

## Foreign Technology Acquisition and Changes in the Real Exchange Rate

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### 1. INTRODUCTION

TECHNOLOGICAL change is the main source of productivity growth in the long run for both developed and developing countries. A central element of technological change is innovation, which allows countries to improve their technologies as well as the quality and the range of products they produce. The sources of innovation among nations, however, differ according to the countries' level of development. While developed countries innovate mostly through investments in R&D, developing countries acquire new technologies and new product designs by copying or purchasing them from industrial countries. This is because it is relatively easier to adopt and adapt a foreign technology than to create an entirely new technology.<sup>1</sup> One way to obtain new and more advanced technologies is through foreign technology licensing agreements, in which the owner of a technology, the licensor, authorises the use of its technology to the buyer, the licensee, in exchange for licence fees or royalty payments.

The purpose of this paper is to study the effects of a significant depreciation of the real exchange rate (RER) that occurred in Chile between 1998 and 2002 on the probability of foreign technology licensing among Chilean manufacturing plants. In theory, a real depreciation has an ambiguous effect on the decision to purchase foreign technologies. A real depreciation makes exporting firms more competitive and therefore more likely to use foreign technologies. Several studies argue that increases in export competitiveness may induce some firms to adopt foreign technologies because they may need to improve the quality of the products they produce for export markets (López, 2009; Lileeva and Trefler, 2010; Bustos, 2011). Increases in export competitiveness may also induce non-exporting firms to upgrade their technologies if, for example, they provide intermediate inputs or services to exporting firms. Becoming a licensee, however, requires finding and contacting the owner of a technology, or a product, willing to license its knowledge in exchange for licence fees or royalty payments. This implies that technology licensing is costly and that relatively larger and more productive firms may be more likely to use foreign technology licences. A real depreciation, however, could also make imports of technology, and related components, such as machinery and equipment, relatively more expensive which may decrease the propensity to import technologies. As the theory, *a priori*, is not clear about the effect of changes in the RER on foreign technology acquisition, this question must be investigated empirically.

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<sup>1</sup> According to Westphal (1982), importing a technology does not require complete mastery of it, as it would be the case of creating a new technology.

This issue is important for several reasons. First of all, licensing is more relevant than ever as a source of technologies. According to the World Bank's *World Development Indicators*, payments in royalties and licence fees worldwide increased from about \$40 million in 1960 to about \$200 billion in 2010/2011. Part of this increase may be explained by the increasing protection of intellectual property rights around the world, which likely discourages copying in favour of licensing.<sup>2</sup> Second, as the globalisation process has deepened, countries are more interconnected than ever with each other, which makes movements in exchange rates potentially important for decisions such as investment and technology adoption. Third, if firms are more likely to import technologies during periods of real depreciation than in appreciation times, then governments should consider the effect of RER fluctuations on technology adoption when designing policies that promote technology transfer.

This paper is related to at least two strands of literature. The first corresponds to the literature that examines the determinants of foreign technology adoption and its impact on firms' performance using microdata at the level of the firm or plant. Studies such as Giannitsis (1991), Montalvo and Yafeh (1994), Kokko and Blomström (1995), Katrak (1997), Vishwasrao and Bosshardt (2001) and Kiyota and Okazaki (2005) provide evidence on the characteristics of licensees and the role of these characteristics in foreign technology adoption. While these studies significantly contribute to understanding foreign technology adoption, they do not examine how changes in RERs may affect the decision to adopt a foreign technology. The second strand of literature examines the effect of RER fluctuations on firm-level outcomes such as export propensity and export intensity (Bernard and Jensen, 2004; Greenaway et al., 2010a, 2010b, 2012; Fitzgerald and Haller, 2012), investment (Kandilov and Leblebicioğlu, 2011) and skill upgrading (Alvarez and López, 2009). The effect of RER changes on foreign technology adoption, however, has not been examined. Thus, our paper complements and extends the existing literature by linking these two strands of literature.

The empirical analysis uses a panel of manufacturing plants and takes advantage of dramatic changes in the aggregate RER in Chile during 1992 and 2002, which can be considered an exogenous shock from the point of view of an individual plant. We use these changes as a quasi-experiment to examine whether the significant real depreciation of the currency affected the decision to import foreign technologies through licences and whether the effect differed across plants and industries with different characteristics. The empirical analysis shows that an increase in the rate of change of the RER increases the probability of acquiring foreign technologies through licensing agreements on plants that export. We also find that RER depreciations increase the probability of using foreign technology licences in more productive and larger plants, but that the effect is not linear: as productivity and size increase, a real depreciation induces technology adoption, but the effect is smaller for the most productive and largest plants. These results are consistent with recent evidence by Bustos (2011) for Argentinean firms, who shows positive effects of decreases in foreign tariffs on technology upgrading and that the effects are higher in the intermediate range of firm-size (productivity) distribution.<sup>3</sup>

The paper is organised as follows. Section 2 describes the data set used in the analysis and documents licensing activity in Chile. Section 3 describes and explains the methodology,

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<sup>2</sup> As intellectual property rights become stronger, it is possible that licensing becomes relatively more attractive than exports and FDI as a channel for technology transfer (Smith, 2001; Hoekman and Javorcik, 2006).

<sup>3</sup> In her empirical analysis for Argentina, Bustos uses a dummy by size quartiles as proxy of productivity and focuses on a reduction in Brazilian tariffs.

while Section 4 presents and discusses the results. Section 5 presents a set of robustness checks and extensions, and Section 6 concludes.

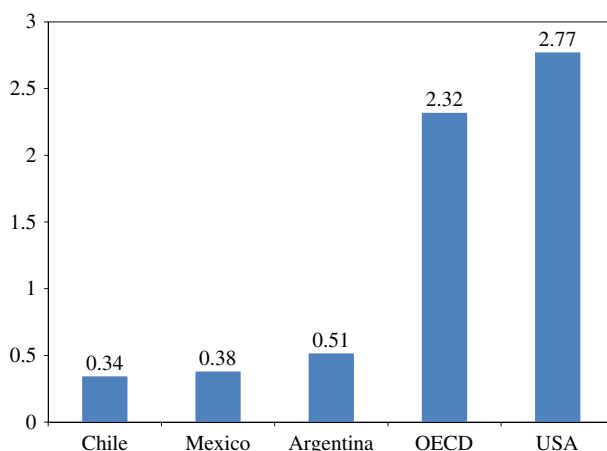
## 2. DATA AND BASIC PATTERNS

Chile spends an insignificant fraction of its GDP on R&D activities. As we can see in Figure 1 for the period 2007–08, the expenditure on R&D in Chile was only 0.34 per cent of the GDP, a number that is considerably lower than that of the OECD countries (2.32 per cent) and the USA (2.77 per cent). Chile spends in R&D even less than other Latin American countries of similar level of development, such as Mexico (0.38 per cent) and Argentina (0.51 per cent).

These numbers suggest that invention and innovation activities are not significant in the case of Chile and that the country has to rely on foreign licences to obtain technologies and new product designs. This is confirmed in Table 1 which shows the payments on royalties and licence fees as a percentage of the GDP for Chile, the Latin American region and the OECD. As we can see from the table, the amount spent on royalties and licence fees in Chile increased from 0.10 per cent of the GDP in 1975–80 to 0.30 per cent in the period 2001–10, a number that is in line with the average for the OECD countries. The table shows that the payments in licences also increased in the Latin American region as well as in the OECD. Although the magnitude of the increase in licence payments in Chile is larger than the increase in Latin America, it is lower than the increase observed in the OECD.

The empirical analysis uses plant-level data from the manufacturing sector of Chile for the period 1992–2002. The data come from the National Annual Industrial Survey (carried out by the National Institute of Statistics of Chile), which covers all manufacturing plants with 10 or more workers. The survey contains information on plants' output, value added, sales, employment, export status, spending on foreign technology licences and industry affiliation. All monetary variables are expressed in constant prices of year 1996 using three-digit-level price deflators.

FIGURE 1  
Expenditure on R&D (Percentage of the GDP, Average 2007–08)



Source: OECD.

TABLE 1  
Royalties and Licence Fees Payments (Percentage of GDP)

	<i>Chile</i>	<i>Latin America</i>	<i>OECD</i>
1975–80	0.10	0.06	0.08
1981–90	0.14	0.09	0.09
1991–2000	0.19	0.11	0.20
2001–10	0.30	0.14	0.33
1975–2010	0.19	0.11	0.19

Source: World Development Indicators.

TABLE 2  
Number of Plants and Licensees

	<i>No. of Plants</i>	<i>% of Licensees</i>	<i>% of Exporters Among</i>		<i>Employment (No. of Workers)</i>	
			<i>Non-licensees</i>	<i>Licensees</i>	<i>Non-licensees</i>	<i>Licensees</i>
1993	4,182	5.9	19.2	56.7	74	273
1994	4,244	5.3	20.8	56.8	78	248
1995	4,241	5.7	21.0	57.4	75	266
1996	4,207	6.1	21.1	59.9	75	254
1997	4,291	5.3	20.5	66.8	74	264
1998	3,931	5.9	20.5	60.0	73	259
1999	3,565	5.5	18.8	59.9	73	258
2000	3,428	5.9	17.5	53.7	68	211
2001	3,376	5.3	19.0	52.2	67	232
2002	3,508	4.8	19.4	56.5	70	226
Average	3,897	5.6	19.8	58.0	73	249

The number of plants in the sample is a little less than 4,000 plants on average each year. The percentage of plants purchasing foreign technology licences is about 6 per cent, and it has not changed significantly over time. There are important differences between plants that invest in licences and those that do not. While 20 per cent of those plants that do not purchase licences are exporters, more than 50 per cent of plants that invest in foreign technologies are exporters. In term of size, plants that purchase licences are larger. They employ, on average, 249 workers, while plants that do not invest in foreign technologies hire about 73 workers (Table 2).

### 3. METHODOLOGY

The empirical analysis exploits the large swings in the RER between 1992 and 2002. Figure 2 shows the evolution of the monthly RER between 1992 and 2003. As we define the RER as the ratio of the international price to the domestic price of a basket of goods, expressed in the same currency, an increase in the RER represents a real depreciation of the Chilean currency.<sup>4</sup> As we

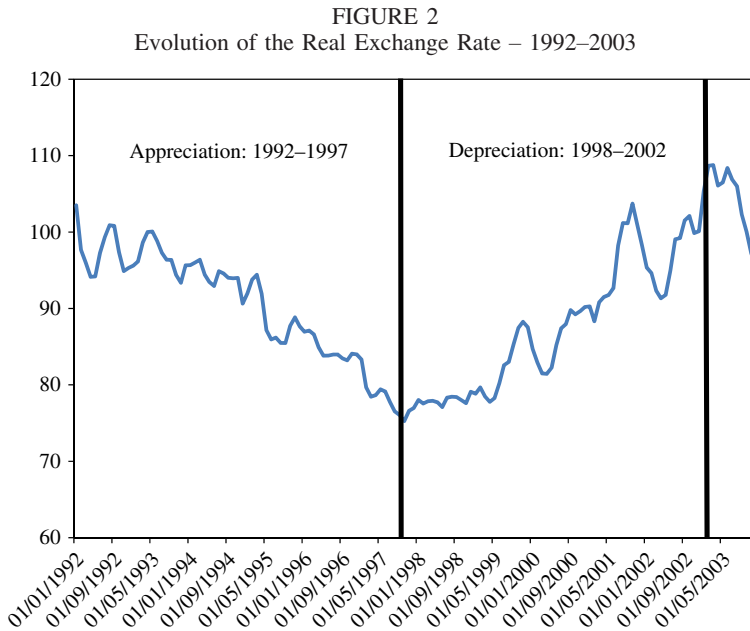
<sup>4</sup> The index of international prices used in the calculation of the RER is constructed as a geometric average of the producer price index (in some cases, the consumer price index is used), expressed in US dollars, of the main trade partners of Chile, where the weights are the share of each trade partner in Chile's total amount of international trade. These weights are calculated and updated every year.

can see in the graph, there are two well-defined periods of significant changes in the RER. The first period, 1992–97, was characterised by a continuous RER appreciation of the Chilean currency. Between January of 1992 and December of 1997, the RER decreased (appreciated) by almost 26 per cent. The second period, 1998–2002, showed a significant real depreciation. Starting on January of 1998, the RER began a slow but continuous increase. Compared to the level of January 1998, the RER had increased (depreciated) by more than 28 per cent by the end of 2002.

As the dramatic changes in the aggregate RER are exogenous from the point of view of an individual Chilean plant, we can use these series of changes as a quasi-experiment and examine whether the significant real depreciation affected the decision to import foreign technologies through licences. The main econometric issue that needs to be addressed is the potential influence of unobserved heterogeneity. Some firms may have managers more willing or more capable to import foreign technologies and may therefore be more likely to use foreign technology licences. In a similar way, due to the nature of the products produced, some sectors may be more likely to use licences to import their technologies. These issues are not easy to address with traditional probability models such as probit or logit. Thus, we use a linear probability model with plant fixed effects, as follows:

$$\Pr(L_{ijt} = 1) = \alpha + \gamma L_{ijt-1} + \beta Z_{ijt-1} + \lambda \Delta \log(RER_{t-\tau}) * Z_{ijt-1} + \mu_i + \delta_t + \epsilon_{ijt}, \quad (1)$$

where  $L_{ijt}$  is an indicator variable equal to 1 if plant  $i$  operating in sector  $j$  is a licensee, that is, it reported payments in foreign technology licences, and foreign technical assistance at time  $t$ ,  $\Delta \log(RER_{t-\tau})$ , is the change in the log of the RER between years  $t$  and  $t - \tau$ . The empirical analysis considers five and three-year changes in the RER ( $\tau = 5$  and  $\tau = 3$ ). The reason for using changes over a relatively long period of time instead of short-run changes (e.g. one-year changes) is that investing in a foreign technology is likely to involve sunk



Source: Central Bank of Chile.

costs, which suggests that firms may not have an incentive to invest when they perceive that the changes in the RER are temporary or short-lived.

The vector  $Z_{ijt} - 1$  is a set of plant characteristics including productivity (value added per worker) and its squared term, export status, and size (number of employees) and size squared.<sup>5</sup> These variables are included because previous studies have documented a positive correlation between foreign technology licensing and variables such as size (Mytelka, 1978; Giannitsis, 1991; Montalvo and Yafeh, 1994; Vishwasrao and Bosshardt, 2001), productivity and capital accumulation (Alvarez et al., 2002; Kiyota and Okazaki, 2005; Yasar and Paul, 2007) and export orientation (Alvarez and López, 2005). Finally,  $\mu_i$  is a set of plant fixed effects that attempt to control for unobserved characteristics at the plant level, and  $\delta_t$  corresponds to a vector of year fixed effects.

Note the estimation of equation (1) requires information only on whether the plant reports any spending on foreign technology licences rather than information on the actual amount of royalties and licence fees paid. Although our data set contains information on royalties and licence fees, we opted for not using this variable as it may not reflect the true value of the technology being transferred. As explained by Pack (2006), royalties and licence fees are more likely to reflect the outcome of a bargaining process between the licensee and the licensor. Moreover, even if licence expenditures are well recorded, they may underestimate the impact of technology transfer, because not all contacts with foreign suppliers are necessarily reflected in the licence fees (Pack, 2006).

The parameter of interest is  $\lambda$ , the estimate for the interaction term between the set of plant characteristics and the change in the RER. The sign and magnitude of the estimated parameter will allow us to find out whether larger, more productive plants and those that export are more, or less, likely to purchase foreign technologies during times of RER depreciation.

We also estimate an extension of (1) that includes interaction terms between the change in the RER and two industry-level characteristics: the degree of external financial needs and an index of revealed comparative advantage. By including a measure of external financial needs, we aim to investigate whether changes in the RER are more or less likely to affect foreign technology acquisition in sectors that are more financially constrained. It is possible that plants operating in sectors more dependent on external finance are more likely to purchase foreign technologies in response to a large depreciation. In this case, the depreciation may reduce the burden of being financially constrained. But a real depreciation may increase the probability of purchasing foreign technologies if the sector is less dependent on external finance, suggesting that a real depreciation may complement the low financial needs of the sector. The measure of comparative advantage tries to capture whether real depreciations affect technology adoption relatively more on firms that operate in comparative advantage sectors. It can be argued that a real depreciation is likely to increase technology licensing in plants operating in sectors in which the country has a comparative advantage, but given that Chile is a relatively natural resource-abundant country, it is expected that comparative advantage sectors are those producing natural resource-intensive products, which may not be intensive in the use of foreign technologies. If this is the case, then the effect may be negative.

<sup>5</sup> The inclusion of square terms for productivity and size attempts to investigate whether the effect of changes in RER on licence acquisition is non-linear on those two variables. As explained earlier, this possibility has been shown theoretically and empirically by Bustos (2011), who finds that a decrease in foreign tariffs induces technology adoption for firms in the middle range of the productivity distribution for the case of Argentina.

These two variables are included as follows:

$$\Pr(L_{ijt} = 1) = \alpha + \beta Z_{ijt-1} + \lambda \Delta \log(RER_{t-\tau}) \times Z_{ijt-1} + \theta_1 \Delta \log(RER_{t-\tau}) \times EFD_j + \theta_2 \Delta \log(RER_{t-\tau}) \times CA_j + \mu_i + \delta_t + \epsilon_{ijt}, \tag{2}$$

where  $EFD_j$  is a variable measuring industry-specific differences in financial needs (external financial dependence), while  $CA_j$  measures differences in comparative advantage among sectors. The variable measuring industry-specific differences in financial needs is taken from Rajan and Zingales (1998), and it is defined as the fraction of capital expenditures not financed with cash flow operations. It is calculated for the median US firm at the three-digit ISIC sector level. Rajan and Zingales (1998) argue that this variable is a useful measure at the industry level for other countries as well, by assuming that this indicator reflects technological factors that may explain why some industries rely more on external finance than others. They argue that these technological differences persist across countries. The variable of comparative advantage corresponds to the average of the Balassa index of revealed comparative advantage ( $RCA$ ) for the period 1992–97. The Balassa index is calculated as  $RCA_{jt} = [(X_{jt}^{Chile}/X_t^{Chile})/X_{jt}^{World}/X_t^{World}]$ , where  $X_{jt}^{Chile}$  is the value of Chilean exports of sector  $j$  in year  $t$ ,  $X_t^{Chile}$  is the total value of exports of Chile in year  $t$ ,  $X_{jt}^{World}$  is the value of world exports of sector  $j$  in year  $t$  and  $X_t^{World}$  corresponds to total world exports in year  $t$ .

Table 3 presents summary statistics for all the variables included in the estimation. The sample average of licensees is 6 per cent, while more than 20 per cent of the plants are exporters. There are also significant differences across plants in terms of size and labour productivity. Regarding industry-level variables, financial external dependence ranges from -0.15 (less dependent) to 1.14 (more dependent), while the average value for the Balassa index fluctuates between 0.023 and 18.27.

#### 4. RESULTS

Table 4 presents the main results of estimating equations (1) and (2) using five and three-year changes in the RER. Columns (1) and (2) measure the change in the RER using five-year intervals, while columns (3) and (4) use three-year changes. First of all, we can see that the estimate for having used licences during the previous year is positive and statistically significant across all the specifications, indicating that there exist sunk costs of adopting foreign technologies, which may

TABLE 3  
Summary Statistics

Variable	Observation	Mean	SD	Min	Max
Licences	38,973	0.06	0.23	0.00	1.00
Productivity	38,973	10044.32	28688.62	69.2	2,249,509
Log (productivity)	38,973	8.63	0.92	4.24	14.6
Exporter dummy	38,973	0.22	0.41	0.00	1.00
Employment	38,973	82.95	159.4	2	3,663
Log (employment)	38,973	3.71	1.06	1.39	8.20
Financial dependence	38,973	0.27	0.29	-0.15	1.14
Comparative advantage	38,973	1.51	1.96	0.023	18.27
5-year change in RER	38,973	-0.10	0.14	-0.21	0.24
3-year change in RER	38,973	-0.04	0.13	-0.17	0.23

produce persistence in the use of technology licences. Having purchased licences in the previous year increases the probability of licensing by about 12 per cent. This number, which suggests a relatively low level of persistence, may be biased downward due to the inclusion of plant fixed effects. Alternative specifications, based on OLS and a probit model, give estimates for the lag of the dependent variable of about 40 to 50 per cent.

Looking across columns in Table 4, we see that there are heterogeneous effects of changes in the RER across plants. As seen in the table, the estimates for the interaction term between the five-year change in the RER and the export dummy are positive and statistically significant, regardless of the specification, indicating that a larger change in the RER (a larger real

TABLE 4  
Basic Results with 5 and 3-year Changes in the Real Exchange Rate (RER)

	(1)	(2)	(3)	(4)
	5-year Change RER		3-year Change RER	
Licensee year before	0.121*** (0.006)	0.121*** (0.006)	0.121*** (0.006)	0.121*** (0.006)
Productivity	-0.006 (0.022)	-0.006 (0.022)	-0.029 (0.021)	-0.029 (0.021)
(Productivity) <sup>2</sup>	0.001 (0.001)	0.001 (0.001)	0.002* (0.001)	0.002* (0.001)
Size	-0.040*** (0.015)	-0.040*** (0.015)	-0.046*** (0.016)	-0.046*** (0.016)
(Size) <sup>2</sup>	0.006*** (0.002)	0.006*** (0.002)	0.007*** (0.002)	0.007*** (0.002)
Export dummy	0.007 (0.005)	0.007 (0.005)	0.004 (0.005)	0.004 (0.005)
DRER × productivity	0.431*** (0.089)	0.432*** (0.090)	0.475*** (0.097)	0.468*** (0.098)
DRER × (productivity) <sup>2</sup>	-0.026*** (0.005)	-0.026*** (0.005)	-0.029*** (0.005)	-0.028*** (0.005)
DRER × size	0.070* (0.042)	0.070* (0.042)	0.103** (0.048)	0.102** (0.048)
DRER × (size) <sup>2</sup>	-0.009* (0.005)	-0.010* (0.005)	-0.013** (0.006)	-0.013** (0.006)
DRER × export dummy	0.058*** (0.021)	0.058*** (0.021)	0.063*** (0.023)	0.063*** (0.023)
DRER × external financial dependence		0.002 (0.027)		0.002 (0.029)
DRER × comparative advantage		0.000 (0.000)		-0.000 (0.000)
Constant	0.353*** (0.100)	0.354*** (0.100)	0.516*** (0.109)	0.510*** (0.110)
Observations	38,973	38,973	38,973	38,973
R-squared (within)	0.018	0.018	0.018	0.018

Notes:

(i) Dependent variable: dummy equal to one if the plant uses foreign technology licences.

(ii) Standard errors in parentheses.

(iii) Productivity: value added per worker; size: number of employees. Productivity and size are in logs. Productivity, size and the export dummy are lagged one year. Plant and year fixed effects were included.

(iv) \*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; \* $p < 0.1$ .



depreciation) increases the probability that plants that export will use foreign licences. We also observe that the effect of an increase in the change in the RER is positive as productivity increases but that the effect starts to decrease after a certain threshold. Similar pattern is observed for the interactions with size, suggesting that a real depreciation has a non-monotonic effect on technology adoption in terms of productivity and size.

Columns (2) and (4) show the results of estimating equation (2), which include interaction terms between the change in the RER and the two industry characteristics: the degree of external financial dependence and the variable measuring comparative advantage. The estimates for both the interaction between the change in the RER and external financial dependence and the interaction between changes in RER and the variable of revealed comparative advantage are not statistically significant.

Overall, our results suggest that real depreciations increase the probability of acquiring foreign technologies through licences for plants that export and for larger and more productive plants, although the effect is not linear.

##### 5. ROBUSTNESS CHECKS AND EXTENSIONS

We have performed a number of robustness checks to verify the validity of our main results. The first exercise attempts to control for the potential spillover effect from plants that use licences and from plants with foreign ownership. It is possible, for example, that some plants start using foreign technology licences when the number of licensees, or the number of foreign-owned plants, increases. This could be due to demonstration effects or information spillover effects. To control for the potential effect of licensing activity and the presence of foreign companies in the sector, we calculate the share of plants using licences and the share of plants with foreign ownership in the total number of plants, the total value added and the total employment in each three-digit ISIC sector and year.

Table 5 presents the results when these additional control variables, lagged one year, are included. Columns (1–3) show the results with the five-year changes in the RER, while columns (4–6) present the results with the three-year changes. Columns (1) and (4) include the share of licensees and foreign-owned plants in the total number of plants, columns (2) and (5) include the share of these plants in value added, while columns (3) and (6) use their share in the employment of the sector. As we can see, an increase in licensing activity of the sector significantly increases the probability that a plant will use foreign technology licences.<sup>6</sup> This is regardless of the way licensing activity is measured. The presence of foreign-owned plants, on the other hand, does not have any significant effect on the probability of licensing. The results seem to suggest the existence of positive horizontal spillover effects from licensing activity, although more work is needed to confirm this.

The estimates for the change in the RER and its interaction with productivity, size and the export dummy remain similar to the ones without the additional controls in Table 4. We continue observing that an increase in the change in the RER increases the probability of using foreign licences for plants that export and in more productive and larger plants, but again the effect of productivity and size is not linear.

Next, we extend the analysis to examine the potential effect of import tariffs. It is possible that the supplier of the foreign technology sells the technology in a package, including both

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<sup>6</sup> This is consistent with the findings of Montalvo and Yafeh (1994) for Japan.

TABLE 5  
Results With Additional Controls

	(1)	(2)	(3)	(4)	(5)	(6)
	5-year Change RER			3-year Change RER		
Licensee year before	0.119*** (0.006)	0.120*** (0.006)	0.120*** (0.006)	0.119*** (0.006)	0.120*** (0.006)	0.120*** (0.006)
Productivity	-0.012 (0.022)	-0.008 (0.022)	-0.009 (0.022)	-0.034 (0.021)	-0.032 (0.021)	-0.032 (0.021)
(Productivity) <sup>2</sup>	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.002** (0.001)	0.002* (0.001)	0.002* (0.001)
Export dummy	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.004 (0.005)	0.004 (0.005)	0.004 (0.005)
Size	-0.041*** (0.015)	-0.041*** (0.015)	-0.042*** (0.015)	-0.046*** (0.016)	-0.046*** (0.016)	-0.047*** (0.016)
(Size) <sup>2</sup>	0.006*** (0.002)	0.006*** (0.002)	0.006*** (0.002)	0.007*** (0.002)	0.007*** (0.002)	0.007*** (0.002)
DRER × productivity	0.412*** (0.090)	0.435*** (0.090)	0.441*** (0.090)	0.448*** (0.098)	0.465*** (0.098)	0.473*** (0.098)
DRER × (productivity) <sup>2</sup>	-0.025*** (0.005)	-0.026*** (0.005)	-0.026*** (0.005)	-0.027*** (0.005)	-0.028*** (0.005)	-0.028*** (0.005)
DRER × export dummy	0.058*** (0.021)	0.055*** (0.021)	0.056*** (0.021)	0.062*** (0.023)	0.061*** (0.023)	0.063*** (0.023)
DRER × size	0.062 (0.042)	0.069 (0.042)	0.067 (0.042)	0.094* (0.048)	0.101** (0.048)	0.100** (0.048)
DRER × (size) <sup>2</sup>	-0.008* (0.005)	-0.009* (0.005)	-0.009* (0.005)	-0.012** (0.006)	-0.013** (0.006)	-0.013** (0.006)
DRER × external financial dependence	0.026 (0.027)	-0.019 (0.027)	-0.017 (0.027)	0.028 (0.029)	-0.019 (0.029)	-0.016 (0.029)
DRER × comparative advantage	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Share licensees	0.594*** (0.048)	0.594*** (0.048)	0.594*** (0.048)	0.594*** (0.048)	0.594*** (0.048)	0.594*** (0.048)
Share foreign	-0.083 (0.061)	-0.083 (0.061)	-0.083 (0.061)	-0.080 (0.061)	-0.080 (0.061)	-0.080 (0.061)
Share licensees in VA	0.076*** (0.010)	0.076*** (0.010)	0.076*** (0.010)	0.076*** (0.010)	0.076*** (0.010)	0.076*** (0.010)

TABLE 5 Continued

	(1)	(2)	(3)	(4)	(5)	(6)
	5-year Change RER			3-year Change RER		
Share foreign in VA		-0.004 (0.015)			-0.000 (0.016)	
Share licensees in L			0.149*** (0.017)			0.149*** (0.017)
Share foreign in L			0.019 (0.028)			0.027 (0.028)
Constant	0.341*** (0.100)	0.346*** (0.100)	0.344*** (0.100)	0.491*** (0.110)	0.501*** (0.110)	0.501*** (0.110)
Observations	38,973	38,973	38,973	38,973	38,973	38,973
R-squared (within)	0.023	0.020	0.020	0.023	0.019	0.020

Notes:

(i) Dependent variable: dummy equal to one if the plant uses foreign technology licences.

(ii) Standard errors in parentheses.

(iii) Productivity: value added per worker; size: number of employees. Productivity and size are in logs. Productivity, size and the export dummy are lagged one year.

(iv) Share licensees, share licensees in VA and share licensees in L correspond to the share of plants that use licensees in the total number of plants, total value added and total employment in each three-digit sector. Share foreign, share foreign in VA and share foreign in L correspond to the share of plants with foreign ownership in the total number of plants, total value added and total employment in each three-digit sector. Plant and year fixed effects were included.

(v) \*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; \* $p < 0.1$ .

technological components and nontechnological components such as intermediate inputs.<sup>7</sup> If this is the case, a higher level of domestic import tariffs should have a negative effect on the probability of using foreign licences. In addition, changes in the RER may not have a significant effect if tariffs are relatively high. Thus, we introduce the tariff rate charged by Chile to imported goods in each three-digit sector and also its interaction with the change in the RER. We use the import-weighted effectively applied tariff from the TRAINS data set.<sup>8</sup> In addition, we also include in some specifications the import-weighted tariff applied by the rest of the world on Chilean products at the three-digit level. Lower foreign tariffs may induce firms to export more, and this may induce foreign technology adoption.

Table 6 presents the results when including import tariffs. Columns (1) and (3) include the domestic import tariff, while columns (2) and (4) also include the foreign tariff rate applied on Chilean products. We have also included interaction terms between the change in the RER and the two tariff rates to see whether the level of tariffs in the sector affects the impact of real depreciations on the probability of using licensing. As seen in the table, the estimates for domestic tariffs and their interactions with the change in the RER are not statistically significant, suggesting that the level of Chilean tariffs does not affect the effect of depreciations on foreign technology licensing. This may be due to the fact that Chilean tariffs are relatively low and similar across industries. During the period under analysis, the average import tariff across industries was 8.4 per cent and the standard deviation was only 1.4 per cent. For the case of foreign tariffs, the results are slightly different. Even though the estimate for foreign tariffs is not significant across columns, the interaction between foreign tariffs and the change in the RER is positive and statistically significant, regardless of whether we measure the change in the RER using five or three-year intervals. Thus, a real depreciation is more likely to increase foreign technology adoption at higher levels of foreign tariffs. This suggests that real depreciations may help offsetting the negative effect of foreign tariffs on export competitiveness. Importantly, the estimates for the other variables are not significantly affected when tariffs are included.

Finally, we study whether annual changes in the RER have significant effects on the use of foreign technology licences. In Table 7, we present the basic results for the probability of licensing using the annual change in the RER instead of the five or three-year changes. The estimates are qualitatively similar to what we obtain with longer changes. We still observe that an increase in the change in the RER increases the probability of licensing in more productive and larger plants and that the effect of productivity and size is not linear. Although the estimate for the interaction between the change in the RER and the export dummy is positive, it is no longer statistically significant. This suggests that exporters do not necessarily respond to short-run changes in the RER when making import decisions of technology.

Summarising, the effect of real depreciations on the probability of acquiring foreign technologies is robust to the inclusion of additional control variables at the sector level and to the way the change in the RER is measured.

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<sup>7</sup> This is indeed common. See, for instance, Dahlman and Westphal (1982), Bhattacharya (1985) and Arora (1996).

<sup>8</sup> We also estimate regressions using the simple average tariff, but the results are similar. The use of a simple average tariff is potentially problematic as it treats all commodities identically. The simple average is also sensitive to changes in goods classification in the tariff code (Anderson and Neary, 2005, chapter 1).

TABLE 6  
Results With Additional Controls and Tariffs

	(1)	(2)	(3)	(4)
	5-year Change RER		3-year Change RER	
Licensee year before	0.119*** (0.006)	0.119*** (0.006)	0.119*** (0.006)	0.119*** (0.006)
Productivity	-0.013 (0.022)	-0.013 (0.022)	-0.034 (0.021)	-0.034 (0.021)
(Productivity) <sup>2</sup>	0.001 (0.001)	0.001 (0.001)	0.002** (0.001)	0.002** (0.001)
Export dummy	0.007 (0.005)	0.007 (0.005)	0.004 (0.005)	0.004 (0.005)
Size	-0.041*** (0.015)	-0.042*** (0.015)	-0.046*** (0.016)	-0.047*** (0.016)
(Size) <sup>2</sup>	0.006*** (0.002)	0.006*** (0.002)	0.007*** (0.002)	0.007*** (0.002)
DRER × productivity	0.411*** (0.090)	0.401*** (0.090)	0.448*** (0.098)	0.434*** (0.098)
DRER × (productivity) <sup>2</sup>	-0.025*** (0.005)	-0.024*** (0.005)	-0.027*** (0.005)	-0.026*** (0.005)
DRER × export dummy	0.058*** (0.021)	0.059*** (0.021)	0.062*** (0.023)	0.064*** (0.023)
DRER × size	0.062 (0.042)	0.064 (0.042)	0.094* (0.048)	0.095** (0.048)
DRER × (size) <sup>2</sup>	-0.008* (0.005)	-0.009* (0.005)	-0.012** (0.006)	-0.012** (0.006)
DRER × external financial dependence	0.027 (0.027)	0.024 (0.027)	0.028 (0.030)	0.026 (0.030)
DRER × comparative advantage	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Share licensees	0.594*** (0.048)	0.587*** (0.048)	0.594*** (0.048)	0.587*** (0.048)
Share foreign	-0.084 (0.061)	-0.084 (0.061)	-0.080 (0.061)	-0.081 (0.061)
Tariff	-0.002 (0.091)	0.000 (0.093)	0.017 (0.079)	0.031 (0.079)
Foreign tariff		0.005 (0.005)		0.005 (0.004)
DRER × tariff	-0.066 (0.412)	-0.134 (0.427)	0.092 (0.545)	-0.032 (0.548)
DRER × foreign tariff		0.028* (0.015)		0.039** (0.015)
Constant	0.325* (0.177)	0.294 (0.179)	0.480*** (0.185)	0.401** (0.188)
Observations	38,973	38,973	38,973	38,973
R-squared (within)	0.023	0.023	0.023	0.023

## Notes:

(i) Dependent variable: dummy equal to one if the plant uses foreign technology licences.

(ii) Standard errors in parentheses.

(iii) Productivity: value added per worker; size: number of employees. Productivity and size are in logs. Productivity, size and the export dummy are lagged one year.

(iv) Share licensees are to the share of plants that use licences in the total number of plants in each three-digit sector. Share foreign is the share of plants with foreign ownership in the total number of plants in each three-digit sector. Plant and year fixed effects were included.

(v) \*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; \* $p < 0.1$ .

TABLE 7  
Basic Model With Annual Changes in Real Exchange Rate (RER)

	(1)	(2)
Licensee year before	0.122*** (0.006)	0.122*** (0.006)
Productivity	-0.037* (0.021)	-0.036* (0.021)
(Productivity) <sup>2</sup>	0.003** (0.001)	0.002** (0.001)
Export dummy	0.006 (0.005)	0.006 (0.005)
Size	-0.046*** (0.016)	-0.046*** (0.016)
(Size) <sup>2</sup>	0.007*** (0.002)	0.007*** (0.002)
DRER × productivity	0.588** (0.235)	0.535** (0.237)
DRER × (productivity) <sup>2</sup>	-0.037*** (0.013)	-0.034*** (0.013)
DRER × export dummy	0.084 (0.054)	0.084 (0.054)
DRER × size	0.240** (0.116)	0.230** (0.117)
DRER × (size) <sup>2</sup>	-0.028** (0.014)	-0.027* (0.014)
DRER × external financial dependence		0.016 (0.069)
DRER × comparative advantage		-0.000 (0.000)
Constant	0.270*** (0.098)	0.264*** (0.098)
Observations	38,973	38,973
R-squared (within)	0.017	0.017

## Notes:

(i) Dependent variable: dummy equal to one if the plant uses foreign technology licences.

(ii) Standard errors in parentheses.

(iii) Productivity: value added per worker; size: number of employees. Productivity and size are in logs. Productivity, size and the export dummy are lagged one year. Plant and year fixed effects were included.

(iv) \*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; \* $p < 0.1$ .

## 6. CONCLUSIONS

This paper used plant-level data from the manufacturing sector of Chile to investigate how changes in the RER affect the decision to purchase foreign technologies through licensing. Most recent models in the international trade literature assume exogenous productivity (Bernard et al., 2003; Melitz, 2003) and do not explicitly consider the possibility of technology-upgrading investments with the purpose of competing in international markets. However, as formalised in recent articles (Bustos, 2011), changes in export competitiveness may affect innovation among firms. In this framework, firms may decide to acquire new technologies to improve their chances of staying in international markets. Moreover, in this type of model, the effect of changes in export competitiveness is potentially heterogeneous across firms.

This paper used exogenous changes in the RER to shed light on these heterogeneous effects. In addition to differences in size and productivity across firms, we also looked at how industry characteristics – comparative advantage and financial needs – affect firms' responses regarding foreign technology acquisition. Our results suggest that RER depreciations increase foreign technology adoption mostly for exporters, as we expected. We also found that as plants' productivity and size increase, the effect of a real depreciation on technology licensing is larger, but the effect is not linear. The highest impact of changes in export competitiveness is for plants in the intermediate range of productivity and size distribution, similar to previous evidence for Argentinean firms provided by Bustos (2011).

Our results are robust to alternative specifications, different definitions of changes in the RER and the inclusion of other control variables. In particular, we find that several measures of the incidence of licensing activity in the same sector are positively correlated with foreign technology adoption at the firm level. Although this is an interesting result, more work is needed to uncover the causal effect of these potentially informational spillovers. An alternative interpretation can be that we are capturing unobserved industry-specific shocks in the costs of foreign technologies. In general, an increase in RER causes a rise in export competitiveness, but it may also increase the cost of importing foreign technologies through licences. With the data at hand, we cannot separate both effects. This can be an interesting question for future research.

The evidence in this paper can potentially have important policy implications for developing countries aiming to increase innovation and productivity. International markets are seen, in general, as an important stimulus, or channel, for upgrading technologies in the domestic economy. However, as this paper shows, the effects of changes in RERs are heterogeneous. Small and low-productivity firms are less likely to upgrade technologies even when they face positive shocks. In such a case, complementary policies may be needed to increase innovation and productivity in these firms.

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