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MULTINATIONAL FIRMS AND PRODUCTIVITY CATCHING-UP: THE CASE OF CHILEAN MANUFACTURING

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Resumen

En este trabajo se estudia el proceso de convergencia en la productividad total de factores (PTF), utilizando información de plantas manufactureras chilenas para un período de 20 años. En el trabajo se estudian dos preguntas principales. Primero, se analiza si existe evidencia de que las plantas menos productivas experimentan un mayor crecimiento de la PTF que aquellas que se encuentran más cerca de la frontera tecnológica. Segundo, se investiga el rol que cumplen las plantas multinacionales en la aceleración del proceso de convergencia de las plantas nacionales menos productivas. Los resultados muestran evidencia de convergencia en la productividad de las plantas manufactureras. Además, se encuentra que una mayor presencia de multinacionales contribuye positivamente al proceso de convergencia. Estos hallazgos son coherentes con la idea de que las multinacionales contribuyen a la transferencia tecnológica hacia otras firmas y/o a incrementar la competencia y productividad en los mercados internos.

Abstract

In this paper we study total factor productivity (TFP) catching-up using 20 years of plant-level data for Chilean manufacturing. The paper addresses two key issues: First, we analyze whether there is evidence that low productivity plants experience larger TFP growth than those closer to the technology frontier. Second, we investigate the role of multinational plants in accelerating the catching-up process by non-frontier domestic plants. Our results show evidence of productivity catching-up, and that a higher presence of multinationals positively contributes to this phenomenon. There findings are consistent with the idea of technology spillovers from high to low productivity plants or that a higher presence of multinationals increase competitiveness and productivity in domestic markets.

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1. Introduction

There is wide cross-country evidence of a large degree of productivity dispersion within-industries. Not only for developing countries, but also for developed countries, it has been found that there are significant differences in firms' productivity even in narrowly defined industries (Bernard, et. al. 2003). This evidence has originated interesting questions regarding whether low productivity firms are able to converge to the productivity levels of sector leaders, and which factors may explain the speed of this convergence. These are the main questions we address in this paper.

We are particularly interested in studying if low-productivity plants converge to the industry productivity frontier. We are also interested in analyzing empirically which factors may accelerate this convergence. In this regard, we follow previous empirical evidence focusing on the role of technological transfers from multinational firms (Griffith, Redding and Simpson, 2005; Peri and Urban, 2006). Specifically, we investigate if knowledge spillovers from these firms may contribute to accelerate convergence. This emphasis is consistent with the idea that high-productivity foreign firms may help to upgrade technologies by domestic firms through technological spillovers.

This phenomenon may be particularly important for a developing country context, where domestic firms can learn from multinationals superior technology. In this context it may be also possible that entry of foreign firms might increase competition in domestic industries accelerating the productivity catching-up. In fact, a higher competition forces to less productive firms to increase productivity, otherwise they will not be able to survive. Yet we cannot distinguish between both effects, we present novel evidence of the potential role of multinationals for increasing productivity in host countries.

The paper is structured as follows. In the second section, we describe the data and show some facts on productivity dynamics for Chilean manufacturing plants. In the third section we study the characteristics of frontier plants. In the fourth section we present our empirical approach and econometric results. Section 5 concludes.

2. Data Description

2.1. Data Source

Our analysis is based on plant-level panel data from Chilean manufacturing industries covering the period 1979-1998. The information is provided by the *Encuesta Nacional Industrial Annual* (the Annual National Manufacturing Survey, ENIA) collected by the *Instituto Nacional de Estadisticas* (INE). For several reasons, these data are an excellent basis for the analysis in this paper. First, they include all Chilean manufacturing plants with at least ten workers that have been active in the Chilean manufacturing sector. Second, it covers a time period of 20 years, a time span long enough to measure plant level productivity dynamics properly. Third, an additional advantage of the data set is that the removal of market distortions coupled with an almost free trade policy followed over the period excludes many possible biases in estimating productivity gains, because almost all prices are determined by world markets[1]. As a consequence we can provide here a productivity measurement that allows for a clearer identification of the spillover effects and technological change.

There are almost 89,877 observations in the data set and, as we can see from Table 1, roughly 30% of them are in the foodstuffs sector, between 15% and 20% in textiles and metalworking and 10% in wood and furniture, and chemicals. These sector shares are stable over time; however it is possible to identify some interesting trends. Over the whole period the textile-related manufacturing branches lose about 7 percentage points in terms of productive units, losses that are offset by an increase in the shares of metalworking and, more marginally, chemicals. However, broadly speaking, there are no dramatic changes in the manufacturing structure in terms of sector shares (what is termed "structural change"). It is important to emphasize here that the sample is focused on the time period "after" the most important pro-market reforms and hence it is expected that in our sample we have relatively stable shares of the different manufacturing branches.

The data has been subject of the following standard cleaning procedures. First, due to lack of representation the tobacco branch (SIC 314) was not considered for the analysis. Second, due to the

[1] The estimated productivity gains in the presence of distorted markets might not reflect true social productivity gains (see Grilliches, 1998).

small number of observations the oil-refining branch (SIC 353) was merged with the oil derivatives one (SIC 354). Finally, we exclude outliers by dropping all plants with yearly total factor productivity growth rates higher than 100% or lower than –100% were left out of the analysis.

[Insert Table 1 about here]

2.2 Productivity Measure

As usual in the growth literature, we estimate total factor productivity from the residual of a production function. Thus, the main empirical concern is how to estimate this production function in an unbiased way. Let us assume that the production technology is well defined by a Cobb-Douglas production function:

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

where y_{it} is the gross output, l_{it} is employment, m_{it} is the quantity of intermediate materials and k_{it} is the capital stock used by firm i in time t (all variables measured in logs). The firm i specific residual μ_{it} can be decomposed as $\mu_{it} = \omega_{it}+\varepsilon_{it}$, where ω_{it} is a productivity term that is known by the firm but not by the econometrician and ε_{it} is an expected productivity shock (unobserved by both the firm and the econometrician). The fact that ω_{it} is known by the firm when it takes its production decisions induces a spurious correlation between the explanatory variables and μ_{it} making impossible to obtain unbiased estimators for the input elasticities by using Ordinary Least Squares (OLS) [2]. In general the biases are hard to sign but in the two factor case where labour is perfectly flexible and capital subject to adjustment costs there will be an upwards bias on the labour coefficient (reacts to shocks) and a downward bias on the capital coefficient

There is not only a simultaneity problem but the fact that the decision set of the firm also includes deciding whether to produce or not, bad productivity shocks might also induce firms to exit

[2] Profit maximising firms will respond to positive productivity shocks by expanding output, which requires additional inputs. Negative productivity shocks, will lead the firms to reduce outputs, decreasing their input usages

the market. This might add a further problem of selection bias to the standard OLS approach. However, it has been shown that the selection bias problem appears to be particularly important in the context of balanced panels (Griliches, 1998). Given that in our estimations strategy we work with a highly unbalanced panel dataset where we use all the available information for estimation, we don't think that selectivity is a particularly relevant in this context.

One alternative to correct for the simultaneity bias is by assuming that ω_{it} is firm specific but constant over time and estimating (1) by using fixed effects-within estimators. However, this is a particularly strong and inconvenient assumption particularly when we are interested in studying convergence mechanisms that require ω_{it} to be time variable.

Olley and Pakes (1996) show that, under certain assumptions regarding the timing of investment[3] and strict monotonicity, investment can be used as proxy for the unobservable shocks. More recently, Levinsohn and Petrin (2003) –LP- point to the evidence that in many firm level datasets, particularly those reporting data from Developing Countries, investment is very lumpy and large fractions of the dataset don't report any investment data at all. Under these circumstances, investment will not smoothly respond to the productivity shock, violating the strict monotonicity condition. LP show the conditions under which intermediate inputs can also solve this simultaneity problem. Because almost all the firms report materials expenditures, this will avoid truncating all the zero investment firms. Another advantage of using materials as a proxy is that if they are less costly to adjust to the productivity shock, they may respond more fully to the entire productivity term than investment, allowing for a better controlling for the correlation between the explanatory variables in (1) and the error term.

In this paper we estimate (1) using the LP approach. The main assumption are the following: (1) l_{it} and m_{it} are variable inputs that react to the productivity shock ω_{it}; (2) investment also reacts to the productivity current shocks, but investment only affects capital in the next period (the same timing as in Olley and Pakes); (3) as a consequence k_{it} is fixed factor that does not respond to the current

[3] Investment must determine the capital stock of the next period but not the capital stock in the current period.

productivity shocks and (4) the productivity shock (ω_{it}) is governed by an unknown first order Markov process. We start by specifying a materials demand non-dynamic equation such as:

$$m_{it} = m_t(k_{it}, \omega_{it}) \quad (2)$$

If (2) is strictly monotonic it can be inverted to obtain:

$$\omega_{it} = h_t(k_{it}, m_{it}) \quad (3)$$

By substituting (3) into the production function (1) we will get:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + h_t(k_{it}, m_{it}) + \varepsilon_{it} \quad (4)$$

$$y_{it} = \beta_0 + \beta_l l_{it} + \phi_t(k_{it}, m_{it}) + \varepsilon_{it} \quad (5)$$

Where the function $\phi(.)$ is defined by:

$$\phi_t(k_{it}, m_{it}) = \beta_k k_{it} + \beta_m m_{it} + h_t(k_{it}, m_{it}) \quad (6)$$

The method is based on a two-step strategy. Because by using the proxy function (3) the productivity shock is a function of both materials and capital stock, at the moment of replacing (3) into the production function to obtain equation (4), it becomes clear that neither β_m nor β_k can be identified separately from the control function h_t. Hence in the first step we can only identify the elasticity of labor (β_l) and for this we only need to approximate $\phi(.)$ by a polynomial function of some degree[4]. In the second stage we use the estimated the elasticity of labor (β_l) and we get estimates for β_m and β_k by making the assumption that the productivity shock is governed by an unknown first order Markov process and estimating using non-linear GMM methods. After this the productivity index is obtained as a residual. That is:

$$\mu_{it} = \beta_0 + \omega_{it} + \xi_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \quad (7)$$

[4]In this paper a 3rd degree polynomial is used. LP note that such a choice leads to estimated parameters that are very similar to more complicated locally weighted estimation.

The production function (1) is estimated separately for each one of the 3-digit industries in the sample, with the exception of some industries with few plants where the estimation is made using 2-digit industries (see Table A.1 in the Appendix). The results of this are shown in the appendix. We also estimated (1) by OLS. Figure A.1 in the appendix also compares the differences in the estimated elasticities using these two methods.

2.2 Productivity Dispersion and Dynamics

This section characterizes some features of the distribution of the TFP index used in this paper. First, we look at the productivity dispersion by showing TFP deviations from the industry mean productivity. Figure 1 shows that for the vast majority of plants, TFP index is located in the interval between -200% and +200%, indicating a massive degree of heterogeneity. Less than 2% of plants have productivity indices greater than +200% or smaller than -200% and the (log) TFP distributions look relatively symmetric.

[Insert Figure 1 about here]

One important issue in studying productivity dynamics is how the different plants move across the productivity distribution. Do they tend to converge towards the best technology practice? To answer these questions we need to see how the ranking of plants changes across the productivity distribution, and over time. Baily *et al.* (1992) and Disney et. al. (2003) analyze productivity dynamics by computing transition matrices. In order to build a transition matrix the plants in the sample may be ranked by relative productivity in each year, and sorted into quintiles. From this we can compute the fractions of plants in the sample that make each alternative movement among quintiles, by each pair of years. Of course, over time incumbent plants may exit from the industry and new plants arrive; as a consequence two additional states must be considered: births and deaths. A transition matrix can give a lot of information about productivity dynamics. For example, for the plants in the top quintile in their own industry at time *t*, we can see what fraction remains in the top quintile in their industry in year $t+k$. The fractions in the second, third, fourth and fifth quintiles can also be determined. Some of the incumbent plants at time t will have been closed down in $t+k$, then we will have the transition to death. Finally, we can find how those plants that enter the industry between t and $t+k$ are distributed across the productivity quintiles in $t+k$.

Table 2 presents the results for the transition between the initial and final year of our sample (1979 and 1998, respectively). The results for the top quintile show that the degree of persistence is low. Of the plants in the top quintile in 1979, only 23.1% of them were still in the top quintile in 1998, 8.9% had moved down one quintile, 4.1% declined to the third quintile, 2.5% went down to the fourth quintile, and 1.4% ended in the fifth quintile. In addition, a significant number of the top plants had exited (43%). It is worth noting here that these figures are very similar to those reported by Disney et. al. (2003) for the UK in 1980-92. Indeed, for this period they found that the persistence in the top productivity group was 31%, and that exits from the top were 50%.

The analysis of the long-run transitions reveals that a large percentage of plants at the bottom of the distribution in 1979 had exited in 1998 (79.7%). The movement towards the top part of the distribution is a very rare event. In fact, only 0.7% of the plants had managed to move up to the tops quintile of the 1998 productivity distribution. For the plants in the middle quintiles, the matrix shows that few plants had managed to move up and between 64% and 75% of them had failed in the end. Note also that the there is a positive correlation between exit probability and initial productivity. The probability of death is reduced from 79.7% to 60.1% when we moved from the bottom to the top part of productivity distribution. Regarding entrant plants, 18.4% entered at the top of the distribution in 1998 and 21.9% at the bottom, while the rest were evenly spread across the middle quintiles.

In summary, three issues are worth emphasizing for productivity dynamics. First, there are many low productivity performers entrants located in the middle or the bottom quintiles of the productivity distribution. Second, there is relatively high persistence, at the top of the distribution, even in the case of the long-run transitions like this. Third, an important number of plants in the middle of the distribution at the beginning were able to move up to the top.

[Insert Table 2 about here]

3. Frontier Plants and their Main Characteristics

To analyze if there is evidence of productivity catching-up in Chilean plants, we need a measure of technological frontier. Once we have this measure, we can test if differences between plant and frontier productivity affect productivity growth. Then, we need first to compute the productivity frontier. We identify plants at the frontier as those on the top part of the productivity distribution for each year and 3-digit industry level. In order to test the robustness of our results we use two thresholds. Frontier plants are those with, alternatively, productivity levels above the 95% and 90% percentiles of the TFP distribution, respectively. Hence, with these two alternatives we have a year and sector specific measure of technological frontier.

The first question that we address in this section is what the characteristics of frontier plants are. We analyze differences between frontier and non-frontier plants in foreign ownership, age, labor skills (measured by the ratio white-collar wages on blue-collar wages), size (measured by employment), purchases of technical licenses, and acquisitions of imported inputs[5].

In Tables 3 and 4, we show the average of these variables for frontier and no frontier plants and for both thresholds (Thre95 and Thre90). The results are very consistent with the two alternatives definitions of frontier plants. It can be appreciated that a larger percentage of frontier firms are foreign owned. For the 95% threshold (Table 3), we have that 10.2% of plants at the frontier are foreign owned. In contrast, for non-frontier plants, only 4.0 are foreign owned. The figures are 9.3% and 3.8%, respectively, using the threshold of 90% (Table 4).

[5] We were interested on exporting activity, but the information for sales to foreign markets at plant-level is not available for the entire period. Alvarez and Lopez (2005) analyze the relationship between export and productivity for the period starting at 1990.

We have found that there are only slight differences in plant age for both groups of plants. In Table 3, it can be appreciated that frontier plants are on average 7.8 years old, and non-frontier firms are 7.5 years old. Similar figures are shown in Table 4.

[Insert Table 3 about here]

Using both definitions, our results reveal that frontier plants tend to be more human capital intensive and significantly larger than non-frontier plants. It is also found that frontier firms are more likely to purchase technical licenses, which it would be an indicator of higher efforts in introducing new technologies and products. Finally, frontier firms are more likely to buy imported inputs. Note that all of these differences for the total sample are, in general, also found within-industries[6].

[Insert Table 4 about here]

To analyze if these differences are robust to a multivariate analysis, we estimate a pooled Probit model for the probability of being classified as a frontier plant. The results are shown in Table 5. In the first columns (1) to (6) each variable is included independently. In column (7) we include all the variables at the same time. The results confirm our previous findings. The probability of being a frontier plant increases with foreign ownership, age, labor skills, size, the acquisition of licenses, and the purchases of imported inputs. More importantly, most of the variables are still significant when controlling for the other plant characteristics[7]. Then, these results are consistent with the idea that only considering foreign plants as those at the frontier may be misleading, other attributes might be also important.

[Insert Table 5 about here]

[6] To save space in these tables we show the average at 2-digit industries, but frontier plants are defined at 3-digit industries.

[7] The only exception is age, which turns out to affect negatively this probability.

4. Empirical Approach and Main Results

Our basic estimation follows closely the approach developed by Griffith et. al. (2006). They postulate that productivity growth for some plant *i* in industry *j* depends on two main factors:

(i) the industry frontier productivity growth $\Delta \ln A_{jt}^{F}$, and

(ii) the previous plant-specific productivity gap $\ln\left(A_j^F / A_i \right)_{t-1}$.

This is, the basic model given by:

$$\Delta \ln A_{ijt} = \beta \Delta \ln A_{jt}^{F} + \delta \ln\left(\frac{A_j^F}{A_i} \right)_{t-1} + u_{it} \tag{8}$$

In this model, the catching-up parameter is given by δ. In the extreme case that low-productivity firms do not catch-up frontier firms, δ will be zero. In the empirical specification, this model may be extended to capture firm-specific capabilities that increase productivity (α_i) and common shocks to technology and macroeconomic fluctuations controlled by a set of time dummy variables (γ_t). In such a case, the empirical model is given by:

$$\Delta \ln A_{ijt} = \alpha_i + \beta \Delta \ln A_{jt}^{F} + \delta \ln\left(\frac{A_j^F}{A_i} \right)_{t-1} + \gamma_t + u_{it} \tag{9}$$

The inclusion of a plant-fixed effect in equation (9) implies that we are assuming conditional convergence only. In other words, the long run equilibrium of the industry may be characterized by a continuum of plants operating with different technologies even in the long run. More graphically, in the long run plants do not converge to a common minimum unit cost (as it is assumed in the standard neoclassical microeconomics textbooks) but to their own minimum unit cost. This assumption is consistent with the empirical finding that exit rates in a given cohort of plants increase with cohort's age.

Using this empirical model, we analyze how the catching-up parameter depends on the presence of multinational firms. To do that, we incorporate an interaction between the productivity gap and the share of foreign firms in the industry (MNS_{jt}). This in line with previous studies (Griffith, Redding and Simpson, 2006; Peri and Urban, 2006), arguing that foreign technologies may spill over on the rest of domestic firms[8], and then a larger presence of multinational may facilitate the catching-up process. To analyze whether multinational also affect productivity growth directly, we also include it as a control variable in our regressions. In such a case, the model is:

$$\Delta \ln A_{it} = \alpha_i + \beta \Delta \ln A_{it}^F + \delta_0 \ln\left(\frac{A_j^F}{A_i}\right)_{t-1} + \delta_1 \ln\left(\frac{A_j^F}{A_i}\right)_{t-1} * MNS_{jt} + \delta_2 * MNS_{jt} + u_{it} \quad (10)$$

The direct effect of multinationals on productivity is captured by the parameter δ_2, and its effect on catch-up is given by the parameter δ_1. In estimating equation (10) we also control for other plants-specific characteristics such as age, a dummy variable for plants importing inputs, a dummy for plants purchasing foreign technical licenses, and a dummy for plants investing in new machinery. Region-specific differences in productivity growth are also controlled for location dummy variables. In all the cases we estimate the model only for non-frontier domestic plants.

Differences in the importance of multinationals (MNS_{jt}) at the industry-level are captured typically for their participation in employment[9]. There are other authors that use the share of multinationals in industry sales (Javorcik, 2004). In this paper, to check the robustness of our results to alternative definitions, we use not only their importance in employment ($MNSE_{jt}$) but also in total output ($MNSQ_{jt}$), and in the number of plants ($MNSP_{jt}$).

Our results are presented in Table 6 for technological frontier defined with a productivity threshold of 95%. First, note that there is positive relationship between frontier and plant productivity growth. We find that overall plant´s TFP growth tends to be larger in industries where technological frontier expands more quickly. Second, these results reveal strong evidence of productivity catch-up. The parameter for the productivity gap – approximately 0.7 - is always positive

[8] See Görg and Strobl (2001) for a review of the empirical evidence on multinationals and productivity spillovers.
[9] See, for example, Takii (2005).

and significant, indicating that plants far away from the technology frontier experience higher productivity growth than plants closer to the frontier. More interestingly the interaction between productivity gap and the importance of multinationals in the industry is also positive. Then, we find evidence that, either by technology spillovers effects or increased competition, the presence of multinationals accelerates the productivity catch-up. However, our findings show that this interaction is not significant when the multinationals participation is measured as the proportion of the number of plants. This finding could be consistent with the idea that the increasing number of foreign plants does not accelerate the productivity catch-up unless that this is accompanied by an increase in multinationals participation in employment or output[10].

[Insert Table 6 about here]

As a further robustness check, we also estimate the model for the case where frontier plants are defined as those in the top decile of each industry productivity distribution (Table 7). The results are similar to those shown in Table 6 in terms of magnitude and significance of the parameters. In general, the evidence shows that plant TFP growth is increasing in the productivity gap, and that the catching-up speed is increasing in the presence of multinationals in the industry. Again, the interaction between productivity gap and the importance of multinationals in the number of plants is not significant.

[Insert Table 7 about here]

5. Conclusions

The paper addresses two key issues: First, we analyze whether there is evidence that low productivity plants experience larger TFP growth than those closer to the technology frontier. Second, we investigate the role of multinational plants in accelerating the catching-up process by non-frontier domestic plants. Our results show evidence of catching-up by low productivity

[10] The employment-driven productivity catch-up may be rationalized in terms of technology spillovers originated by worker mobility from multinationals to domestic firms. A theoretical model is developed by Fosfuri, et. al. (2001). For empirical evidence on this regard, see Görg and Strobl (2005).

performers, and that a larger presence of multinationals positively contributes to this phenomenon. This would be consistent with the idea that technology spillovers from high to low productivity plants or that a higher presence of multinationals induce more competition pressures and productivity in domestic markets. In the process, we also uncover some characteristics of those plants located at the technological frontier. In general, they tend to be larger, more innovative, more human capital intensive, and owned by foreign firms.

From the industrial policy point of view, our findings suggest that MNEs subsidiaries in the domestic economy are a significant vehicle for technology transfer and upgrade. This empirical evidence may be supportive of policy instruments such as tax subsidies and grants to incentive the location of multinationals in the host markets. However, a properly defined policy should also look at the absorptive capacity requirements by domestic firms needed to profit from this channel of technology transfer and also to the sort of technological efforts and behaviors by MNEs subsidiaries in the domestic markets. Do all subsidiaries behave in the same way in the host markets? If not, can this heterogeneity be exploited in order to maximize technology transfer impacts and catching up?[11] With the typical manufacturing census data at hand we cannot answer these research questions here, however some steps forward could be taken by linking our dataset with the several Chilean innovation surveys. This challenge is definitively part of our future research agenda.

[11] Some steps in these direction are taken by Bell and Marin (2006) in the context of Argentinean manufacturing

Table 1: **Number of Manufacturing Plants by Sector (2-Digit Level) and Year**

ISIC	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
31	1805	1678	1566	1520	1491	1516	1502	1438	1476	1478	1471	1486	1503	1540	1520	1502	1483	1600	1563	1492
	32	33	34	35	37	36	37	36	34	35	34	34	33	33	32	31	30	31	31	33
32	1167	1036	920	808	741	777	752	758	845	819	813	834	876	905	853	868	841	906	820	697
	21	20	20	19	18	19	18	19	20	19	19	19	19	19	18	18	17	17	16	15
33	706	616	553	476	429	433	433	396	410	395	415	418	417	432	510	506	504	550	525	470
	13	12	12	11	11	10	11	10	9	9	10	10	9	9	11	10	10	11	11	10
34	295	280	251	236	214	210	205	203	240	235	234	237	250	260	274	278	272	284	275	256
	5	6	5	6	5	5	5	5	6	6	5	5	6	6	6	6	6	5	6	6
35	427	410	382	359	346	384	378	378	417	414	428	437	473	500	538	551	577	573	548	514
	8	8	8	8	9	9	9	9	10	10	10	10	10	11	11	11	12	11	11	11
36	165	166	153	135	122	126	132	126	133	125	129	140	157	167	170	186	187	198	191	169
	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
37	91	75	66	60	55	55	55	55	72	87	70	68	67	65	69	67	75	83	75	72
	2	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2
38	831	760	708	637	575	615	609	599	681	651	691	682	727	767	811	824	898	945	925	846
	15	15	15	15	14	15	15	15	16	15	16	16	16	16	17	17	18	18	19	19
39	73	61	58	51	41	45	47	45	53	46	49	50	50	51	54	59	64	96	64	56
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
Total	5560	5082	4657	4282	4014	4161	4113	3998	4327	4250	4300	4352	4520	4687	4799	4841	4901	5235	4986	4572
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: alternate rows show the column %. Source: Instituto Nacional de Estadísticas.

Table 2: **1979-1998 Transition Probability Matrix**

Quintile 1998/ Quintile 1979	1	2	3	4	5	Death	Total
1	23.1	8.9	4.1	2.5	1.4	60.1	100.0
2	6.8	13.2	9.9	4.7	1.2	64.2	100.0
3	2.3	6.7	12.4	10.2	0.9	67.5	100.0
4	1.9	3.9	5.2	7.9	5.5	75.6	100.0
5	0.7	0.7	0.5	1.8	16.6	79.7	100.0
Entry	18.4	18.9	19.5	21.3	21.9	0.0	100.0

Table 3: **Mean Characteristics of Frontier and No Frontier Plants,**

95% Threshold

Sector	Frontier	No Frontier	Frontier	No Frontier	Frontier	No Frontier
	Foreign Ownership		Age		Skilled Labor	
31	10.7	2.7	8.1	7.8	2.0	0.9
32	4.6	1.9	7.4	7.3	1.6	0.8
33	2.6	2.1	6.0	6.6	0.7	0.7
34	10.4	3.2	9.0	7.6	2.3	1.5
35	27.5	14.1	7.8	7.6	13.3	2.2
36	15.9	4.9	7.2	7.6	1.7	0.9
37	3.4	11.4	8.2	7.8	1.7	2.1
38	9.7	3.5	8.6	7.6	2.1	1.3
39	1.5	4.7	7.8	7.9	2.2	0.9
Total	10.2	4.0	7.8	7.5	2.9	1.1
	Size		Technical Licenses		Imported Inputs	
31	199.1	55.2	13.1	3.0	49.1	11.3
32	126.7	62.8	8.6	3.4	48.7	28.0
33	69.1	58.2	4.2	2.1	13.7	8.4
34	229.4	70.6	9.3	4.0	47.4	19.8
35	78.0	76.5	23.6	13.1	64.8	54.4
36	102.9	75.0	21.6	7.9	42.6	22.8
37	747.2	206.7	7.9	10.5	49.4	44.1
38	137.5	61.7	10.4	4.0	50.3	27.2
39	25.0	32.6	7.6	3.6	28.8	27.6
Total	155.8	63.6	11.9	4.5	46.6	22.4

Table 4: **Mean Characteristics of Frontier and No Frontier Plants, Thre90**

Sector	Frontier	No Frontier	Frontier	No Frontier	Frontier	No Frontier
	Foreign Ownership		Age		Skilled Labor	
31	9.5	2.4	8.1	7.8	1.7	0.8
32	4.7	1.8	7.6	7.2	1.6	0.8
33	3.2	2.0	6.1	6.7	0.8	0.7
34	8.9	3.0	8.7	7.5	2.0	1.5
35	24.5	13.7	8.1	7.6	11.0	1.9
36	14.1	4.5	7.5	7.6	1.5	0.8
37	3.8	11.8	8.4	7.7	1.4	2.2
38	9.0	3.3	8.6	7.5	2.1	1.3
39	3.3	4.6	8.2	7.9	1.6	0.9
Total	9.3	3.8	7.9	7.5	2.6	1.0
	Size		Technical Licenses		Imported Inputs	
31	186.8	48.6	11.2	2.7	49.5	9.1
32	131.5	58.7	8.4	3.2	50.4	26.7
33	66.5	57.9	3.7	2.1	13.6	8.1
34	187.0	66.6	7.3	3.9	46.5	18.4
35	94.1	74.5	25.2	12.3	65.4	53.7
36	125.5	70.6	22.2	7.0	39.9	21.9
37	801.7	169.2	15.2	9.7	57.6	42.7
38	120.6	59.4	8.8	3.8	49.5	26.0
39	24.8	33.1	6.6	3.5	27.3	27.7
Total	150.1	59.1	11.1	4.2	46.9	21.1

Table 5: **Probit Model for Probability of being classified at Frontier**

	Thre95							Thre90						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	0.079						0.024	0.132						0.036
	(18.42)**						(7.11)**	(23.09)**						(7.50)**
Age		0.001					-0.001		0.002					-0.001
		(4.80)**					(3.15)**		(9.21)**					(2.18)*
Skill			0.000				0.000			0.002				0.001
			(1.69)				(1.76)			(5.71)**				(5.18)**
Size				0.027			0.020				0.056			0.041
				(43.78)**			(28.76)**				(63.12)**			(41.57)**
Tech					0.084		0.018					0.146		0.032
					(20.82)**		(6.00)**					(27.17)**		(7.46)**
Imp						0.076	0.033						0.152	0.074
						(35.72)**	(16.56)**						(52.56)**	(26.02)**
Observations	91566	91566	89512	91566	91566	91566	89512	91566	91566	89512	91566	91566	91566	89512

Foreign is a dummy variable for foreign firms, Age is plant age, skill is white-collar wages over blue-collar wages, Size is employment measured in logs, Imp is a dummy for importers of inputs, and Tech is a dummy for firms purchasing foreign technical licenses. Coefficients correspond to marginal effects. Robust z statistics in parentheses. * significant at 5%; ** significant at 1%.

Table 6: **Productivity Catch-Up Model, Thre 95**

	(1)	(2)	(3)
Frontier TFP growth	0.834	0.825	0.835
	[24.90]***	[24.96]***	[22.76]***
Gap	0.696	0.706	0.708
	[34.15]***	[39.04]***	[34.69]***
MNS employment (MNSE)	0.151		
	[1.05]		
MNSE*Gap	0.177		
	[1.96]*		
MNS output (MNSQ)		0.255	
		[2.89]***	
MNSQ*Gap		0.010	
		[0.15]	
MNS plants (MNSP)			0.464
			[1.33]
MNSP*Gap			-0.057
			[0.23]
Age	-0.008	-0.009	-0.008
	[7.42]***	[7.75]***	[7.09]***
Imports of raw materials	0.025	0.026	0.026
	[5.80]***	[6.09]***	[6.09]***
Technical Assistance	0.018	0.019	0.019
	[1.92]*	[2.00]*	[1.96]*
Investment New Machinery	0.025	0.025	0.026
	[7.14]***	[7.18]***	[7.64]***
Constant	-1.205	-0.779	-0.784
	[17.30]***	[10.13]***	[10.98]***
Observations	73418	72547	72547
R-squared	0.67	0.66	0.66

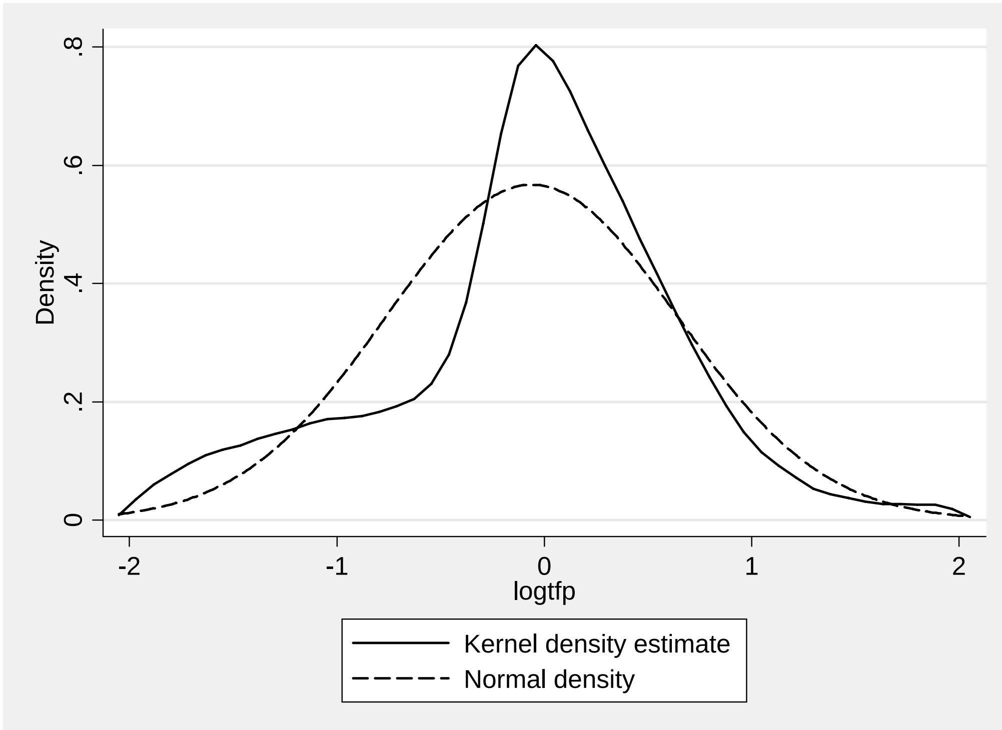
Robust t statistics in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: **Productivity Catch-Up Model, Thre 90**

	(1)	(2)	(3)
Frontier TFP growth	0.895	0.887	0.894
	[52.58]***	[51.23]***	[46.91]***
Gap	0.711	0.716	0.710
	[42.22]***	[47.72]***	[43.47]***
MNS employment (MNSE)	0.088		
	[0.89]		
MNSE*Gap	0.181		
	[2.78]***		
MNS output (MNSQ)		0.131	
		[2.30]**	
MNSQ*Gap		0.021	
		[0.48]	
MNS plants (MNSP)			0.264
			[1.27]
MNSP*Gap			0.129
			[0.87]
Plant's age	-0.007	-0.007	-0.007
	[7.81]***	[8.89]***	[8.67]***
Imports of raw materials	0.025	0.026	0.026
	[6.58]***	[6.99]***	[6.97]***
Technical Assistance	0.016	0.016	0.016
	[1.97]*	[1.82]*	[1.78]*
Investment New Machinery	0.027	0.026	0.026
	[8.25]***	[8.09]***	[8.18]***
Constant	-0.793	-0.830	-0.835
	[18.79]***	[9.71]***	[10.10]***
Observations	72077	70562	70562
R-squared	0.70	0.68	0.68

Robust t statistics in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1: Productivity Distribution, all years



Appendix

Table A1: Production Function Estimates

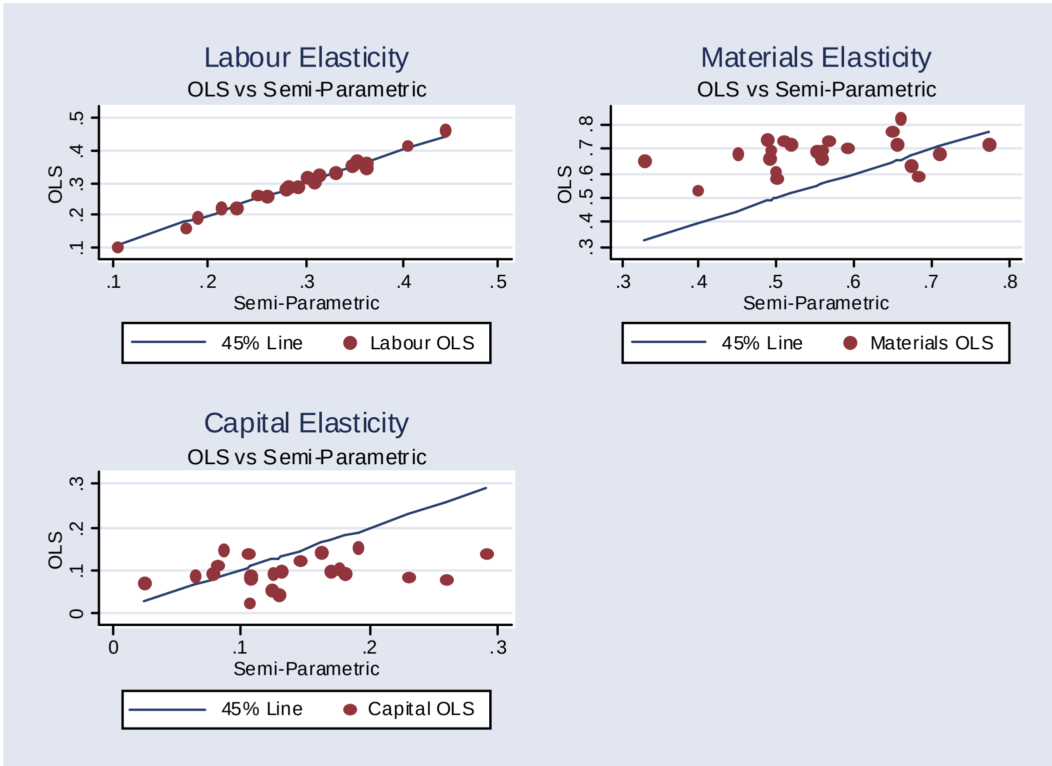
Sector (ISIC 2 rev)	Ll	Lm	lk	obs	CRS	F	P-Value
Food (311)	0.188	0.659	0.025	24161	0.87	62.23	0.00
	[50.83]***	[53.42]***	[2.98]***				
Food Misc (312)	0.212	0.774	0.081	1277	1.07	1.68	0.19
	[11.33]***	[7.36]***	[1.10]				
Beverages (313)	0.362	0.518	0.175	1999	1.06	0.89	0.34
	[17.40]***	[9.64]***	[3.20]***				
Textiles (321)	0.292	0.558	0.108	6153	0.96	2.44	0.12
	[24.33]***	[15.52]***	[3.18]***				
Apparel (322)	0.353	0.489	0.128	5575	0.97	1.01	0.32
	[35.35]***	[8.08]***	[3.30]***				
Leather (323)	0.249	0.655	0.107	947	1.01	0.02	0.88
	[10.02]***	[9.19]***	[1.58]				
Footwear (324)	0.313	0.551	0.125	2498	0.99	0.04	0.84
	[20.84]***	[8.79]***	[2.18]**				
Wood Prod (331)	0.278	0.709	0.077	6208	1.06	3.71	0.05
	[33.41]***	[10.79]***	[1.62]				
Furniture (332)	0.310	0.485	0.259	2303	1.05	0.68	0.41
	[16.68]***	[3.47]***	[2.51]**				
Pulp & Paper (341)	0.228	0.591	0.291	1042	1.11	0.44	0.50
	[9.19]***	[4.07]***	[2.88]***				
Printing (342)	0.405	0.396	0.190	3359	0.99	0.02	0.90
	[22.20]***	[5.61]***	[1.78]*				
Basic Chemicals (351-53-54)	0.105	0.648	0.146	1347	0.90	0.73	0.39
	[5.77]***	[4.76]***	[2.08]**				
Fine Chemicals (352)	0.362	0.498	0.163	2832	1.02	0.10	0.76
	[18.69]***	[5.63]***	[2.15]**				
Rubber (355)	0.302	0.682	0.086	962	1.07	0.69	0.40
	[10.93]***	[4.57]***	[0.97]				
Plastics (356)	0.283	0.557	0.131	2988	0.97	0.32	0.57
	[22.42]***	[5.50]***	[2.29]**				
Non-Metallic Minerals (36)	0.283	0.565	0.180	2736	1.03	0.44	0.51
	[20.37]***	[11.28]***	[4.20]***				
Basic Metals (37)	0.175	0.509	0.106	1229	0.79	2.51	0.11
	[7.28]***	[3.04]***	[1.26]				

Table A1: Production Function Estimates, continuation

Fabricated Metals (381)	0.331	0.448	0.229	6905	1.01	0.13	0.72
	[36.12]***	[7.64]***	[4.35]***				
Machinery and Equipment (382)	0.260	0.328	0.169	2955	0.76	5.90	0.02
	[13.60]***	[3.02]***	[3.10]***				
Electrical Machinery (383)	0.350	0.492	0.124	1100	0.97	0.22	0.64
	[13.84]***	[5.69]***	[1.60]				
Transport Equipment (384)	0.349	0.674	0.064	1861	1.09	4.33	0.04
	[19.48]***	[8.65]***	[1.01]				
Instruments & Tools (385)	0.444	0.500	0.106	1296	1.05	0.50	0.48
	[18.03]***	[5.49]***	[1.69]*				

Robust t statistics in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%

Figure A1: OLS vs. LP Estimated Input Elasticities



REFERENCES

Alvarez, R. and R. A. Lopez. (2005). "Exporting and Performance: Evidence from Chilean Plants". *Canadian Journal of Economics*, 38(4): 1384-1400,

Baily, M. N., Hulten, Ch.m and D. Campbell. "Productivity Dynamics in Manufacturing Establishments," *Brookings Papers on Economic Activity: Microeconomics*, 187-249.

Bernard, A. B., Eaton, J., Jensen, J. B., and S. S. Kortum (2003). "Plants and Productivity in International Trade," *American Economic Review* 93(4): 1268-1290.

Bell, M and A. Marin (2006): "Technology Spillovers from Foreign Direct Investment (DFI): The Active Role of MNC Subsidiaries in Argentina in the 1990s", *Journal of Development Studies,* Vol 42, N0 4, 678-697.

Disney, R., Haskel, J. and Y. Heden. (2003). "Restructuring and Productivity Growth in UK manufacturing", *Economic Journal*, 113 (489): 666-694.

Fosfuri, A., Motta, M. and T. Rønde. (2001). "Foreign Direct Investment and Spillovers through Workers' Mobility", *Journal of International Economics*, 53(1): 205-222.

Griffith, R., Redding, S. and H. Simpson. (2006). "Technological Catch-up and the Role of Multinationals," mimeo.

Griliches, Z (1998). R&D and Productivity: The Econometric Evidence. The University of Chicago Press and NBER, Chicago, USA.

Görg, H. and E. Strobl (2001), "Multinational Companies and Productivity Spillovers: A Meta-Analysis", *Economic Journal*, 111(475): 723-739.

________________________ , "Spillovers from Foreign Firms through Worker Mobility: an Empirical Investigation", *Scandinavian Journal of Economics*, 107(4): 693-709.

Javorcik, B.S. (2004). "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages", *American Economic Review,* 94(3): 605-627.

Levinsohn, J., and A. Petrin (2003). "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70(2): 317-341.

Olley, G. S., and A. Pakes (1996). "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6): 1263-1297.

Peri, G. and D. Urban. 2006. "Catching-up to Foreign Technology? Evidence on the Veblen-Gerschenkron Effect of Foreign Investments", *Regional Science and Urban Economics*, 36 (1): 72-98.

Takii, S. (2005). "Productivity Spillovers and Characteristics of Foreign Multinational Plants in Indonesian Manufacturing 1990–1995", *Journal of Development Economics*, 76(2): 521-542.

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