Skill-biased technology adoption: Evidence for the Chilean manufacturing sector

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Abstract

We examine the evolution of the demand for skilled workers relative to unskilled workers in the Chilean manufacturing sector following Chile's liberalization of trade in the late 1970's. Following such trade reforms, the standard Heckscher-Olin model predicts that a low labor-cost country like Chile should experience an increased demand for low skilled workers relative to high skilled workers. Alternatively, if trade liberalization is associated with the adoption of new technologies, and technology is skill-biased, the relative demand for skilled workers may rise. Using a newly available plant-level data set that spans the sixteen year period 1979-1995, we find that the relative demand for skilled workers rose sharply during the 1979-1986 period and then stabilized. The sharp increase in demand for skilled workers coincided with an increased propensity to adopt new technologies as measured by patent usage. Plant-level analysis of labor demand confirms a significant relationship between the relative demand for skilled workers and technology adoption as measured by patent usage and other technology indicators. Our results suggest that skill-biased technological change is a significant determinant of labor demand and wage structures in developing economies.

1 Introduction

Chile, as well as much of Latin America during the 60's and early 70's, followed an import substitution policy, characterized by high and differentiated tariffs, quotas, and market regulations. After the coup d'etat in 1973, the new government introduced a series of structural reforms in the late 1970's and early 1980's. Most non-trade barriers and quantitative trade restrictions were eliminated between 1973 and 1975 and import tariffs were reduced from an average of 105% in 1973 to a uniform level of 10% across industries by June of 1979. Capital and labor markets were also deregulated during this time period.

Such dramatic changes in the free-trade environment have first-order implications for labor markets in Chile. The standard Heckscher-Ohlin model predicts that a low labor-cost country like Chile trading with high labor-cost developed economies such as the United States will experience a fall in the capital-labor ratio and a reduction in demand for skilled workers relative to unskilled workers once trade barriers are reduced. More recent theories lead to the opposite conclusion however, if trade liberalization is associated with the adoption of new technologies. The adoption of new technologies may occur because the free trade environment directly facilitates the transfer of knowledge or because the mix of investment goods shifts towards imported high-technology capital goods that are complementary with skilled labor. In this case, trade liberalization may lead to rising capital-labor ratios and a shift towards skilled labor relative to unskilled labor. Trade liberalization may also imply increased wage inequality owing to such skill-biased technological change.

In this paper we study the determinants of demand for skilled manufacturing workers in Chile over a fifteen year period 1979-1995. We view Chile as a representative developing economy subject to a rapid liberalization that resulted in a free-market, trade-oriented economy. We focus on three issues: 1) to what extent did the demand for skilled workers change over the fifteen year period following trade liberalization; 2) to what extent is the change in demand for skilled workers linked to technology adoption and 3) to what extent is the change in demand for skilled workers linked to the accumulation of capital in general and imported capital goods in specific.

Our results imply that labor demand did indeed shift towards skilled workers relative to unskilled workers, especially during the 1979-1986 period. Our results also imply that the relative demand for skilled workers is closely tied to the adoption of new technologies as measured by patent usage at the plant level. These results are apparent in both simple graphical analysis of plant averages as well as a more detailed regression analysis at the plant level. We also find small but significant complemenarities between capital and skilled labor. We find no evidence in favor of the hypothesis that skilled labor demand is associated with the adoption of new technologies through investment in imported capital goods however. To the extent that the economic reforms adopted by Chile in the late 1970's influenced the relative demand for skilled workers at the plant level, they did so by creating an economic environment that encouraged the adoption of new technologies rather than through direct mechanisms that allowed Chilean plants to import high technology capital goods.

Our paper begins with a descriptive exercise, characterizing the broad movements in labor composition and wage structure between skilled and unskilled workers over the period 1979-1995. We then consider a more formal analysis of the relationship between labor market outcomes and imported technology. We adopt a cost minimization approach based on a restricted variable translog cost function to provide direct estimates of the relative demand for skilled workers. The same methodology has been used to study the presence of capital depening and skill-biased technological change in developed economies (Berman and Machin (2000)) and developing economies (Pavcnik (2002b)).

The paper is organized in the following way. Section 1 gives a brief summary of the empirical evidence in favor of skill-biased technological change. Section 2 provides descriptive statistics documenting the composition and evolution of manufacturing employment in Chile over the period 1979-1995. In Section 3, we provide a more formal analysis of the evolution of the mix of skilled and unskilled workers: we decompose shifts in the labor share for skilled workers into within-and between-industry components, and we use a cost-minimization approach to study the relationship between labor composition, capital deepening and technology adoption. Section 4 studies the link between skilled labor demand, investment and imported capital goods. Section 5 concludes.

2 Empirical evidence in favor of SBTC

Empirical evidence for OECD countries suggests that the wages of skilled workers relative to unskilled workers increased or remained stable over the last two decades despite their increasing labor force participation relative to unskilled workers.[1] For example, in the United States, real wages for young men with twelve or fewer years of education fell by 26% between 1979 and 1993. Overall, the empirical evidence is consistent with a considerable rise in wage inequality and demand for skilled workers in the United States and United Kingdom and moderate increases in countries like Japan, Sweden and Germany (Machin and Van Reenen, 1998).

[1] See Katz and Autor (1999) for a survey.

For developed economies, the observed rise in skill premia is potentially consistent with both Stolper-Samuelson trade effects and the presence of pervasive skill-biased technological change. The trade effects can be understood through a standard Heckscher-Ohlin model which predicts that a skill-abundant country such as the United States, trading with a less skill-abundant developing country, will experience an increase in the relative price of the skill-intensive good, which translates into an increase in the relative wage of skilled workers. As emphasized by Berman and Machin (2000), pervasive skill-biased technological change implies an increase in the proportion of skilled labor and a rise in the relative wages of skilled workers. Importantly, skill-biased technological change implies within-industry skill upgrading which induces within-industry increases in the demand for skilled workers. In contrast, the Stolper-Samuelson trade mechanism increases the relative demand for skilled workers owing to shifts in labor demand across rather than within industries.

Although some researchers have argued in favor of Stolper-Samuelson effects owing to increased trade, most researchers argue that pervasive skill-biased technological change (SBTC) is the main force behind the behavior of relative wages and the relative demand for skilled versus unskilled workers in developed economies. Evidence in favor of SBTC is summarized by the following well-documented empirical results: (1) the increase in skill intensity and income inequality mainly occurred within rather than across-industries and tends to be concentrated in the same industries across countries; (2) capital-skill complementarities explain only a small part of the increase in skill upgrading (Berman and Machin, 2000); and (3) employment shifts to skill-intensive sectors are too small to be consistent with the notion that international trade mechanisms are the prime determinants of the changing skill mix.

For a developing economy, the Stolper-Samuelson mechanism implies the opposite effect in terms of skill intensity and wage-bill shares. A less developed country that trades with skill-abundant developed economies would experience a decrease in the labor share of skilled workers and a shift in the relative wage in favor of unskilled workers. To the extent that technology adoption is linked to trade liberalizations, developing economies may also experience an increase in demand for skilled workers following trade liberalizations. This mechanism may occur either because local producers adopt new technologies to remain competitive vis-a-vis foreign markets, or because trade liberalizations reduce barriers to importing high-technology capital goods which are complementary with skilled workers. According to this hypothesis, the presence of pervasive, sector-neutral, skill-biased technological change is a potential explanation for increases in wage inequality between skilled and unskilled workers even in the case of less developed, small open economies such as Chile.

For developing economies there are only a few studies analyzing changes in wage and labor structure. For the case of Mexico, the findings suggest that returns to higher education increased between the late 80's and mid 90's (Meza, 1999), and that the shifts in the relative demand for skilled workers have taken place mostly within industries. Cragg and Epelbaum (1994) found evidence to support capital-skill complementarity in explaining the increase in the wage dispersion. Hanson and Harrison (1999) explain the increase in wage inequality in Mexican firms in the late 80's by arguing that the reduction in trade protection that took place in 1985 affected more low-skilled industries, those receiving relatively high trade protection before the liberalization process. Similar results were found by Revenga (1997). Robbins (1994, 1995b) found evidence of higher wage inequality following trade liberalization in the case of Chile. For Colombia, the results were mixed. After experiencing a fall in wage disparity following the trade reform, the relative wage for skilled workers increased after 1987.

Cross country analyses have found some evidence of skill-biased technical transfer. Berman and Machin (2000), using data for middle income countries, found increasing demand for skilled workers, which concentrated in the same industries across countries and are highly correlated with indicators of OECD technical change. Robbins (1995a) found a high correlation between the increasing demand for skilled labor and imports of machinery and equipment, also known as the skill- enhancing trade hypothesis.

In a closely related study, Pavcnik (2002b) examines the evolution of the white collar share for Chilean manufacturing plants over the period 1979-1986. Pavcnik finds some evidence in favor of capital-skill complementarity but finds no relationship between technology adoption and skill upgrading after controlling for unobserved plant heterogeneity.[2] Pavcnik used three measures of technology adoption: imported materials, the use of patented technology and expenses on foreign technical assistance. Building on her approach, we extend the analysis over an additional nine years to cover the period 1979-1995. This extended data is helpful in analyzing long-run trend issues such as the evolution of skill bias in the Chilean labor market following such significant economic reforms. Importantly, the extended data set is also helpful in controlling for unobserved plant-level heterogeneity. It is well known that plant-level fixed-effects estimators suffer from high noise to signal ratios in short panels. Applying a fixed-effect estimator to a short panel may lead to downward bias in the effect of technology adoption on skilled labor demand. With a panel data set that spans sixteen years, our empirical methodology is less subject to this criticism. In contrast to the findings in Pavcnik, after controlling for unobserved plant-level heterogeneity, we find a robust

[2] Doms et al. (1997) found similar results for US plants.

association between skilled labor demand and the adoption of new technologies.

3 Data Overview

Our current plant-level data set was obtained from the World Bank and the National Statistics Institute of Chile (INE); the data were collected by INE. The dataset is a census of manufacturing plants with ten or more employees and contains annual information for the period 1979-1995. It includes a large set of variables about production, employment, investment, capital stocks, intermediate inputs, sales, and plant indicators such as location, business type and industry classification. All variables considered are in terms of 1980 prices. After the elimination of extreme outliers, and confining our attention to plants who remain in the sample for at least five years, this panel data contains approximately 28,000 observations across plants and years. We construct appropriately defined capital indices using the perpetual inventory method, aggregated material inputs using industry-level deflators, and put all variables on a comparably deflated basis. The appendix provides further details on data construction.

Employment is measured as the number of workers hired per year and is decomposed by skill-type: white collar and blue collar. Given that we want to study the relationship between employment composition according to skill level and technology adoption, we require proxies for the technology measure. The data provide different plant-level measures to indicate technology adoption: imported materials, expenses on patent use and foreign technical assistance.[3]

Table 1 summarizes the evolution of the white collar share of total employment and the evolution of the total wage bill computed using both unweighted plant means and value-weighted plant means. Using unweighted plant means, we find that the share of skilled workers in the total wage-bill for the average plant in our sample increased 14% over the full sample period. Similarly, the employment share for white collar workers at the average plant rose 21% over this period. According to the weighted means, the white-collar share of the total wage bill remained unchanged while the white-collar share of total employment rose by a relatively modest 7%.

[3] Previous studies have relied on foreign direct investment and expenditures on research and development as useful proxies for technology adoption. Neither foreign direct investment nor R&D expenditures are available in out data set however.

Table 1. White-collar shares

Year	*Unweighted means* White-collar share in total employment	*Unweighted means* White-collar share in total wage-bill	*Weighted means* White-collar share in total employment	*Weighted means* White-collar share in total wage-bill
1979	0.1884	0.3068	0.2522	0.5174
1980	0.1877	0.3026	0.2507	0.5161
1981	0.1903	0.3093	0.2547	0.5229
1982	0.2083	0.3340	0.2658	0.5351
1983	0.2077	0.3362	0.2623	0.5388
1984	0.2024	0.3329	0.2447	0.5394
1985	0.2019	0.3307	0.2417	0.5278
1986	0.2124	0.3366	0.2516	0.5465
1987	0.2208	0.3409	0.2560	0.5267
1988	0.2312	0.3454	0.2607	0.5271
1989	0.2253	0.3430	0.2557	0.5258
1990	0.2243	0.3448	0.2584	0.5239
1991	0.2273	0.3510	0.2578	0.5143
1992	0.2212	0.3486	0.2533	0.5077
1993	0.2224	0.3456	0.2577	0.5067
1994	0.2269	0.3480	0.2670	0.5116
1995	0.2278	0.3485	0.2706	0.5171

Source: Authors' calculations.

Differences between weighted and unweighted means deserve some comment. Up until 1986, the trend in the skilled-worker wage-bill share computed using unweighted versus weighted means are similar – both show a steady increase. After 1986, the wage-bill shares computed using weighted versus unweighted means diverge. The wage-bill share computed using weighted means actually peaks in 1986 and by 1995 has returned to its 1979 level. The wage-bill share computed using unweighted means shows a steady increase until 1986 and is relatively constant thereafter. In contrast, the employment share of skilled workers increases over the full sample period when measured using either the weighted or unweighted means. Since the skilled-worker wage-bill share depends on both demand and supply effects, it is plausible that demand for skilled workers rises while wage premia remain relatively constant or decline over time. This in fact appears to be the case – the wage premium computed using weighted means rose from 2.05 to 2.17 between 1979 and 1986, it then fell to 1.91 between 1986 and 1995. Such supply affects are more likely to affect the aggregate behavior (weighted mean) than the average behavior of plants (unweighted mean). With either measure however, the overall pattern is fairly clear – there is evidence of a rapid expansion in the wage-bill share of skilled workers during the 1979-1986 period which either stabilized or fell in absolute terms thereafter. In this paper, we focus on plant-level determinants of the demand for skilled workers, in particular the linkages between technology adoption and skilled labor demand, we therefore abstract from supply induced shifts which may cause a divergence between aggregates and plant-level averages.[4]

As emphasized in the introduction, the most prevalent explanation for rising skill premia is skill-biased technological change: as plants adopt new technologies they increases their demand for skilled workers. Our data set has three potential measures of technology adoption: patent usage, the share of imported materials, and the share of foreign technical assistance. For all three of these measures, plants report the expenditures to outside parties. We thus observe whether a plant uses a given technology indicator as well as the amount in pesos spend on the relevant indicator.

To understand the relationship between skilled labor demand and technology adoption, we again report trends in sample means for the percentage of plants that use a given technology measure, and the corresponding (unweighted) average employment and wage bill share of such plants. These results are reported in table 2.

Table 2. Plant-level technology adoption variables

Year	*Share of plants that use patents*	*Employment share*	*Wage-bill share*	*Share of plants with imported materials*	*Employment share*	*Wage-bill share*	*Share of plants with foreign technical assistance*	*Employment share*	*Wage-bill share*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1979	0.699	0.196	0.315	0.280	0.256	0.448	0.048	0.290	0.503
1980	0.691	0.200	0.323	0.263	0.265	0.461	0.044	0.301	0.526
1981	0.708	0.200	0.327	0.277	0.267	0.465	0.041	0.313	0.538
1982	0.714	0.223	0.359	0.241	0.293	0.506	0.043	0.326	0.541
1983	0.757	0.219	0.356	0.248	0.294	0.503	0.040	0.342	0.563
1984	0.767	0.212	0.349	0.253	0.285	0.493	0.045	0.308	0.533
1985	0.791	0.211	0.346	0.260	0.284	0.491	0.047	0.326	0.542
1986	0.806	0.219	0.348	0.265	0.291	0.493	0.046	0.342	0.548
1987	0.811	0.225	0.348	0.257	0.299	0.487	0.042	0.354	0.557
1988	0.800	0.238	0.356	0.244	0.315	0.498	0.039	0.373	0.570
1989	0.801	0.234	0.360	0.222	0.307	0.496	0.045	0.342	0.547
1990	0.799	0.233	0.360	0.212	0.306	0.500	0.046	0.342	0.546
1991	0.807	0.235	0.365	0.218	0.313	0.499	0.053	0.349	0.524
1992	0.808	0.229	0.362	0.247	0.307	0.495	0.051	0.343	0.532
1993	0.814	0.230	0.360	0.262	0.304	0.485	0.055	0.311	0.495
1994	0.815	0.238	0.366	0.283	0.300	0.482	0.053	0.346	0.522
1995	0.826	0.238	0.365	0.259	0.300	0.484	0.059	0.327	0.504

Source: Authors' calculations.

According to Table 2, firms who report using either of these three measures of technology have higher employment shares and wage-bill shares for skilled workers relative to the full sample. The skilled-worker shares are particularly high for firms who report using foreign technical assistance. The extent to which any of these three measures of technology can explain the rising trend in

[4] Such supply shifts are effectively controlled for by including time dummies in our regression framework.

skilled labor demand at the plant level depends on the fraction of the overall sample accounted for by such plants, and the rate at which technology use expanded according to such measures. Plants with foreign technical assistance account for less than six percent of the total sample – thus although the proportion of plants using foreign technical assistance rose 20% (from 0.048 to 0.059), the share of such firms is simply too small to explain the overall plant-level trends. Similarly, although plants who use imported materials account for a significant fraction of the total plants (28% at the beginning of the sample period), the proportion of such plants actually fell over time. In contrast, the share of plants that report using patents is both large – 69% at the beginning of the sample – and expanded rapidly over time – rising to 82.6% by then end of the sample period. An expansion in patent usage is therefore a good candidate measure of technology to explain the rise in skilled labor demand at the plant level.

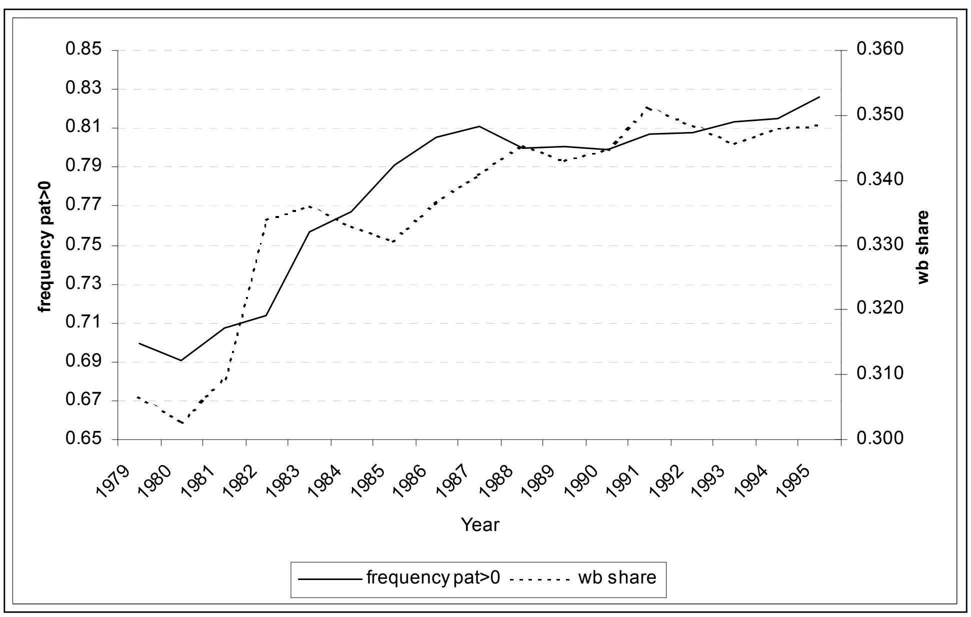

Figure 1: Wage bill share and patent usage

Figure 2: Wage bill share and patent expenditures

We now consider the timing of the expansion in patent usage relative to the rise in skilled labor demand at the plant level. In figure 1, we plot the average wage-bill share of skilled workers along with the percentage of plants reporting patent usage for each year. The rapid expansion of the wage bill- share during the 1979-1986 sample period coincides with the rapid expansion in patent usage – the percentage of plants reporting patent usage rose from 69% in 1979 to 81% in 1987. The stability of the wage bill share in subsequent years is also reflected in the stable percentage of plants reporting patent use from 1987-1995.

Figure 2 shows similar results regarding the coincident expansion of patent usage and rising wage-bill shares for skilled workers. Here our measure of patent usage is the log of the peso amount expended on patents normalized by the total wage bill. Figure 2 confirms that, in expenditure terms, the rapid expansion of patent usage coincides with the rise in the wage bill for skilled workers.

Table 3. Patents

	unweighted means				*weighted means*			
	patents indicator=1		*patents indicator=0*		*patents indicator=1*		*patents indicator=0*	
Year	*employment share*	*wagebill share*	*employment share*	*wagebill share*	*employment share*	*wagebill share*	*employment share*	*wagebill share*
1979	0.196	0.315	0.172	0.287	0.258	0.525	0.237	0.496
1980	0.200	0.323	0.161	0.257	0.260	0.539	0.225	0.452
1981	0.200	0.327	0.168	0.266	0.265	0.541	0.224	0.462
1982	0.223	0.359	0.172	0.271	0.279	0.557	0.222	0.455
1983	0.219	0.356	0.173	0.276	0.269	0.553	0.233	0.477
1984	0.212	0.349	0.169	0.281	0.254	0.555	0.208	0.474
1985	0.211	0.346	0.169	0.271	0.249	0.543	0.205	0.451
1986	0.219	0.348	0.184	0.290	0.251	0.543	0.255	0.563
1987	0.225	0.348	0.204	0.310	0.255	0.527	0.258	0.527
1988	0.238	0.356	0.204	0.304	0.268	0.540	0.226	0.473
1989	0.234	0.360	0.189	0.276	0.263	0.536	0.219	0.469
1990	0.233	0.360	0.190	0.284	0.264	0.536	0.225	0.459
1991	0.235	0.365	0.196	0.292	0.263	0.525	0.233	0.463
1992	0.229	0.362	0.190	0.293	0.256	0.512	0.239	0.484
1993	0.230	0.360	0.190	0.283	0.262	0.516	0.231	0.448
1994	0.238	0.366	0.177	0.269	0.276	0.525	0.215	0.428
1995	0.238	0.365	0.181	0.268	0.277	0.530	0.230	0.423

Source: Authors' calculations.

Finally, table 3 provides a decomposition of trends in the employment and wage-bill share for plants that report using patents versus those who do not use patents. Using unweighted means, we find that plants who do not use patents experience a drop in the wage-bill share and at best a modest rise in the employment share. Plants who do use patents experience a sharp increase in both. Using weighted means, we find relatively stable employment and wage-bill shares for the plants that use patents and a sharp decline in the wage-bill share for plants that do not.

4 The Determinants of Skilled Labor Demand

We begin our empirical analysis of the determinants of the demand for skilled workers relative to unskilled workers by decomposing the overall change in the labor share of skilled workers relative to total workers, Δ, into within- versus between-industry shifts in employment. One of the arguments in favor of SBTC is that the shifts in the share of skilled workers in total employment and in the total wage bill take place within rather than between industries.[5] The decomposition of the change in the labor share over a period of time is given by:

[5] Total employment is defined by the sum of skilled and unskilled workers, where skilled workers include: executive, administrative and production workers (engineers, etc); and unskilled-workers include: production and non-production blue-collar workers. The remainder categories available in the data: owners, workers at home and salesperson on comission are not included. The wage-bill is defined accordingly.

$$\Delta S_t = \sum_i \Delta s_{it} E_{i.} + \sum_i \Delta E_{it} s_{i.} \tag{1}$$

where s_{it} is the share of white collar labor in total employment for industry i and year t, and E_{it} is the share of industry i's employment in total employment in year t. $E_{i.}$ and $s_{i.}$ denote industry means over time for E_{it} and s_{it}, respectively. The first term on the right hand side of equation 1 measures the within variation, while the second represents the between contribution to the total change in the share ΔS_t. We compute an analogous decomposition for the wage bill share. This decomposition is reported in table 2. For comparison purposes, we report both the decomposition obtained from the full sample period as well as a decomposition over the sub-sample period 1979-1986.

Table 4. Decomposition of Relative Labor Shifts

	1979-1995		1979-1986	
Indicator	Employment share	Wage-bill share	Employment share	Wage-bill share
Within industry	0.0229	0.0029	0.0068	0.0248
Between industry	-0.0044	-0.0032	-0.0074	0.0043
Total	0.0185	-0.0003	-0.0005	0.0291
Within/Total	1.24	-9.37	-13.17	0.85

Source: Authors' calculations.

Table 4 implies that the aggregate employment share of skilled workers rose by a modest 1.85 percent while the aggregate wage bill share remained unchanged over the full 1979-1995 sample period. The total movements in the wage bill share and the employment share mask significant differences between the within versus between industry contribution. The within industry contribution was positive for both the wage bill share and the employment share over both the full sample period, as well as the sub-sample period considered by Pavcnik. In contrast, the between industry effect was negative for both the employment share and the wage bill share for the full sample period, and either negative or neglible in terms of its contribution during the 1976-1986 sub-sample. The positive within-industry effect is consistent with the notion that within industry skill upgrading had a positive effect on the skill premium in Chilean manufacturing. The negative effect of the between industry variation is also consistent with the Stolper-Samuelson hypothesis that economic activity shifted towards low skilled industries.

We now consider a more structural analysis of the determinants of the wage bill share at the plant level. In the presence of SBTC, we expect the wage-bill share to be correlated with measures of technology adoption at the plant level. To the extent that capital and skilled labor are complements in the production function, we also expect the wage-bill share for skilled workers to be positively related to capital intensity. This would be particularly true if new capital goods embodied new technologies that required high-skill workers.

To analyze the relationship between labor composition, technology adoption and capital intensity, we adopt a cost minimization approach where capital is assumed to be quasi-fixed and plants minimize the cost of unskilled and skilled labor. We assume constant returns to scale in production and consider a restricted translog variable cost function for plant i in year t, which results in the following expression for the share of skilled labor in the wage bill:

$$Share_{it} = \alpha + \beta \ln\left(\frac{w_{it}^s}{w_{it}^u}\right) + \gamma \ln\left(\frac{K_{it-1}}{Y_{it}}\right) + \delta Tech_{it} + \varepsilon_{it} \tag{2}$$

In equation 2, w_{it}^s and w_{it}^u are wages for skilled and unskilled labor, K_{it-1} is capital which is predetermined, Y_{it} is value added. The coefficient γ measures the extent to which capital and skilled labor are complements. To measure the extent to which technology affects the relative demand for skilled workers, we include $Tech_{it}$, a vector of observable technology measures. Equations of this form have been estimated in other studies linking technology changes and employment structure for developed countries (see Machin and Van Reenen (1998) and Berman, Bound and Machin (1998)) and developing economies (Pavcnik (2002b)).

Our technology vector is defined as $Tech_{it} = [1(x_{it} > 0), \log(x_{it}) * 1(x_{it} > 0)]$ for $x_{it} = [pat_{it}, fta_{it}, m_{it}]$, the proxies for technology use. Here pat_{it} measures the expenses on patents used as a share of value added. fta_{it} measures the expenses in foreign technical assistance relative to value added and m_{it} is the share of imported materials in total materials. Each of these variables is either zero or positive. We therefore include both the zero-one indicator and the log of the expenditure variable interacted with the zero-one indicator in the technology vector.

The patent-use indicator is arguably the most direct measure of technology use among the three indicators that are available. Imported materials are only likely to be proxies for technology use if they are correlated with the use of imported technologies. Foreign direct assistance is arguably a good measure of the adoption of foreign technologies but it is the least prevalent of the three measures and thus only provides information for a small sub-sample of the population. We therefore consider baseline regressions that only include patent use as our measure of technology, and report additional regressions that also include foreign technical assistance and imported materials inputs.

To measure the effect of capital on the demand for skilled workers, we include the log of the capital-labor ratio. If capital is complementary to skilled workers, γ should have a positive sign. For robustness, we also include the log of output as a separate regressor. The log of output controls for a systematic relationship between plant size and the demand for skilled workers; it also allows for deviations from constant-returns-to-scale and controls for business cycle fluctutations in plant-level demand for skilled workers relative to unskilled workers. Such fluctuations may occur if plants are more likely to layoff unskilled workers than skilled workers during a temporary downturn.

To control for unobserved shocks to the relative demand for skilled workers, we also include time, industry and location dummies. Industry dummies are constructed using a 4-digit industry classification. Given that relative wages are highly endogenous, they are not directly included in the estimated equation. Time dummies capture endogenous movements in wages owing to supply shifts and other general equilibrium mechanisms. The final equation to be estimated is:

$$Share_{it} = \alpha + \gamma_1 \ln\left(\frac{K_{it-1}}{Y_{it}}\right) + \gamma_2 \ln(Y_{it}) + \delta Tech_{it} + \eta Year_t + \theta Location_i + \mu Industry_j + \varepsilon_{it} \quad (3)$$

We report separate regressions for the wage-bill share (Table 5) and the employment share of skilled workers (Table 6).

The regression results in table 5 imply a quantitatively significant relationship between technology adoption and the wage-bill share of skilled workers. In all regressions, both the zero-one patent use indicator and the patent-expenditure variable are highly statistically significant and quantitatively important. Column 1 of Table 5 reports the baseline regression for the wage bill share that does not include either industry- or plant-level fixed effects. The coefficients on patent use and the patent indicator are 0.09 and 0.59 respectively, and significant at the 1% level. Controlling for industry-level fixed effects reduces these coefficients by a factor of two (column 3, table 5). Controlling for plant-level fixed effects further reduces the coefficients to 0.013 and 0.121 respectively (column 5, table 5); the coefficients nonetheless remain statistically significant at the 1% level.

To understand the quantitative significance of these coefficients, note that patent usage increased by 14 percent over the 1979-1986 time period. Patent expenditures relative to value added increased by 65% over this period. Using the coefficients on technology use obtained from the regression that controls for industry effects (Table 5 column 3), these increases imply a 7% increase in the wage bill share. The actual increase in the wage bill share was 9% over this period. Using the coefficients obtained from the regression that controls for plant-level effects (Table 5, column 5), the implied increase in the wage bill share is 1.9%. Since it is likely that the plant-level fixed effects estimator is downward biased to some extent, our empirical results suggest that increased technology adoption can account for between 22% and 78% of the total rise in the wage bill share over the 1979-1986 period.

Table 5: Regressions for Skilled Labor Share in Wage Bill

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
lk_va	0.040**	0.041**	0.004	0.002	0.027**	0.026**
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)
lva	0.221**	0.176**	0.101**	0.080**	0.029**	0.027**
	(0.006)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)
lpat_vax	0.079**	0.058**	0.036**	0.029**	0.009*	0.008*
	(0.008)	(0.007)	(0.006)	(0.006)	(0.004)	(0.004)
pat_ind	0.600**	0.459**	0.314**	0.265**	0.090**	0.086**
	(0.050)	(0.048)	(0.042)	(0.042)	(0.022)	(0.023)
lm_mtotx		0.043**		0.016*		0.006
		(0.008)		(0.007)		(0.004)
m_ind		0.312**		0.162**		0.030*
		(0.022)		(0.021)		(0.013)
lfta_vax		0.031**		0.019*		0.004
		(0.010)		(0.008)		(0.008)
fta_ind		0.218**		0.128**		0.058
		(0.054)		(0.047)		(0.041)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies[1]	No	No	Yes	Yes	No	No
Plant effects	No	No	No	No	Yes	Yes
Observations	28,844	28,844	28,843	28,843	28,844	28,844
R-squared	0.238	0.260	0.394	0.399	0.734	0.734

Robust standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
[1] Location, busisness type, trade orientation and four-digit industry dummies.

Adding the additional technology controls, we find evidence that both imported materials and foreign direct assistance have a statistically significant positive effect on the skilled-worker wage-bill share (column 2 and 4). In contrast to the patent use variables, these effects are both quantitatively and statistically insignificant once one controls for plant-level fixed effects however (column 6). With these controls in place, the coefficients on the patent variables remain essentially unchanged by the inclusion of additional technology measures..

Consistent with previous research, we also find evidence in favor of capital-skill complementarity as measured by the small but positive coefficient on the log of the capital-value-added ratio. The complementarity between capital and skilled workers is robust to including plant-level fixed effects. Independently controlling for size as measured by value added is important in the regressions that do not allow for plant-level fixed-effects. The coefficient on the log of value added is insignificant once we include such controls.

Table 6: Regressions for Skilled Labor Share in Total Employment

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
lk_va	0.028**	0.029**	0.002	-0.002	0.033**	0.033**
	(0.010)	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)
lva	0.147**	0.091**	0.056**	0.029**	0.002	0.000
	(0.007)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)
lpat_vax	0.081**	0.057**	0.042**	0.033**	0.013**	0.013**
	(0.009)	(0.008)	(0.007)	(0.007)	(0.004)	(0.004)
pat_ind	0.597**	0.428**	0.336**	0.273**	0.124**	0.121**
	(0.057)	(0.054)	(0.047)	(0.046)	(0.023)	(0.023)
lm_mtotx		0.055**		0.020*		-0.002
		(0.010)		(0.009)		(0.005)
m_ind		0.362**		0.194**		0.010
		(0.029)		(0.025)		(0.013)
lfta_vax		0.033*		0.028*		-0.004
		(0.015)		(0.012)		(0.008)
fta_ind		0.342**		0.258**		0.034
		(0.079)		(0.066)		(0.042)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects[1]	No	No	Yes	Yes	No	No
Plant effects	No	No	No	No	Yes	Yes
Observations	28,816	28,816	28,815	28,815	28,816	28,816
R-squared	0.110	0.143	0.302	0.311	0.717	0.717

Robust standard errors in parentheses (clustering by plant id).
+ significant at 10%; * significant at 5%; ** significant at 1%
[1] Location, business type, and four-digit industry dummies.

Table 6 reports regression results using the employment share as our dependent variable. The results are very similar to those obtained using the wage-bill share. In particular, when measuring technology through the patent variables, we again find a statistically significant and quantitatively important relationship between technology adoption and the relative demand for skilled workers. This finding is again robust to the inclusion of either industry- or plant-level fixed effects.

5 Technology adoption and capital accumulation:

We now assess the role of investment in capital goods on the demand for skilled workers. We do this in two ways. First, we study the effect of investment spikes at the plant level – large increases in investment above the normal rate of replacement – on the relative demand for skilled workers. Second, we construct an industry specific measure of imported capital goods and study the extent to which plant-level demand for skilled workers is influenced by increases in imported capital goods. We begin with an assessment of the overall trends in both plant-level investment and investment in imported capital goods for the Chilean manufacturing sector. We then consider the effect of such investment on the relative demand for skilled workers at the plant.

Imported capital goods is a potentially promising mechanism through which foreign technologies may be adopted by local producers. Most of the capital equipment in the world is produced by a small group of developed economies intensive in R&D activities. These economies are also the main exporters of capital equipment.[6] For this reason, skill-biased technological change is often linked to the adoption of new technologies through imported capital inputs following trade liberalization. This mechanism may be particularly relevant for a developing economy like Chile which experienced a gradual but deep trade liberalization process between 1973 and 1979.

Despite its appeal, we in fact find no evidence in favor of the arugment that skilled labor demand is influenced by either new investment at the plant level or an increase in imported capital goods. Figure 3 plots both the average investment rate for all manufacturing plants in our sample. It also plots the proportion of plants that invest in new capital goods in any given year. Both the overall investment rate and the proportion of plants that invest exhibit a strong positive correlation over our sixteen year sample period. The timing of these investment patterns is the opposite of what one would expect if there were strong complementarities between new investment and the relative demand for skilled workers. In particular, the rapid expansion in the wage bill share of skilled workers occurred in the 1979-1986 period. The average investment rate is substantially below trend for most of this period however, as is the proportion of plants investing. In contrast, the investment rate rises sharply between 1987 and 1990, a period during which the wage-bill share for skilled workers is relatively constant.

[6] Eaton and Kortum (2201), Caselli and Wilson (2003).

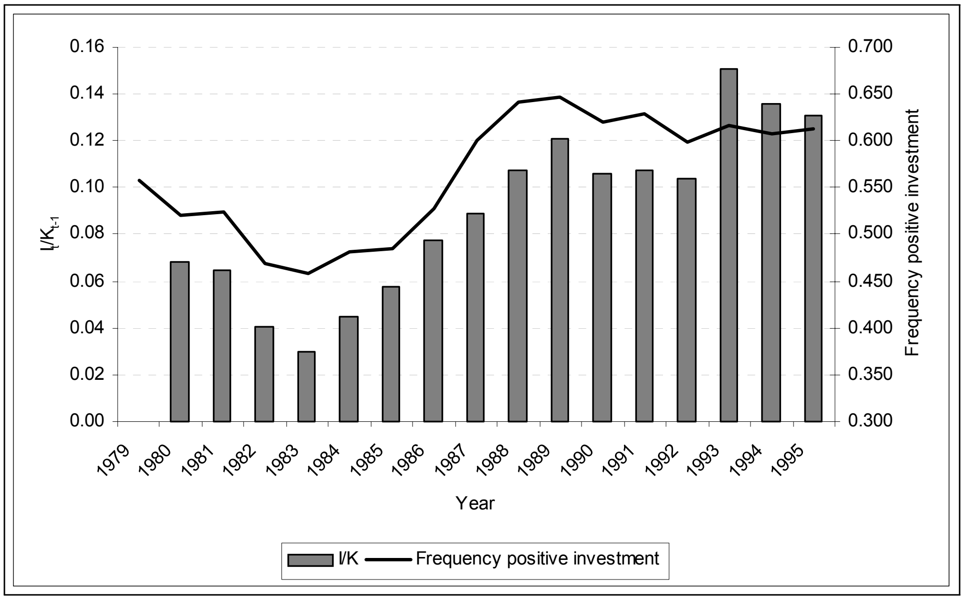

Figure 3: Investment rate

Figure four plots imported capital goods as a proportion of GDP over our sample period (solid line). For comparison purposes, we also plot the sample average of the investment-output ratio for Chilean plants over the same period (dotted line). The investment to GDP ratio for imported capital goods mirrors the overall investment behavior of Chilean manufacturing plants. Again, capital imports are lowest during the period that coincides with the rapid expansion of the wage-bill share for skilled workers. Capital imports pick up during the latter half of the sample when the wage-bill share is relatively stable. Thus, although we find a strong association between the timing of the expansion in patent usage and the wage bill share for skilled workers, we find no systematic evidence linking the timing of plant-level investment or the timing of capital imports to the timing of the expansion in the relative demand for skilled workers.

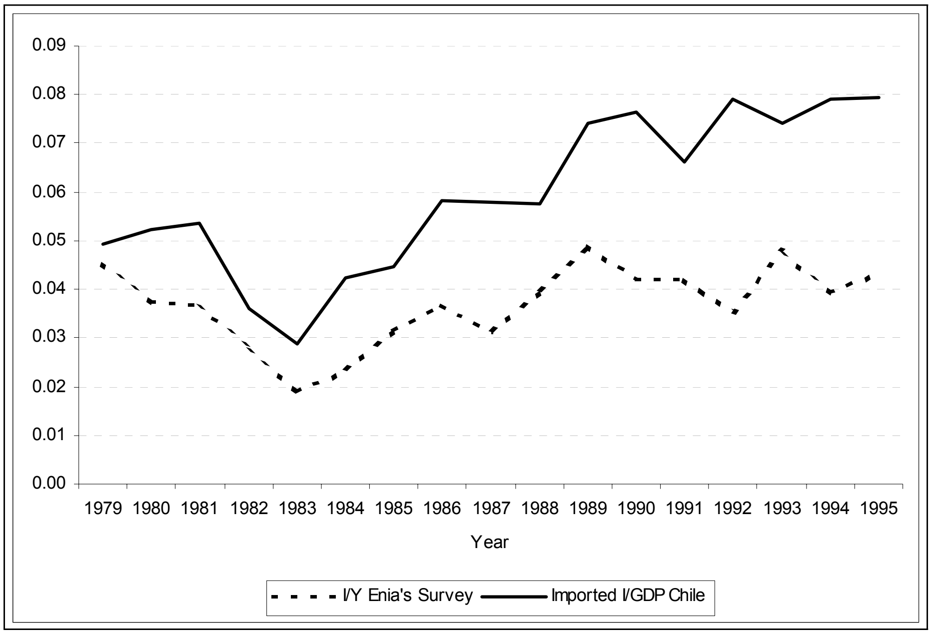

Figure 4:

To examine this issue further, we now turn to the plant level regression analysis. We augment the previous regression framework to include measures of plant level investment activity. To focus on investment activity that is clearly expansionary rather than simple replacement investment, we following Cooper, Haltiwanger and Power (1999) and measure unusual bursts of investment activity – investment spikes – as rates of investment above 20%. Because we expect technology to be adopted through new machinery rather than investment in capital structures we measure separate investment spikes for both machinery investment (spikem) and building investment (spikeb). To allow for the possibility that investment today increases labor demand tomorrow, we include both the current and lagged investment spike in the regression. To distinguish between new investment and the overall level of capital intensity, we also include the log of the capital-output ratio and the log-level of output in the regression. We again include the patent variables as technology indicators (results are similar if we include the full set of technology indicators). To control for unobserved heterogeneity, we consider regressions with industry-level versus plant-level fixed effects. Regression results are reported in Table 7.

Table 10: Investment Spikes				
	Wage Bill Share		Employment Share	
Explanatory variables	(1)	(2)	(3)	(4)
lk_va	0.001	0.028**	0.000	0.034**
	(0.009)	(0.009)	(0.009)	(0.009)
lva	0.100**	0.032**	0.058**	0.005
	(0.007)	(0.009)	(0.008)	(0.010)
lpat_vax	0.037**	0.010**	0.043**	0.015**
	(0.007)	(0.004)	(0.008)	(0.004)
pat_ind	0.313**	0.097**	0.339**	0.135**
	(0.044)	(0.023)	(0.049)	(0.024)
spikem	-0.009	-0.001	-0.005	0.001
	(0.010)	(0.007)	(0.011)	(0.007)
spikem_1	-0.010	-0.004	-0.013	-0.006
	(0.009)	(0.007)	(0.011)	(0.007)
spikeb	-0.003	0.004	-0.001	0.002
	(0.012)	(0.010)	(0.014)	(0.010)
spikeb_1	0.008	0.002	-0.004	-0.008
	(0.012)	(0.010)	(0.014)	(0.010)
Year effects	Yes	Yes	Yes	Yes
Industry effects[1]	Yes	No	Yes	No
Plant effects	No	Yes	No	Yes
Observations	26,434	26,435	26,409	26,410
R-squared	0.394	0.743	0.303	0.729

Robust standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
[1] Location, business type, and four-digit industry dummies.

The results reported in Table 7 clearly indicates that investment spikes – bursts of new investment at the plant level – have no discernable effect on either the wage-bill or employment share of skilled workers. This is true for investment spikes in both machinery and building investment, and holds regardless of whether or not we include fixed effects at the industry or plant level. While it is often difficult to find statistically significant effects in regressions that include plant-level fixed effects, the lack of any statistically significant effect of investment spikes on skilled labor demand in the regression that includes only industry effects strikes us as particularly strong evidence against a systematic link between new investment and the relative demand for skilled labor.

Table 11: Total Imported Capital from OECD Countries

	Wage Bill Share		Employment Share	
Explanatory variables	(1)	(2)	(3)	(4)
lk_va	0.004	0.026**	0.002	0.032**
	(0.008)	(0.008)	(0.009)	(0.008)
lva	0.101**	0.029**	0.056**	0.001
	(0.007)	(0.008)	(0.008)	(0.009)
lpat_vax	0.036**	0.009*	0.042**	0.013**
	(0.006)	(0.004)	(0.007)	(0.004)
pat_ind	0.313**	0.089**	0.335**	0.124**
	(0.042)	(0.022)	(0.047)	(0.023)
lik_tot	-0.025	-0.008	-0.030+	-0.007
	(0.016)	(0.007)	(0.017)	(0.007)
Year effects	Yes	Yes	Yes	Yes
Industry effects[1]	Yes	No	Yes	No
Plant effects	No	Yes	No	Yes
Observations	28,843	28,844	28,815	28,816
R-squared	0.394	0.734	0.302	0.717

Robust standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
[1] Location, business type, and four-digit industry dummies.

The investment spike data is constructed at the plant level and does not distinguish between investment in imported and domestically produced capital goods. To construct a measure of imported capital investments we must therefore rely on industry aggregates. Imported capital goods are reported by type of investment good but not by industry of destination. Although capital goods imports are not explicitly designated to individual industries it is possible to use the input-output structure of the Chilean manufacturing sector to allocate the various capital imports to each industry using input-output weights. Following this procedure, we construct a measure of imported capital goods for each four digit industry in our sample (details are provided in the appendix). When measuring capital imports, we confine our attention to imported capital goods from OECD countries – capital imports from these countries are most likely to reflect new technologies (we find similiar results using all capital imports however). We again augment our plant-level regression framework to include this four-digit industry measure of imported capital goods (lik_tot).

Regression results for this exercise are reported in table 8. Again we find no evidence of a positive effect of investment on either the skilled-worker wage-bill share or employment share. When using industry-level fixed effects we in fact find a small negative effect of imported capital goods on skilled labor demand. Controlling for heterogeneity at the plant-level, we find no relationship between investment in imported capital goods and skilled labor demand. For robustness, we have also considered limiting the imported capital goods to high technology industries such as computers, and we have considered instrumenting the imported capital goods measure using industry-specific exchange rates. Neither of these exercises alters our conclusion however.

6 Conclusions

In this paper we analyze the determinants of the relative demand for skilled workers at the plant level for the Chilean manufacturing sector over the period 1979-1995. This period immediately follows a period of dramatic change in the underlying structure of the Chilean economy – a rapid trade liberalization and a variety of economic reforms that inaugaurated a sustained free-market, trade-oriented economic environment that stands in stark contrast to the high-tariff, regulated environment of the late 1960's and early 1970's. The onset of this period is characterized by a rapid increase in the relative demand for skilled workers that coincides with an extensive increase in the adoption and use of new technologies as measured by patents used in manufacturing. Decompositions of both the wage-bill and employment share of skilled workers show that the rise in skilled labor demand can be entirely attributed to within industry changes. Both of these pieces of evidence are consistent with the hypothesis that the relative demand for skilled workers is linked to technology adoption at the plant level owing to skill-biased technological change. Regression analysis confirms these findings. In particular, we document a strong positive relationship between the relative demand for skilled workers and technology adoption at the plant level, a finding which is robust to controlling for unobserved plant-level heterogeneity. Finally, we examine the relationship between skilled labor demand, plant-level investment and imported capital goods. We find no evidence to support the notion that trade liberalization increased the demand for skilled workers by reducing the cost of imported capital goods that embodied new technologies.

An unanswered question is why the rate of technology adoption increased following the trade liberalization and resulting market-oriented reforms. Although we have not identified explicit policies that facillitated the adoption of new technologies, we suspect that the free market orientation of the Chilean economy encouraged technology adoption at the plant-level. Further investigations of this issue are left to future research.

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