	0.38	0.09	0.14	0.13	0.13	0.13
lnunskilled	0.22	0.21	0.19	0.26	0.40	0.11	0.12	0.13	0.34	0.17	0.18	0.14	0.16	0.15	0.22	1.18	0.20
lnkstock	0.62	0.66	0.66	0.60	0.52	0.82	0.71	0.80	0.58	0.72	0.68	0.47	0.75	0.71	0.65	-0.31	0.67
RTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OP Manually																	
No. of Obs.	4477	696	578	302	1088	500	755	1170	1064	748	1044	765	219	95	173	134	543
lnskilled	0.27	0.33	0.21	0.25	0.11	0.17	0.26	0.39	0.23	0.33	0.26	0.36	0.28	0.40	0.44	0.28	0.37
lnunskilled	0.18	0.28	0.24	0.30	0.05	0.05	0.20	0.17	0.19	0.17	0.23	0.30	0.28	0.26	0.36	0.24	0.38
lnkstock	0.12	0.15	0.24	0.07	0.13	0.03	0.28	0.13	0.22	0.09	0.17	0.06	0.06	0.32	0.29	0.11	0.08
RTS	0.56	0.76	0.69	0.62	0.29	0.25	0.74	0.68	0.63	0.59	0.65	0.72	0.62	0.99	1.09	0.62	0.84
Olley and Pakes																	
No of Obs.	5604	851	729	388	1354	618	956	1468	1342	961	1312	969	283	121	218	177	709
lnskilled	0.16	0.20	0.16	0.12	0.10	0.31	0.36	0.15	0.21	0.04	0.23	0.03	0.28	0.29	0.21	0.22	0.26
lnunskilled	0.27	0.33	0.21	0.25	0.10	0.18	0.26	0.38	0.23	0.33	0.26	0.36	0.28	0.40	0.45	0.29	0.38
lnkstock	0.18	0.28	0.24	0.30	0.06	0.06	0.19	0.16	0.19	0.17	0.23	0.29	0.29	0.27	0.35	0.22	0.38
RTS	0.61	0.81	0.61	0.67	0.26	0.55	0.81	0.69	0.63	0.55	0.72	0.68	0.84	0.97	1.01	0.73	1.02
Levinsohn and Petrin																	
No of Obs.	10733	1654	1771	875	2317	1025	1709	1953	2143	1777	2469	1834	499	205	482	296	1607
lnskilled	0.22	0.34	0.24	0.32	0.14	0.20	0.26	0.46	0.25	0.23	0.27	0.40	0.29	0.38	0.54	0.41	0.38
lnunskilled	0.17	0.31	0.23	0.29	0.07	0.11	0.20	0.17	0.21	0.09	0.24	0.29	0.25	0.18	0.36	0.28	0.37
lnkstock	0.14	0.16	0.17	0.14	0.14	0.07	0.19	0.17	0.23	0.09	0.18	0.11	0.26	0.38	0.26	0.16	0.14
RTS	0.53	0.81	0.64	0.75	0.35	0.38	0.65	0.80	0.69	0.41	0.69	0.80	0.80	0.94	1.16	0.84	0.88
Ackerberg, Caves, and Fraser																	
No of Obs.	8400	1295	1365	681	1793	818	1338	1598	1672	1406	1903	1414	388	163	366	222	1212
lnskilled	0.35	0.48	0.42	0.28	0.40	0.56	0.42	0.54	0.36	0.42	0.36	0.54	0.19	0.47	0.47	0.62	0.46
lnunskilled	0.34	0.64	0.35	0.39	0.29	0.56	0.29	0.21	0.32	0.30	0.34	0.49	0.05	0.42	0.52	0.34	0.56
lnkstock	0.13	0.16	0.22	0.15	0.13	0.06	0.20	0.15	0.21	0.16	0.21	0.10	0.18	0.18	0.16	0.14	0.12
RTS	0.81	1.28	1.00	0.82	0.81	1.18	0.91	0.90	0.90	0.88	0.91	1.14	0.42	1.06	1.14	1.11	1.13

C.4 Robustness tests

Table C.2: No Foreign Presence

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Horizontal Spillovers	0.02	-0.25	-0.21
	(0.96)	(0.46)	(0.24)
Backward Spillovers	4.15**	3.37***	1.41***
	(1.80)	(0.58)	(0.44)
Forward Spillovers	-2.52**	-1.22*	-0.06
	(1.20)	(0.73)	(0.39)
IPR Fraser		-0.58***	
		(0.22)	
IPR Fraser x Horizontal Spillovers		0.01	
		(0.06)	
IPR Fraser x Backward Spillovers		-0.40***	
		(0.05)	
IPR Fraser x Forward Spillovers		0.23**	
		(0.09)	
Dummy IPR			0.11***
			(0.04)
Dummy IPR x Horizontal Spillovers			-0.00
			(0.17)
Dummy IPR x Backward Spillovers			-1.10***
			(0.15)
Dummy IPR x Forward Spillovers			0.70**
			(0.28)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.21	0.65	0.65
Observations	2,884	8,932	8,932
R-squared	0.00	0.00	0.00
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.3: No Foreign Presence
Balanced Panel

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Horizontal Spillovers	0.79	0.31	0.22
	(1.01)	(0.59)	(0.32)
Backward Spillovers	1.20	2.49***	0.77
	(1.96)	(0.76)	(0.54)
Forward Spillovers	-2.47**	-2.12**	-0.77*
	(1.23)	(0.87)	(0.45)
IPR Fraser		-0.39	
		(0.25)	
IPR Fraser x Horizontal Spillovers		-0.02	
		(0.07)	
IPR Fraser x Backward Spillovers		-0.35***	
		(0.07)	
IPR Fraser x Forward Spillovers		0.29**	
		(0.11)	
Dummy IPR			0.13***
			(0.04)
Dummy IPR x Horizontal Spillovers			-0.09
			(0.21)
Dummy IPR x Backward Spillovers			-0.98***
			(0.20)
Dummy IPR x Forward Spillovers			0.84**
			(0.33)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.31	0.40	0.38
Observations	2,337	7,227	7,227
R-squared	0.00	0.01	0.01
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.4: No Horizontal Spillovers

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	4.26***	2.66***	1.13***
	(1.30)	(0.55)	(0.41)
Forward Spillovers	-2.84***	-1.33***	-0.30
	(0.79)	(0.48)	(0.29)
IPR Fraser		-0.53**	
		(0.22)	
IPR Fraser x Backward Spillovers		-0.31***	
		(0.07)	
IPR Fraser x Forward Spillovers		0.21***	
		(0.07)	
Dummy IPR			0.10***
			(0.03)
Dummy IPR x Backward Spillovers			-0.90***
			(0.21)
Dummy IPR x Forward Spillovers			0.61***
			(0.20)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.63	0.62	0.63
Observations	2,884	8,932	8,932
R-squared	0.01	0.00	0.00
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.5: No Horizontal Spillovers
Balanced Panel

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	2.43	2.12***	0.93**
	(1.90)	(0.67)	(0.42)
Forward Spillovers	-2.26*	-1.56***	-0.51*
	(1.16)	(0.50)	(0.26)
IPR Fraser		-0.56***	
		(0.21)	
IPR Fraser x Backward Spillovers		-0.25***	
		(0.09)	
IPR Fraser x Forward Spillovers		0.22***	
		(0.07)	
Dummy IPR			0.13***
			(0.03)
Dummy IPR x Backward Spillovers			-0.71***
			(0.25)
Dummy IPR x Forward Spillovers			0.63***
			(0.20)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.12	0.63	0.62
Observations	2,409	7,227	7,227
R-squared	0.00	0.01	0.01
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.6: No Foreign Presence/Horizontal Spillovers

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	4.26***	3.13***	1.13***
	(1.23)	(0.44)	(0.41)
Forward Spillovers	-2.57***	-1.56***	-0.30
	(0.73)	(0.47)	(0.29)
IPR Fraser		-0.51**	
		(0.20)	
IPR Fraser x Backward Spillovers		-0.39***	
		(0.04)	
IPR Fraser x Forward Spillovers		0.25***	
		(0.06)	
Dummy IPR			0.10***
			(0.03)
Dummy IPR x Backward Spillovers			-0.90***
			(0.21)
Dummy IPR x Forward Spillovers			0.61***
			(0.20)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.31	0.78	0.62
Observations	2,884	8,932	8,932
R-squared	0.00	0.00	0.00
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.7: No Foreign Presence/Horizontal Spillovers
Balanced Panel

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	3.65**	2.79***	1.08***
	(1.57)	(0.55)	(0.36)
Forward Spillovers	-2.67***	-1.85***	-0.56**
	(0.95)	(0.46)	(0.25)
IPR Fraser		-0.53***	
		(0.20)	
IPR Fraser x Backward Spillovers		-0.35***	
		(0.06)	
IPR Fraser x Forward Spillovers		0.27***	
		(0.06)	
Dummy IPR			0.14***
			(0.04)
Dummy IPR x Backward Spillovers			-0.98***
			(0.18)
Dummy IPR x Forward Spillovers			0.76***
			(0.17)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.38	0.63	0.62
Observations	2,409	7,227	7,227
R-squared	0.00	0.01	0.01
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.8: Horizontal is not used as Instrument

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	4.47**	3.08***	1.32***
	(1.77)	(0.54)	(0.51)
Forward Spillovers	-2.71**	-1.58***	-0.46
	(1.10)	(0.53)	(0.39)
IPR Fraser		-0.55**	
		(0.22)	
IPR Fraser x Backward Spillovers		-0.37***	
		(0.06)	
IPR Fraser x Forward Spillovers		0.24***	
		(0.07)	
Dummy IPR			0.11**
			(0.04)
Dummy IPR x Backward Spillovers			-0.85***
			(0.23)
Dummy IPR x Forward Spillovers			0.56**
			(0.22)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.25	0.48	0.44
Observations	2,884	8,932	8,932
R-squared	0.00	0.00	0.00
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.9: Horizontal is not used as Instrument
Balanced Panel

Dependent variable: log (TFP)	No IPR	Fraser IPR	Dummy IPR
Backward Spillovers	3.82*	2.21***	0.75
	(2.08)	(0.76)	(0.47)
Forward Spillovers	-2.80**	-1.57***	-0.41
	(1.32)	(0.55)	(0.31)
IPR Fraser		-0.49**	
		(0.22)	
IPR Fraser x Backward Spillovers		-0.31***	
		(0.07)	
IPR Fraser x Forward Spillovers		0.25***	
		(0.06)	
Dummy IPR			0.14***
			(0.04)
Dummy IPR x Backward Spillovers			-0.88***
			(0.21)
Dummy IPR x Forward Spillovers			0.71***
			(0.18)
Kleibergen-Paap LM Statistic (under-identification test)	0.00	0.00	0.00
Hansen J Statistic (over-identification test)	0.22	0.37	0.37
Observations	2,409	7,227	7,227
R-squared	0.00	0.01	0.01
Time, Industry and Region Dummies	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D FDI Vs. Licensing

Table D.1: Descriptive Statistics (Low-Tech vs. High-Tech Firms)

Variable	Low-Tech Firms (31,300 firms)				High-Tech Firms (2,308 firms)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Capital Stock	1509.42	9322.24	0	680,000	8057.26	48590.63	0	953,000
% Domesic Capital	96.73	16.63	0	100	79.89	38.39	0	100
% Foreign Capital	3.26	16.59	0	100	20.11	38.39	0	100
Value Added	1758.89	8594.42	0	470,000	10496.43	66820.67	0.51	1,720,000
Sale of Production	2934.43	11245.13	0	367,000	16126	105000.00	0	1,770,000
Total Wages	331.84	1793.99	0	275,000	978.91	4879.48	1.87	205,000
Gross Production Value	4078.29	15670.79	2.28	504,000	24622.16	168000.00	6.17	3,480,000
Licenses and Foreign Assistance	4.12	72.84	0	5,578	63	515.47	0	11,864
Income Due to Exports	945.39	6913.39	0	311,000	3118.39	21210.31	0	401,000
Number of Skilled Workers	12.36	43.71	0	1,554	23.08	74.04	0	1,057
Skilled/Unskilled Workers Ratio	0.64	3.39	0	159	0.98	5.03	0	139
Skilled/Total Workers Ratio	0.24	0.3	0	1	0.24	0.29	0	1