E C O N O M I C S   B U L L E T I N

Foreign technology acquisition, spillovers, and sunk costs: evidence from plant-level data

Ricardo Lopez
Indiana University

Abstract

This paper studies empirically the determinants of foreign technology acquisition through licenses. We extend the previous literature by examining spillover effects of general licensing activity in the sector as well as in downstream sectors.

Citation: Lopez, Ricardo, (2008) "Foreign technology acquisition, spillovers, and sunk costs: evidence from plant-level data." *Economics Bulletin,* Vol. 15, No. 11 pp. 1-7
Submitted: April 24, 2008. **Accepted:** July 3, 2008.
URL: http://economicsbulletin.vanderbilt.edu/2008/volume15/EB-08O30003A.pdf

1. Introduction

Previous studies find that firm characteristics such as size, foreign ownership, and export status are important determinants of foreign technology acquisition.[1] But the potential spillover effect from licensing in the same industry as well as in vertically related industries has been largely overlooked.[2] Using Chilean data, this paper shows that plants operating in sectors that rely relatively more on foreign technology licensing are less likely to use foreign licenses, but plants that provide intermediate inputs to sectors with high licensing activity are more like to import technologies, even after controlling for a variety of plant characteristics. Plants with previous experience importing technologies are more likely to use technology licenses. This suggests that sunk costs of importing technologies may be important. One implication of this paper is that incentives to purchase foreign technologies through licenses may potentially have important effects on technology acquisition by other firms operating in the same industry and in upstream sectors.

2. Data and Basic Patterns

The empirical analysis uses plant-level data from Chile for the years 1990 through 1999. The data covers the universe of Chilean manufacturing plants with 10 or more workers. For each plant and year, information on production, value added, sales, employment and wages (production and non-production), exports, investment, depreciation, energy usage, foreign technology licenses, and other plant characteristics is available.

Table 1 shows the annual distribution of plants by licensing activity for the period 1990-1999. On average, 5.4% of the total number of plants uses foreign technology licenses. The share of licensees increased during the period. In 1991 only 4.8% of the plants spent on foreign licenses while in 1999 the share of plants was 5.5%.

Table 1: Number and Percentage of Plants Importing Technologies through Licensing

	Total Number of Plants	Licensees	
		Number	% of Total
1990	4,574	218	4.8
1991	4,758	255	5.4
1992	4,931	254	5.2
1993	5,036	276	5.5
1994	5,078	263	5.2
1995	5,107	277	5.4
1996	5,447	308	5.7
1997	4,960	259	5.2
1998	4,815	276	5.7
1999	4,400	243	5.5
Average 1990-1999	4,911	263	5.4

[1] See, for example, Giannitsis (1991), Montalvo and Yafeh (1994), Kokko and Blomström (1995), Katrak (1997), Vishwasrao and Bosshardt (2001), and Kiyota and Okazaki (2005).

[2] Montalvo and Yafeh (1994) and Vishwasrao and Bosshardt (2001) study horizontal spillovers but they do not examine the effect of licensing in downstream sectors. But interactions between suppliers of inputs and purchasers may have been very important to diffuse technology in many countries (Stewart and Ghani, 1992).

Table 2 presents the percentage of licensees in a given year that continue using licenses the following year. Using the sample of all firms, an average of 62% of licensees continues purchasing technology through this mechanism the following period. By restricting the sample to plants that operated during the entire period, the number increases to 70%. These numbers suggest that sunk costs of importing technologies may be important.

Table 2: Persistence in Licensing Status
(% of Licensees in year t-1 that continue using licenses in year t)

Year t	All Plants	Balanced Panel
1991	66.5	77.6
1992	59.2	68.5
1993	67.3	75.7
1994	60.1	71.7
1995	64.3	71.7
1996	59.9	71.7
1997	56.8	58.0
1998	64.1	70.4
1999	62.7	67.2
Average 1990-1999	62.3	70.3

3. Methodology

We employ a dynamic empirical model developed by Roberts and Tybout (1997) and later used by Kiyota and Okazaki (2005) to analyze the decision to import a foreign technology with sunk fixed costs. A firm uses a foreign technology if current and expected revenues are greater than current period costs plus any sunk cost of importing it:

$$I_{ijt} = \begin{cases} 1 \text{ if } \hat{\pi}_{ijt} > c_{ijt} + F(1 - I_{ijt\text{-}1}) \\ 0 \text{ otherwise} \end{cases},$$

where I_{ijt} is equal to 1 if firm i operating in sector j imported a technology at time t, $\hat{\pi}_{ijt}$ measures current and expected revenues, c_{ijt} are current costs, and F represents the fixed cost of importing a technology. To identify the factors that affect the probability of importing a technology we use a binary-choice model of the form:

$$I_{ijt} = \begin{cases} 1 \text{ if } \beta X_{ijt} + \gamma Y_{ijt} - F(1 - I_{ijt\text{-}1}) + \varepsilon_{ijt} > 0 \\ 0 \text{ otherwise} \end{cases},$$

where X_{ijt} is a vector of plant characteristics, which includes total factor productivity (TFP), size, a dummy equal to one for exporters, a dummy equal to one for plants importing intermediate inputs, a dummy variable for plants with foreign ownership, the ratio of skilled workers to total workers, and age. The vector $Y_{ijt} = \{Horizontal_{ijt}, Downstream_{jt}\}$ attempts to measure the potential spillover effect from importing technologies in the same industry (*Horizontal*) and in downstream industries (*Downstream*). The horizontal variable is defined as the stock of other firms' royalties and license fees (SL_{kjt}) as a fraction of sales ($Sales_{kjt}$):

$$Horizontal_{ijt} = \frac{\sum_{k \in j, k \neq i} SL_{kjt}}{\sum_{k \in j, k \neq i} Sales_{kjt}}.$$

The stock of licenses is obtained using the perpetual inventory method for each plant as in Hasan (2002): $SL_{kjt} = L_{kjt} + SL_{kjt-1}(1-\delta)$, where L_{kjt} are royalties and license fees paid at time t, and δ is the rate of depreciation, assumed to be 5%.[3] To determine the starting values for SL, information on royalties and license fees for the year 1979 is used. For plants that entered after 1979, the value of the first payment in royalties and licenses is used as the initial value of SL.

The $Downstream_{jt}$ variable is a proxy for the licensing activity of industries that are supplied by industry j:

$$Downstream_{jt} = \sum_{m, m \neq j} \alpha_{jm} \left(\frac{\sum_{k \in m} SL_{kmt}}{\sum_{k \in m} Sales_{kmt}} \right),$$

where α_{jm} is the proportion of sector j's output supplied to sector m.[4] Table 3 shows descriptive statistics for all variables.

Table 3: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Licensee Dummy	40,476	0.060	0.237	0	1
Log(Total Factor Productivity)	40,476	6.933	1.136	-4.572	12.739
Log(Employment)	40,476	3.751	1.048	1.099	8.270
Export Dummy	40,476	0.231	0.421	0	1
Import Intermediate Inputs Dummy	40,476	0.265	0.441	0	1
Log(Age)	40,476	2.136	0.845	0	3.045
Foreign Ownership Dummy	40,476	0.059	0.235	0	1
Skilled / Total Employment	40,476	0.246	0.180	0.005	0.993
Log(Horizontal)	40,476	-4.698	0.907	-8.924	-1.882
Log(Downstream)	40,476	-6.688	1.498	-11.247	-3.635

[3] Hasan (2002) assumes a rate of depreciation of 6%. We also calculated the stocks using a depreciation rate of 10%. The results, however, do not change if this depreciation rate is used.

[4] We calculate these coefficients using data from the input-output matrix of Chile, constructed by the Central Bank of Chile, at the 3-digit ISIC level for the year 1996. Given that we are interested in linkages within the country and across productive sectors, we exclude the output for final consumption as well as the imports of intermediate products.

The binary-choice model is estimated as:

$$\Pr(I_{ijt} = 1) = \alpha_1 I_{ijt\text{-}1} + \alpha_1 I_{ijt\text{-}2} + \beta X_{ijt-1} + \gamma_1 \log(Horizontal)_{ijt} + \gamma_2 \log(Downstream)_{jt} + \delta_j + \delta_t + \varepsilon_{ijt}, \tag{1}$$

where δ_j and δ_t are sector and year dummy variables. To reduce potential simultaneity problems, all plant characteristics are lagged one period.

4. Results

Equation (1) is first estimated using OLS. Columns (1) and (4) in Table 4 show the results. More productive and skill-intensive plants are more likely to import technologies. Exporters, importers, and plants with foreign ownership are also more likely to use licenses. Employment has a non-monotonic effect. As employment increases, plants appear less likely to use licenses, but after a certain threshold they tend to rely more on licenses. Plants that imported technologies the previous year, and two years before, are more likely to import technologies, implying that sunk costs of importing may be important. The estimate for the horizontal variable is negative and significant, suggesting there may be a negative spillover effect from other firms' licensing. The backward variable is positive and significant, which suggests that contacts between licensees and their suppliers may increase the suppliers' probability of importing foreign technologies. Columns (2) and (5) present the estimates using a probit model. The estimates are similar than those obtained by OLS, with the exception of employment which is no longer significant.

Neither OLS nor probit estimation provides a consistent estimate of the lag of the dependent variable. Moreover, they do not take into account the role of unobserved plant heterogeneity and the potential endogeneity of the right-hand side variables. In order to deal with these issues, equation (1) is estimated using a dynamic panel estimation method, System GMM. The results are in columns (3) and (6). Most plant characteristics become not significant, although productivity and employment are still significant at 10%. The first lag of the dependent variable is positive and significant, while the second lag is not significant. The horizontal spillover variable remains negative but it is only significant at 10%, while the estimate of the backward variable remains virtually unchanged, and significant at 1%.

One possible explanation for the negative effect of the horizontal variable can be found in the literature of technology diffusion.[5] One group of models, "stock models" (e.g., Reinganum, 1981a, 1981b), suggests that as the number of firms that adopt a technology increases, the benefits of the marginal adopter decrease. Thus, there is a point at which technology adoption is not profitable anymore. A second group of models, "order models" (e.g., Fudenberg and Tirole, 1985), is based on the idea that the order in which firms adopt a technology determines the net return the firm can obtain from it. Earlier adopters get the higher net returns.

5. Conclusions

This paper shows that licensing activity may have important spillover effects. Higher stocks of royalties and license fees by other firms in a given sector decreases the probability that a plant

[5] See, for example, Karshenas and Stoneman (1993), and Stoneman (2002).

operating in that sector purchase foreign technologies through licenses. But there are also positive vertical spillovers since higher licensing activity increases the probability that plants in upstream sectors import technologies using licenses. These results suggest that policies that induce firms to buy foreign technologies through licenses may potentially have important effects on technology acquisition of other firms in the same industry as well as firms in upstream sectors.

Table 4: The Probability of Importing Technologies through Licensing

	(1) OLS	(2) Probit	(3) System GMM	(4) OLS	(5) Probit	(6) System GMM
Licensee Previous Year	0.4113	0.2877	0.4410	0.4106	0.2857	0.4348
	(32.67)**	(38.12)**	(3.71)**	(24.35)**	(34.36)**	(3.68)**
Licensee Two Years	0.2289	0.1083	0.0732	0.2282	0.1073	0.0912
Before	(19.33)**	(19.00)**	(0.56)	(17.03)**	(18.80)**	(0.73)
TFP	0.0071	0.0062	0.0426	0.0071	0.0062	0.0421
	(4.27)**	(4.71)**	(1.88)+	(3.92)**	(4.24)**	(1.87)+
Employment	-0.0365	-0.0001	-0.2299	-0.0361	-0.0003	-0.2201
	(3.68)**	(0.02)	(1.83)+	(3.84)**	(0.05)	(1.81)+
Employment Squared	0.0058	0.0009	0.0268	0.0057	0.0010	0.0256
	(4.54)**	(1.52)	(1.91)+	(4.87)**	(1.44)	(1.89)+
Exporter	0.0101	0.0085	-0.0094	0.0100	0.0084	-0.0103
	(2.78)**	(3.43)**	(0.23)	(2.65)**	(3.12)**	(0.26)
Importer Intermediate	0.0070	0.0056	0.0333	0.0068	0.0055	0.0324
Inputs	(2.06)*	(2.21)*	(0.72)	(1.85)+	(2.02)*	(0.70)
Foreign Ownership	0.0374	0.0152	0.0115	0.0368	0.0148	0.0186
	(4.32)**	(3.86)**	(0.12)	(5.46)**	(4.22)**	(0.19)
Age	0.0009	0.0045	0.0135	0.0019	0.0054	0.0155
	(0.08)	(0.43)	(0.42)	(0.17)	(0.54)	(0.53)
Age Squared	0.0001	-0.0011	-0.0013	-0.0002	-0.0014	-0.0018
	(0.04)	(0.43)	(0.17)	(0.05)	(0.54)	(0.26)
Skill Intensity	0.0262	0.0144	-0.0353	0.0273	0.0148	-0.0422
	(3.71)**	(2.77)**	(0.35)	(4.42)**	(3.27)**	(0.42)
Horizontal				-0.0172	-0.0066	-0.0155
				(3.76)**	(2.28)*	(1.96)+
Downstream				0.0220	0.0216	0.0272
				(4.98)**	(4.77)**	(3.22)**
Observations	28,330	28,330	28,330	28,330	28,330	28,330
R-squared	0.416			0.416		
AR(2) p-value			0.732			0.828
Hansen Test p-value			0.530			0.583

Absolute value of robust t statistics in parentheses. **, *, +: statistically significant at 1%, 5%, and 10%. Three digit ISIC sector and year dummy variables were included but not reported. Standard errors were clustered at the plant level in (1)-(2) and at each sector-year in (4)-(5). For columns (3) and (6) the Windmeijer (2005) correction was used. All plants characteristics are lagged one period. TFP, Employment, Age, Horizontal and Downstream are in logs. Probit estimates in (2) and (5) are the marginal effects.

References

Fudenberg, D., and J. Tirole (1985) "Preemption and Rent Equalization in the Adoption of New Technology" *Review of Economic Studies* **52**, 383-401.

Giannitsis, T. (1991) "Licensing in a Newly Industrializing Country: The Case of Greek Manufacturing" *World Development* **19**, 349-362.

Hasan, R. (2002) "The Impact of Imported and Domestic Technologies on the Productivity of Firms: Panel Data Evidence from Indian Manufacturing Plants" *Journal of Development Economics* **69**, 23-49.

Karshenas, M., and P.L. Stoneman (1993) "Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model" *RAND Journal of Economics* **24**, 503-528.

Katrak, H. (1997) "Developing Countries' Imports of Technology, In-House Technological Capabilities and Efforts: An Analysis of the Indian Experience" *Journal of Development Economics* **53**, 67-83.

Kiyota, K., and T. Okazaki (2005) "Foreign Technology Acquisition Policy and Firm Performance in Japan, 1957-1970: Micro-Aspects of Industrial Policy" *International Journal of Industrial Organization* **23**, 563-586.

Kokko, A., and M. Blomström (1995) "Policies to Encourage Inflows of Technology through Foreign Multinationals" *World Development* **23**, 459-468.

Montalvo, J. G., and Y. Yafeh (1994) "A Microeconometric Analysis of Technology Transfer: The Case of Licensing Agreements of Japanese Firms" *International Journal of Industrial Organization* **12**, 227-244.

Reinganum, J.F. (1981a) "On the Diffusion of New Technology: A Game Theoretic Approach" *Review of Economic Studies* **48**, 395-405.

Reinganum, J.F. (1981b) "Market Structure and the Diffusion of New Technology" *Bell Journal of Economics* **12**, 618-624.

Roberts, M., and J.R. Tybout (1997) "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs" *American Economic Review* **87**, 545-563.

Stewart, F., and E. Ghani (1992) "Externalities, Development, and Trade" in *Trade Policy, Industrialization, and Development: New Perspectives* by G. K. Helleiner, Ed., Clarendon Press: Oxford, UK, pp. 122-154.

Stoneman, P. (2002) *The Economics of Technological Diffusion,* Blackwell Publishers: Oxford, UK.

Vishwasrao, S., and W. Bosshardt (2001) "Foreign Ownership and Technology Adoption: Evidence from Indian Firms" *Journal of Development Economics* **65**, 367-387.

Windmeijer, F. (2005) "A Finite Sample Correction for the Variance of Linear Efficient Two-Step GMM Estimators" *Journal of Econometrics* **126,** 25-51.