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Skill Premium in Chile: Studying Skill Upgrading in the South

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JEL Classification Number: O3, J31

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Keywords: Wage premium, Skill Upgrading, Openness, Skill Biased Technical Change, Chile.

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1 Introduction

A large body of the literature has analyzed the evolution of the skill premium in developed and developing economies. In the case of developed countries, the literature presents different explanations: some stress the role of some form of endogenous skill-biased technical change (SBTC) and others emphasize trade openness and other related factors as the driving force of the evolution of the skill premium (e.g. see Acemoglu, 2002a; Autor et al. 2003; Beaudry and Green 2003; Feenstra and Hanson, 2001; Grossman and Rossi-Hansberg, 2008; and Krugman, 2000, among others). In the case of developing economies, while SBTC could also play a role, a body of research emphasizes the effects of globalization and reforms such as trade openness on wage differentials, albeit the results are not uncontroversial (see a recent complete review of the literature in Goldberg and Pavnick, 2007). Relatedly, some papers have tried to relate the developed-world SBTC phenomenon with the evolution of skill upgrading in developing countries (see Acemoglu, 2003a for a theoretical motivation, Goldberg and Pavnick, 2007 for a review of the arguments and some evidence, and Berman et al., 1998 and Berman and Machin, 2000 for cross-country evidence).

Chile is a particularly interesting case of study because it corresponds to a small open economy that has undergone a significant change in its economic structure over the last 40 years. I estimate that the skill premium has increased significantly from about 82 log points in the 1960s to an average of 120 and 123 log points in the 1980s and 1990s, respectively. In turn, the relative supply of skilled workers increased significantly over the same period: the ratio of college graduate equivalents to high-school graduate equivalents (my basic measure of the relative supply of skilled workers) has increased from 0.14 in the 1960s to 0.21 and 0.31 over the 1980s and the 1990s, respectively. This suggests that the relative demand for skilled workers has increased significantly in the latter period in most sectors of the economy. In addition, I estimate than most of the skill upgrading corresponds to a within sector phenomenon (ie. skill upgrading took place in most sectors of the economy). Robbins (1994b) presents similar results for a shorter period (1957-1992).

I provide macro and sectoral evidence of a close relationship between patterns of skill upgrading in the US and Chile. The correlation between skill upgrading in different countries may be a result of different theoretical mechanisms. First, a model of skill upgrading along the lines of Acemoglu (2003a) would imply that the patterns of skill-upgrading in developing economies –which adopt new technologies created in developed countries–should be correlated with the skill premium in developed economies, controlling for the relative supply of skilled and unskilled workers in developing countries. Second, some papers emphasize changes in the organizational structure of production, related to outsourcing and the international fragmentation of production (eg., Feenstra and Hanson, 1996, 1997, 2003; Hsieh and Woo, 2005). In these papers, trade in intermediate inputs could create within-sector substitution of production implying within sector skill-upgrading both in developed and developing countries. Third, other papers emphasize that firms that compete in tradable sectors are either more productive or produce higher quality goods or are pressed by international competition to adopt technologies that are more productive, and to do so they perform activities that are more skill intensive (eg. Melitz, 2003; Bernard and Jensen, 1997; Stokey, 1996; Verhoogen, 2008). This phenomenon may happen at the same time in developed and developing countries thus explaining a pattern in which skill upgrading is correlated across countries. It is worth noting that this explanation only applies to tradable sectors.

My sectoral evidence also suggests that the correlation between skill-upgrading in both countries is significant in both tradable sectors and non-tradable sectors that are highly intensive in imported capital, thus confirming a potential role for international trade in the transmission of patterns of skill upgrading. Results are robust to controls for changes in taxes and in FDI investment at the sectoral level. However, the fact that the patterns of skill upgrading in both countries are correlated *also in non-tradable* sectors suggests that the identified correlation between skill upgrading in Chile and the US cannot be explained only by the trade-related theories mentioned above that emphasize outsourcing or the skill-intensity of tradable activities. In contrast, for the non-tradable sectors that are not intensive in imported capital, sectoral results seem to suggest that most of the skill upgrading is related to the sectoral stock of FDI, suggesting the importance of direct transmission of skill intensive activities–although the estimates are not precisely estimated (see a related discussion in Goldberg and Pavnick, 2007).

Finally, I take a semi-structural approach and present macro-time series estimates that are consistent with some of the implications of the Acemoglu (2003a) model of international transmission of skill-upgrading. In particular, I relate the time-series estimates of the correlation between the wage premium in Chile and skill upgrading in the US to the numerical predictions of the Acemoglu (2003a) model in which technologies are developed in the North –and respond to the skill bias of the North– and used in the South. Results imply that the *size* of the elasticity I obtain for the case of Chile is not statistically different from what I expect from the Acemoglu model. This evidence, however non-conclusive, suggests that the patterns I observe in the data for Chile may be explained by a model in which skill upgrading in developing countries responds to a pattern of SBTC in developed countries.

In this paper, I extend the research on wage inequality in emerging countries in four dimensions. First, I extend previous analyses using sectoral data that study the correlation between skill upgrading across countries (Berman et al., 1998 and Berman and Machin, 2000) by including sectors outside manufacturing, data from a longer span of time (1960-2000), and, more importantly, by using a unique panel data set which allows me to control for time and sector specific effects. To my knowledge, no other paper has studied this correlation using information *within* sectors of the same country for a *long* period of time. The more related papers by Berman et al. (1998) and Berman and Machin (2000) only report positive correlations between measures of skill upgrading in high and middle income countries for the manufacturing sector in the 1970s and 1980s.[1]

Second, I explicitly study the correlation between the wage premium and skill upgrading in a developed country (the US) and a developing country (Chile), controlling for other determinants of skill upgrading, using macro time series econometrics. While some papers have implemented time series analyses of the wage premium in emerging countries (eg. Beyer et al., 1999), to my knowledge this is the first paper that correlates proxies for and determinants of skill upgrading in the US with the evolution of skill upgrading in developing countries. Third, given that my sectoral and macro results are consistent with a number of different theories of the transmission of skill upgrading across countries (Goldberg and Pavnick, 2007), I present sectoral evidence suggesting that the correlation between skill upgrading is also present in non-tradable sectors, implying that theories that relate skill-upgrading with outsourcing or the skill-intensity of tradable activities can be alone explain the data for Chile. Moreover, I extend the literature by studying factors –such as the degree of tradability and the share of imported capital in total sectoral capital–that may differentially affect skill-upgrading of different sectors and, therefore, may allow to understand the mechanisms behind the estimated correlations. Fourth, my use of a semi-structural approach to relate my time-series estimates of the correlation between the wage premium in Chile and skill upgrading and trade openness in the US to the numerical predictions of the Acemoglu (2003a) model is also a contribution to the literature and an alternative way of distinguishing across different theories.[2]

[1]While most correlations in Berman and Machin (2000) are positive, the correlations are statistically significant only for about 10% of the countries.

[2]Unfortunately, I know of no explict model that relates patterns of skill-upgrading in a country with

The related empirical literature also includes several studies for Chile and other developing countries. For the case of Chile,[3] Robbins (1994a) and Gindling and Robbins (2001) argue that the increase in the relative demand for skilled workers is related to trade openness and, in particular, to technology transfers from abroad, which is also emphasized by Pavcnik (2000) and Sánchez-Páramo and Schady (2002). The basic finding of this literature is a correlation between variables such as imports of capital goods or the FDI stock and skill upgrading at the micro level. Some evidence, however, contradicts these explanations. First, Robbins (1994a) and Gindling and Robbins (2001) focus the analysis on the 1975-1990 period, but the big increase in the relative demand for skilled workers takes place only since the mid 1980s, while trade openness increases significantly in the 1970s. Second, the evidence on the role of technology transfer has no clear causal interpretation. It may well be the case that some sectors have a higher demand for skilled workers and for equipment capital because of a third (omitted) variable. Recent evidence in Fuentes and Gilchrist (2004) and Pavcnik (2003) show that the correlation between skill upgrading and proxies for technology transfers disappears after controlling for plant fixed effects. Putting it differently, *within-firm* variation does not support the claim that measures of technology adoption from abroad are per se correlated with changes in the relative demand for skilled workers. Results in my paper confirm this recent evidence for sectors that are tradable or highly intensive in imported capital–notice that the papers by Fuentes and Gilchrist (2004) and Pavcnik (2003) use data only for the manufacturing sector, which tends to be tradable and also highly intensive in imported capital– but my evidence also points out that sectoral FDI seems to be correlated with skill upgrading for non-tradable sectors that do not use much imported capital.

Finally, even though a literal interpretation of my results is about correlation between skill upgrading in the US and Chile, I interpret my results as a correlation between skill upgrading in developed countries and Chile. The basic evidence supporting this idea is three-fold: (i) a high correlation between skill upgrading at the sectoral level in all high income countries, as documented in Berman et al. (1998), (ii) a high share of the domestic supply of non-transportation machinery and equipment comes from developed countries–I document that about 85% of the supply of non-transportation machinery and equipment in Chile is imported (using data from the Chilean output-input matrix

the other theoretical arguments for a correlation between skill upgrading in two countries. Therefore, I cannot contrast my estimates with alternative models.

[3] Recent papers for other Latin American countries include Bustos (2005) and Galiani and Sanguinetti (2003) for Argentina, Attanasio et al. (2004) for Colombia, and Pavcnik et al. (2004) for Brazil.

for 1996), and (iii) most imports of non-transportation machinery and equipment (and data-processing machines) come from the US (the most important exporter country to Chile in each year and category) and OECD countries (using data from Feenstra et al., 2005). In other words, Chile seems to be using technologies that mostly come from a group of developed countries that are producing skill-biased technologies.

The paper is organized as follows. Section 2 presents a group of stylized facts related to the evolution of the skill premium in Chile. Section 3 presents sectoral evidence from 1960 to 2000. Section 4 presents macro time series evidence and a simplified version of the theoretical model in Acemoglu (2003a) to evaluate, using a semi-structural approach, whether this model could explain the correlation between skill upgrading in Chile and the US and Section 5 briefly concludes.

2 Stylized Facts

2.1 Time-Series Evidence: A CES Framework

To organize the discussion on the determinants of the skill premium in Chile I use the Katz and Murphy (1992) framework that allows me to compose the skill premium between its demand and supply components. Competitive markets and a nested CES production function that includes three inputs (skilled and unskilled labor and physical capital)[4] imply that the (log of the) wage premium is given by:

$$\ln \varpi = \ln \frac{\pi}{(1-\pi)} + \left(\frac{\sigma - 1}{\sigma}\right) \ln \frac{A_h}{A_l} - \frac{1}{\sigma} \ln \frac{H}{L}. \tag{1}$$

where A_h is skilled labor augmenting technological change, H is skilled labor, A_l is unskilled labor augmenting technological change, L is unskilled labor, π is a technology parameter that can be interpreted as the share of work activities allocated to skilled labor, and σ is the elasticity of substitution between skilled and unskilled workers.

I take expression (1) to the data. Data on the skill premium come from the Employment Survey of the University of Chile that spans the period from 1957 to 2002.[5] This survey collects a representative sample of the Santiago Metropolitan Area (which represents about 40% of the Chilean population and 50% of the Chilean GDP). The University of Chile survey is the only source of microdata that covers a long period of time and has been widely used in studies of wage inequality in Chile (e.g. Contreras, 2002; Gindling and Robbins, 2001; Robbins, 1994a and 1994b; Sánchez-Páramo and Schady, 2002) and has the additional advantage of providing reasonably comparable data on

[4] A simple microfoundation for this aggregate production function is in the Acemoglu (2003a) model.
[5] Data on educational variables are missing for 1959, and 1963-1964.

monthly earnings, hours worked, economic sectors, and educational categories. Robbins (1994b) argues that this sample is a good representation of the labor market in Chile, except for the agriculture and mining sectors.

I focus on the monthly earnings of full-time (working at least 35 hours) wage and salary workers aged 16 to 64 years. To compute an estimate of the skill premium I apply the methodology of Autor et al. (2005). I focus on male workers and run a regression of (log) earnings on dummies for eight education groups (no education, primary-school drop-out, primary-school graduate, high-school drop-out, high-school graduate, college drop-out, college graduate, and other education), and a cubic on experience for each education category for each year.[6] Using the estimated regression I predict the wage for each observation for each year and define the log skill premium as the difference between the average log wage for the group of college graduates and high-school graduates using fixed-weighted averages of the 32 education $\times$ experience sub-group means (using the average share of total hours worked for each sub-group from 1957 to 2002 as weights) to adjust for compositional changes within each group.[7]

I use the difference between college and high-school graduates as my main proxy for the difference between skilled and unskilled workers. There are some alternative measures of skilled and unskilled workers: college graduate equivalents and primary school graduate equivalents (used in Beyer et al, 1999), non-production and production workers (used in Berman et al., 1998 and Berman and Machin, 2000), for instance. My choice to use college graduate and high-school graduate equivalents to measure skilled and unskilled workers over these two alternative classifications is motivated by two facts:

1. The Chilean data suggest that the big increase in wages occurs for workers having more than 12 years of formal schooling (as also reported in Contreras, 2002). Putting it differently, this evidence implies that the correlation between the college-secondary wage premium and college-primary wage premium should be high. Indeed, the correlation between the college-secondary and the college-primary wage premium is 0.73 (0.83) in levels (first-differences) using data from 1957 to 2002.

2. The use of production and non-production workers as a proxy for skilled and unskilled workers in many papers is motivated by the lack of educational categories in most datasets more than by a direct preference for this classification of workers.

[6]It is worth noting that the estimated regressions are not meant to identify causal effects of the observables on wages–instead, the regressions are just meant to be the best linear predictions of wages on observables, i.e. these regressions are meant to be used to *predict* wages on observables.

[7]The four experience categories are 0-9, 10-19, 20-29, and 30+ years.

> The available evidence suggests that while using production and non-production workers identifies similar *trends* as using education categories (e.g. Feenstra and Hanson, 2001), the wage premium of non-production to production workers only corresponds to a small increase in the inequality between skilled and unskilled workers (e.g., Katz and Autor, 1999 for the US and Bustos, 2005 for Argentina). Therefore, I prefer a more direct proxy for skilled and unskilled workers.

The relative supply of skilled labor is defined as the ratio of hours worked by college graduate equivalents to high-school graduate equivalents. The supply of college graduate equivalents is the sum of hours worked by college graduates plus half the sum of hours worked by college drop-outs. The supply of high-school graduate equivalent workers is the sum of hours worked by high-school graduates, plus half the sum of hours worked by college and high-school drop-outs, plus 25% the sum of hours worked by primary-school graduates and by workers with other education, plus 12.5% the sum of hours worked by primary-school drop-outs. These weights roughly correspond to the average differences in returns to each group obtained in the above mentioned regressions.

Figure 1 shows the evolution of the skill premium in Chile from 1957 to 2000 (the skill premium is defined as the log difference between average wages of college graduates and high-school graduates). The skill premium presents a relatively volatile behavior before 1985. Initially, there is an increase in the skill premium in the mid 1960s, followed by a marked decreased at the same time of the first oil crisis and the collapse of the political and economic situation in Chile in the mid 1970s. Next, the skill premium returns to its previous level of the mid 1960s and starts a slow increase that seems to stabilize around the mid 1980s. My estimates of the evolution of the wage premium are roughly comparable to the estimates of the wage premium reported by Beyer et al. (1999) for 1960-1996, Contreras (2002) for 1958-1996, and Gindling and Robbins, 2001 for 1957-1992.[8]

The high level of the skill premium in Chile is a second factor that clearly emerges from Figure 1. The skill premium in Chile is about 110 log points on average over the 1965-2000 period, while the same variable for the US is about 50 log points over the same period. OECD (2004) reports skill premia of an average of 41 log points for a group of countries in the 1997-2002 period, with a maximum of 82 log points in the case of Hungary. IADB (2004) reports that the skill premium in Chile is high even in

[8] The correlation between my indicator of the wage premium and the estimate of the same variable implicit in Contreras (2002) is 0.91. I construct the log of the wage difference between a college graduate and a high-school graduate as $5\beta_t$, where β_t is the estimate of the return of an additional year of education for college students for year t in a Mincerian regression, as reported in Contreras (2002).

comparison to other Latin American countries. To compare the wage premium in Chile with that of a sample of countries, in Table 1 I present estimates of the wage premium in 79 countries, taken from Acemoglu (2003b), Banerjee and Duflo (2005), and Caselli and Coleman (2006). Chile is located in the percentile 87th (85th) [71th] of the distribution of the wage premium if I consider the complete sample of countries (I exclude Sub-Saharan countries) [I include only Latin American countries]. All in all, these results show that the wage premium is significantly high in Chile, even in comparison to the highly unequal Latin American countries.[9]

Figure 2 presents the evolution of the relative supply of skilled to unskilled labor during the same period. The relative supply increases slowly until around the early 1990s and takes off afterwards, after the big expansion of the higher education sector in the mid 1980s and the long period of high and positive economic growth.[10]

Regarding the level of the relative supply of skilled workers, differences with the US are evident. While the relative supply was about 0.30 in the case of Chile in the 1990s, the same variable reached a value of about 1.10 for the US. Certainly, this low relative supply could explain the above mentioned differences in skill premium. Using the series on skill premium and relative supply in Chile and the US (from Autor et al. 2005), and equation (1), I construct an estimate of the share of the difference in skill premium between both countries that is explained by differences in their relative supplies. This is given by: $\frac{-\frac{1}{\sigma}\left(\ln\frac{H}{L}-\ln\frac{H}{L}_{US}\right)}{\ln\varpi-\ln\varpi_{US}}$.

To implement this exercise, I need an estimate of σ. Most papers in the literature report estimates in the interval between 1 and 2 (see Ciccone and Peri, 2005 for a review of estimates for the US and other countries and Robbins, 1996 for estimates for a group of small open economies). My estimates for Chile using cointegration techniques produce estimates of σ in the interval from 1.40 to 1.70.[11] Given these results and the similarity

[9] In order to make estimates comparable with other countries in Table 1, I use the average return to attending school –and not the marginal return of attending college– in Contreras (2002) to compute the wage premium for Chile. If I used the marginal return, the wage premium would be 1.07 for Chile.

[10] A valid concern to the construction of the relative supply is that a big share of the increase in the relative supply during the 1990s is related to the creation of the so-called private universities. If graduates from these universities did not receive an education comparable to the education provided by the old universities, my estimates of the relative supply may be biased. To address this concern, I study whether cohort effects vary significantly for workers of the cohorts that enter the market after 1985, using a framework similar to Card and Lemieux (2001)–i.e. including year, cohort, and age effects. Results, available upon request, suggest that cohort effects are not significantly different for the youngest cohorts. Robbins (1994b) and Gindling and Robbins (2001) present similar results using different methodologies. In addition, results in Rappoport et al. (2004) suggest that differences in wages among the old and new universities are not clearly significant, depending on the career and the geographic area.

[11] I estimate (1) using cointegration techniques because unit root tests suggest that the skill premium and the relative supply have a unit root. Estimates are obtained from a system of the skill premium

to results in other papers, I choose $\sigma = 1.50$, which is around the mean value of the available estimates and the preferred estimate in Ciccone and Peri (2005).

Results suggest that differences in the relative supply explain 113 and 117% of the differences in skill premium between Chile and the US in the 1965-2000 period and in the 1990s, respectively. In other words, only differences in the relative supply of skilled labor can explain completely the differences between Chile and the US in terms of skill premia. This is a very important initial macro stylized fact for the analyses I perform below on the correlation between skill upgrading in Chile and the US.

Using data on skill premia, the relative supply of skilled labor, and equation (1) is possible to construct an estimate of the relative demand for skilled labor as:

$$D\left(\frac{H}{L}\right) \equiv \ln \varpi + \frac{1}{\sigma} \ln \frac{H}{L}. \tag{2}$$

Figure 3 presents the evolution of the estimated demand in Chile from 1957 to 2000. Results confirm the presumption that the relative demand increased significantly in the 1980s and 1990s to explain a flat skill premium in the presence of a rising relative supply. There is also an increase in the mid 1970s and a subsequent slow increase of demand until the mid 1980s. A noteworthy aspect of the figure is that the big increase in relative demand observed in Chile seems to be more significant in the period starting in the mid-1980s. The liberalization period that starts in 1975 is accompanied by only a mild increase in the relative demand. Section 4.2 presents a detailed discussion of the factors behind the increase in demand using a time series approach.

Finally, I extend the analysis to include both equipment capital (K_e) and capital structures (K_s) in a CES production function (closely following the derivations in Goldin and Katz, 1998 and Krusell et al. 2000). Under this assumption and taking a log-linear approximation, the skill premium is given by (see the derivations in Krusell et al. 2000):

$$\ln \varpi \cong \frac{w_h}{w_l} = (1-\lambda)\frac{\sigma-\rho}{\sigma(\rho-1)}\left(\frac{K_e}{A_h H}\right)^{\frac{\rho-1}{\rho}} + \frac{\sigma-1}{\sigma}\ln\left(\frac{A_h}{A_l}\right) - \frac{1}{\sigma}\ln\left(\frac{H}{L}\right).$$

where σ is the elasticity of substitution between unskilled and skilled labor, which is the same value as the elasticity of substitution between equipment capital and unskilled labor; ρ is the elasticity of substitution between skilled labor and capital, and λ is a technology parameter that can be interpreted as the share of work activities allocated

and the relative supply as endogenous variables, dummies for 1972 and 1973 as exogenous variables, and assuming a linear trend in the data. The system is estimated using a vector error correction model including one lag. In this case the estimate of σ is 1.40 (with a t-test of 3.88) If I include the real minimum wage and unemployment in the equation, my estimated σ increases to 1.70 (with a t-test of 2.70). Detailed estimates are available upon request.

to skilled labor vis-a-vis capital equipment.[12] This expression implies that skill-capital complementarity requires $\sigma > \rho$.

In this case the relative demand for skilled labor is given by:

$$D\left(\frac{H}{L}\right) \equiv \ln \varpi + \frac{1}{\sigma} \ln \frac{H}{L} - (1-\lambda) \frac{\sigma - \rho}{\sigma(\rho - 1)} \left(\frac{K_e}{A_h H}\right)^{\frac{\rho-1}{\rho}}. \tag{3}$$

This extension is important because the Chilean economy has experienced a process of capital deepening in the last years. Several papers suggest that equipment capital is more complementary to skilled labor than to unskilled labor (e.g., Krusell et al. 2000). This expression suggests two important points. First, equipment capital deepening increases the skill premium as long as $\left(\frac{K_e}{A_h H}\right)$ increases. An empirical problem is having a good measure of the quality of equipment capital. Chumacero and Fuentes (2002) argue that available measures of the price of equipment capital in Chile are not good measures of its quality. To overcome this problem, I use two assumptions regarding the evolution of the quality of equipment capital: (i) the evolution of the quality of equipment capital in Chile is similar to the evolution of the same variable in the US and (ii) the evolution of the quality of equipment capital is similar to the evolution of A_h.

Figure 4 presents the evolution of $\left(\frac{K_e}{A_h H}\right)$ from 1957 to 2000. Strikingly, results suggest that the level of this variable is *not significantly higher* in the post-liberalization period and only starts increasing significantly over the 1990s. Putting it differently, in spite of the big increase in equipment capital, the supply of skilled labor also increased significantly, and, therefore, the ratio of both variables does not increase.[13]

The second point that is derived from (3) is that the effect of capital deepening on the skill premium is likely to be small. To see this, following Krusel et al. (2000), I take the time derivative of (3) and, after some algebraic manipulations, the growth rate of the relative demand is:

$$g_D \equiv \left(\frac{\sigma - 1}{\sigma}\right)(g_{A_h} - g_{A_l}) = g_{\varpi} + \frac{1}{\sigma}(g_H - g_L) - \theta(g_{K_e} - g_H - g_{A_h}). \tag{4}$$

where g denotes growth rate, and $\theta = (1-\lambda)\frac{\sigma-\rho}{\sigma\rho}\left(\frac{K_e}{A_h H}\right)^{\frac{\rho-1}{\rho}}$. Using results in Krusel et al. (2000), estimates from Figure 4, and a value for the capital share of 1/3, I get

[12] I use the Krusell et al. 2000 production function, ie.:

$$Y = K_s^{\alpha}\left[\mu\left(\lambda(A_h H)^{\frac{\rho-1}{\rho}} + (1-\lambda) K_e^{\frac{\rho-1}{\rho}}\right)^{\left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\rho}{\rho-1}\right)} + (1-\mu)(A_l L)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma(1-\alpha)}{\sigma-1}}.$$

[13] Braun and Braun (1999) make a related point. They argue, contrary to the conventional wisdom, that the ratio of physical to human capital is relatively low in Chile.

that $\theta = 0.20$. Therefore, the relative contribution of equipment capital deepening to explain any increase in the demand is probably small, even if the figures in Figure 4 are underestimated.[14]

Figure 5 presents the evolution of the growth rate of the skill premium using (4) to disentangle the contributions of relative supply, equipment capital deepening, and relative demand. The results suggest that the two major contributors are relative supply and demand. Capital deepening has a minor impact on the evolution of the skill premium. The big increase in the skill premium during the 1980s was an outcome of the combination of a strong demand with a relative slowdown in the growth rate of the relative supply. By contrast, the small increase in the 1990s was a consequence of an important expansion in the relative supply, which almost fully compensates for a strong demand.

In summary, the accounting framework presented in this section suggests that, from a macro perspective, both supply and demand play a significant role in explaining the evolution of the skill premium in Chile. This paper focuses on explaining the evolution of the relative demand for skilled labor. An analysis of the evolution of the relative supply in Chile will be the focus of future research, probably using detailed microdata.

2.2 Between and Within Sector Decomposition

The sectoral composition of the demand for skilled labor adds another group of important stylized facts to understand the evolution of the skill premium in Chile (Gindling and Robbins, 2001). Subsection 2.1 suggests changes in the relative demand for skilled workers are significant especially in the 1980s and 1990s. It remains to be analyzed whether the increase in demand is a between or a within sector shift. This decomposition is particularly useful to disentangle several theories. For instance, an increase in the relative demand that is a consequence of inter-sectoral reallocation of workers would support theories that emphasize the reallocation of skilled labor toward sectors more intensive in skilled labor as suggested by Matsuyama (2005). By contrast, a within-sector increase in the relative demand would be consistent with theories that emphasize skill bias technical change.

To implement this decomposition, I focus on the evolution of the skilled labor share of the wage bill as a proxy for skill upgrading at the sectoral level.[15] I decompose both

[14] The result that equipment capital does not have a first order importance to explain the skill premium is also reported by Berman et al. (1994) and Acemoglu (2002).

[15] This proxy is equal to the relative demand if $\sigma = 1$. See Autor et al. (1998) for a detailed discussion.

components of skill upgrading according to Berman et al. (1994) and Autor et al. (1998):

$$\Delta\left(S_{jt}\right)=\sum_{k}\left(\Delta S_{kt}\gamma_{jk}\right)+\sum_{k}\left(\Delta\gamma_{jkt}S_{k}\right),$$

where S_{jt} is the group j (i.e., skilled and unskilled labor) share of the wage bill in year t, S_{jkt} is the group j share of the wage bill of sector k in year t, $S_{kt}=\sum_{j}S_{jkt}$ is the sector k share of the wage bill in year t, $\gamma_{jkt}=\frac{S_{jkt}}{S_{kt}}$ is the group j share of the wage bill of sector k in year t, $\gamma_{jk}=\frac{\gamma_{jkt}+\gamma_{jkt-1}}{2}$, and $S_{k}=\frac{S_{kt}+S_{kt-1}}{2}$. Thus, the first term in the right-hand side of the equation captures the change in the skilled labor share of the wage bill related to reallocation of the demand for workers between sectors, and the second term reflects within-sector changes.

I implement this decomposition using data on 21 two-digit ISIC sectors from the Employment Survey of the University of Chile for 1960, 1970, 1980, 1990, and 2000. Appendix 1 describes the construction of the sectors and Table 2 presents annual changes in the skilled labor share of the wage bill.

The results confirm the macro evidence in that while skill upgrading in the 1960s and 1970s is roughly constant, this variable seems to increase significantly during the 1980s and the 1990s. More importantly, the within component of skill upgrading explains between 75 and 93% of skill upgrading for the economy. Results for the tradable sector suggest sizeable skill upgrading in the 1980s jointly with a small increase in the 1990s. In the tradable sectors, the within sector component also explains more than 90% of skill upgrading.[16] [17]

All these results suggest that within sector skill upgrading explains the major part of the increase in the relative demand observed in Chile during the 1980s and 1990s, while between sector changes are small, thus confirming previous evidence for shorter periods (Gindling and Robbins, 2001).

[16] A valid concern about this decomposition is that I use only 2-digit sectors, so a lot of reallocation could be between 3- and 4-digit industries. I do not have more disaggregated sectors in the University of Chile dataset. If I use the ENIA survey that includes a 4-digit disaggregation of economic sectors (but only includes manufacturing plants from 1979 to 2001 and a rough proxy of skilled workers–e.g., non-production workers), I find that within sector reallocation explains 93 and 96% of skill upgrading in the 1980s and the 1990s, respectively. Still, the recent paper by Schott (2004) suggests that using very detailed information on reallocation between firms producing the same goods gives a more important role for the between -firm component.

[17] Wacziarg and Wallack (2004) and Caballero (2005) present evidence that inter-sectoral reallocation does not significantly increase after trade and other reforms that liberalize markets.

2.3 Technology Imports to Chile

In this sub-section, I present descriptive evidence of (i) the share of the supply of non-transportation machinery and equipment that is imported and (ii) the main importers of machinery and equipment.

The input-output tables of Chile allow me to estimate the share of the domestic supply of machinery and equipment that is imported. Using the 1996 version of the tables (Banco Central de Chile, 2001), I estimate that about 85% of the non-transportation machinery and equipment is imported. In addition, using data on the exporter of non-transportation machinery and equipment imports to Chile from Feenstra et al., (2005), I estimate the share of imports of machinery and equipment that comes from the US and OECD countries (as a proxy for developed countries). I also present estimates for data-processing equipment, probably a more direct proxy of skill-biased technologies. Results in Table 3 suggest that most machinery and equipment come from developed countries. The US alone sends more than 50% of the non-transportation machinery and equipment imported to Chile, and OECD countries account for at least two-thirds of import share of machinery and equipment and data-processing machines.

3 Sectoral Evidence

In this section I study whether there is a positive correlation between skill upgrading in the US and skill upgrading in Chile as suggested by several theories. I use sectoral data on the share of the wage bill of skilled labor in Chile and the US from 1960 to 2000, as a proxy for skill upgrading. I use 20 two-digit sectors that are consistent across time and across countries. The University of Chile Employment Survey provides the sectoral classification in Chile at the two-digit level. I follow Robbins (1994b) in the definition of sectors and in the exclusion of public employees and the agriculture and mining sectors. For the US, I use the 1% Census Public Use Micro Samples of the decennial censuses of 1960, 1970, 1980, 1990, and 2000 provided by the Integrated Public Use Microdata Series (IPUMS) of the University of Minnesota to construct wage bill shares for each sector. I follow Autor et al. (1998) and extend their methodology to the 2000 census, using information from the Census Bureau. This methodology produces 142 four-digit sectors in the US that are consistent from 1960 to 2000. Next, I aggregate these US four-digit sectors to have two-digit sectors that are consistent with the Chilean data.

The basic estimating equation is:

$$S_{jt} = \beta_1 + \beta_2 S_{jt}^{US} + D_j + D_t + \upsilon_{jt}, \tag{5}$$

where S_{jt}^{US} is skilled labor share in the US (recall that S_{jt} is the skilled labor share in Chile), D_j are sector fixed effects, D_t are year dummies, and v_{jt} is an error term. This regression allows me to identify the effect of skill upgrading in the US from *within-sector* variation and after controlling for time effects. This is important because not including these time and sector fixed effects may generate spurious estimates if there are sectoral differences in skill intensity or time effects that are common to both countries. This is an important extension of the literature because the using of panel data allows me to identify *within* sectors patterns –i.e. after controlling for sector invariant characteristics and by wide-economy patterns–of skill upgrading.

The first column of Panel A of Table 4 presents results of these estimates. The proxy for skill upgrading in the US is significantly correlated with skill upgrading in Chile, after controlling for sector and year dummies. This result supports the hypothesis that patterns of skill upgrading in the US are correlated with patterns of skill upgrading in Chile at the sectoral level. In addition, the effects are economically relevant. The implicit elasticity is about 0.83 (evaluated at the average values of the shares in the US and Chile). This elasticity predicts an increase of about 150% in the skilled-labor share of the wage bill in Chile, which is equal to 170% from 1960 to 2000. Putting it differently, the estimated elasticities imply that the evolution of skill upgrading in the US explains about 90% of the skill upgrading in Chile from 1960 to 2000.

The following column of Panel A present results of studying whether the effects are different for sectors with different intensities of imported capital. Using data from the input-output tables of Chile (Banco Central de Chile, 2001) I split the sectors among those above and below the median in the share of imported capital to total capital. Results imply that the correlation between skill upgrading in the US and Chile is not statisticaly different from 0 for sectors that are not intensive in imported capital, but the estimates are statistically different from 0 for sectors that use high levels of imported capital (the estimate for these sectors is equal to 2.383–the sum of 0.643 and 1.740–the p-value of the estimate is 0.08). This result gives additional support to the idea that the correlation between skill upgrading in both countries is happening mainly through technology transfers and not through the other channels mentioned in the introduction. The elasticities implicit in the estimates imply that skill upgrading in the US explains about 120% of skill upgrading in Chile in the sectors intensive in imported capital.

The next column present results now studying whether there are different correlations for tradable and non-tradable sectors. The estimates imply that the correlations between patterns of skill upgrading in the US and Chile are not statistically different for tradable and non-tradable sectors. The point estimates are bigger for tradable sectors, but they are not statistically different from the estimates for non-tradable sectors. This lack of statistical significance may be a consequence of the small number of sectors I have available in this dataset, so I leave this an open question for future research.

One exercise I perform is to study whether within non-tradable sectors there is a difference across sectors depending on the intensity of imported capital. I present the results of this exercise in the last column of Panel A in Table 4.[18] Results imply that the correlation between skill upgrading in the US and Chile in non-tradable sectors intensive in imported capital is statistically and economically significant, while the same is not true for non-tradable sectors that do not use a lot of imported capital. This result is important because it implies that skill upgrading in the US is correlated with skill upgrading in Chile outside tradable sectors and, therefore, suggesting that explanations of this correlation just due to international trade in goods cannot alone explain my results.[19]

In Panel B of Table 4 I extend previous estimates to control for potential effects of the process of economic liberalization that took place in Chile since the mid 1970s. I focus on trade liberalization and FDI at the sectoral level, measuring trade liberalization using an index of implicit taxes at the sectoral level (from Hachette, 1998) and measuring FDI at the sectoral level as (the log of) the stock of real FDI divided by employment in each sector.[20] I start presenting regressions that control for FDI. In column 1 I estimate equation (5) for the complete sample. My estimate for the impact of skill upgrading in the US barely changes when controlling for the FDI stock, which has a positive but insignificant impact on skill upgrading in Chile. Next, in column 2, I run the same specification as in column 2 of Panel A but now controlling for the FDI stock. Results are not precisely estimated but seem to suggest that for sectors non-intensve in imported capital the stock of FDI has a positive and economically relevant impact on skill upgrading, although the estimated coefficient is only marginally significant (p-value of 0.13). Something very similar happens in non-tradable sectors (column 3). Results

[18]In my sample, all tradable sectors have imported capital above the median of the distribution.

[19]In additional regressions, I use a second proxy for skill upgrading in the US: an index of computer use at the sectoral level, from Autor et al., 1998. Several papers use this as a proxy for technological changes that increase the demand for skilled workers (e.g., Autor et al., 1998, Berman and Machin, 2000). Given that the data on computer use are not available for 1960 and 1970, I assume that computer use was 0 in those periods. Results are very similar to the results presented here and are available upon request.

[20]My procedure to construct the stock of real FDI is as follows. I use annual flows of FDI, deflate the flows using the investment deflator, and use an annual depreciation rate of 10%. I have sectoral data on FDI only from 1974. To extend the series backwards I use total FDI flows from Diaz et al. (2005) and the sectoral shares observed in 1974-1975 to allocate the total flows to each sector.

confirm my previous evidence from the last column of Panel A: skill upgrading in the US has a positive and significant impact on the same variable in Chile. Finally, in column 4, I present estimates for tradable sectors after controlling for tariffs at the sectoral level. Results again are not precisely estimated, but a look at the point estimated imply that this variable does not have a significant impact on skill upgrading in Chile at the sectoral level (notice that I am already controlling for time effects, so this variables captures within sector variation of tariffs).[21]

Overall, these results suggest that for tradable sectors and non-tradable sectors intensive in imported capital, skill upgrading in Chile is significantly correlated with the same variable in the US. This suggests that the correlation between skill upgrading in Chile and in the US is not just driven by explanations that emphasize the potential role of outsourcing and the international fragmentation of production (eg., Feenstra and Hanson, 1996, 1997, 2003; Hsieh and Woo, 2005). In contrast, for non-tradable sectors that do not import much foreign capital, FDI seems to be associated with skill upgrading in Chile.

4 A Simple Semi-Structural Approach using Time Series Data

The previous evidence, while suggestive of the main implications of models that emphasize the international transmission of skill-upgrading trough technology transfers (Acemoglu, 2003a), may still be explained by the alternative models discussed before. Thus, to have a better sense of how the Acemoglu (2003a) model fits the data, in this section I relate the time-series estimates of the correlation between the wage premium in Chile and skill upgrading in the US to the numerical predictions of the Acemoglu (2003a) model in which technologies are developed in the North –and respond to the skill bias of the North– and used in the South.

The model analyses the balanced growth path (BGP) conditions of the evolution of a world where a country (the US) develops technologies and developing countries (like Chile) adopt technologies. The basic empirical implication of the model for this paper is that the bias of technology in the US affects the bias of technology in a country like Chile. In addition, the model also predicts that trade openness in the US increases the skill premium in Chile. I use three important assumptions in the model. First, I assume that inventors in the US do not receive payments for technologies that are adopted in developing countries.[22] Second, I solve the model considering the extreme

[21] I have also tried interactions between skill upgrading in the US and the FDI stock and tariffs and they are not statistically significant.

[22] This assumption is related to the absence of intellectual property rights in developing countries,

case of a closed economy in the goods market.[23] Third, I assume, as do most papers in this literature, that domestic relative supply is exogenously given.[24]

4.1 The Model

Consider an economy with $J+1$ countries (J developing countries and the US) and H and L are skilled and unskilled labor, respectively. All consumers in all countries have identical linear preferences:

$$U(t) \equiv \int_t^\infty \exp\left(-r\left(\tau - t\right)\right) C\left(\tau\right) d\tau,$$

where $C\left(\tau\right)$ is consumption at time τ and r is the discount rate. Consumption is defined over a CES aggregate of skilled and unskilled intensive goods, C_h and C_l, respectively:

$$C^j = \left[\gamma \left(C_l^j\right)^{\frac{\epsilon-1}{\epsilon}} + (1-\gamma)\left(C_h^j\right)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{6}$$

where ϵ is the elasticity of substitution between the two goods. Assuming the goods market is competitive, the relative price of both goods is:

$$p^j \equiv \frac{p_h^j}{p_l^j} = \frac{1-\gamma}{\gamma}\left(\frac{C_h^j}{C_l^j}\right)^{-\frac{1}{\epsilon}}.$$

which make it unprofitable for inventors to develop technologies that are "appropriate" for developing countries. In the case of Chile, this assumption may appear as extreme because institutions in Chile are more developed than in most emerging countries. A (likely complementary) alternative assumption is that foreign inventors have to pay a fixed cost in order to start developing technologies abroad. In this case, small countries, like Chile, may not have enough size to make it profitable for frontier inventors to develop new technologies. In this case, only an improvement in intellectual property rights implemented by a (big) group of developing countries creates an incentive to invent technologies that are appropriated for developing countries.

[23] I do so basically to simplify the analysis. This assumption does not change the main implications of model (i.e., a correlation between skill premia in the US and Chile and the effect of openness in the US on the skill premium in Chile). The main implication of assuming a closed economy is that I allow the domestic relative supply of skilled labor to have a negative effect on the skill premium. The alternative polar case, complete trade openness, generates the prediction that the domestic relative supply of skilled labor has no impact on the skill premium (as long as the country is small, and technology adoption does not depend on the domestic relative supply of skilled labor). As previously stated, the significance of the domestic supply to understand the evolution of the skill premia in open economies is supported by the data. Robbins (1996) presents evidence that domestic relative supply has a negative and significant effect for a group of middle-income open economies. Moreover, the estimates for Chile I present in section 2.1 are not significantly different from other estimates of the elasticity of substitution between skilled and unskilled labor. Desjounqueres et al. (1999) present simple generalizations of the basic open economy model that allow domestic supply to have an impact on the skill premium.

[24] Regarding this assumption, Acemoglu (2003a, Appendix C) shows that the major conclusions of the model are robust to adding this factor. The main additional implication for the case of Chile is that an increase in the relative supply of skilled labor in the US, through its effect on technology and the skill premium, encourages the accumulation of skills in Chile.

Assuming a closed economy, we have that $C_s^j = Y_s^j$, for $s = h, l$, where Y_s is the production of the $s-$intensive good. Then,

$$p^j = \frac{1-\gamma}{\gamma}\left(\frac{Y_h^j}{Y_l^j}\right)^{-\frac{1}{\epsilon}}. \tag{7}$$

The production functions of each good in country j are:

$$Y_l^j = \int_0^1 \widetilde{q}_l^j(i)^\beta x_l^j(i)^{1-\beta}\left(L^j\right)^\beta di, \text{ and } Y_h^j = \int_0^1 \widetilde{q}_h^j(i)^\beta x_h^j(i)^{1-\beta}\left(H^j\right)^\beta di \tag{8}$$

where $x_s^j(i)$ and $\widetilde{q}_h^j(i)$ are the quantity and the quality (productivity) of machine i used with workers s in country j, respectively. These production functions assume a continuum of different types of machines or intermediates used by unskilled labor and a different group of machines used by skilled labor and present constant returns to scale at the firm level. In contrast, the aggregate production possibilities set presents increasing returns to scale because the quality of technologies is determined endogenously.

Therefore, the demand for machines is:

$$x_s^j\left(\widetilde{q}_s^j(i)\right) = \left[\frac{(1-\beta)\,p_s^j}{\chi_s^j\left(\widetilde{q}_s^j(i)\right)}\right]^\beta \widetilde{q}_s^j(i)\, S^j, \text{ with } s = h, l; \text{and } S = H, L. \tag{9}$$

$\chi_s^j\left(\widetilde{q}_s^j(i)\right)$ is the rental price of machine i of quality $\widetilde{q}_s^j(i)$ for skill type s in country j.

Firms in all countries can use domestic or foreign technologies, accordingly to the following rule:

$$\widetilde{q}_h^j(i) = \begin{cases} q_h^j(i) \\ \theta^j q_h^{j'}(i) \text{ if } j \neq j' \end{cases}, \text{ with } \theta^j \leq 1\,,$$

where q_h^j is the most advanced technology developed in country j. This expression implies that countries can use domestic technologies or adopt foreign technologies. The important point is that foreign technologies may not be "appropriate" for the firms in country j (in the sense of Basu and Weil, 1998; Acemoglu and Zilibotti, 2001; and, Caselli and Coleman, 2006), and, therefore, the productivity of machines produced in country j' may be lower when used abroad.[25]

Technical progress is related to R&D activities (Aghion and Howitt, 1998). Innovating over a machine of quality q creates a new vintage with quality λq ($\lambda > 1$). One unit

[25] Various papers present evidence that developing countries tend to suffer from using inappropriate technologies (given their endowments)–e.g., Acemoglu and Zilibotti, 2001; Berman and Machin, 2000; Caselli and Coleman, 2006. For instance, Caselli and Coleman (2006) present estimates that the degree of inappropriateness of using US technologies decreases per-capita income (e.g. Chile would lose 20% of its GDP by using US technologies).

of R&D spending (in terms of the final good) produces a flow rate of innovation $z\phi(z)$. R&D cost (also in terms of the final good) of innovating z over a machine of quality q is Bqz ($B = \beta(1-\beta)\lambda$), with $\phi'(z) < 0$ and $\phi(z)z$ is increasing in z.

The inventor of a new machine in the US becomes the monopolist of this technology. Given the demand functions in (9), the monopolist price is a constant markup over the marginal cost.[26] Finally, as in Acemoglu (2003a), I assume that machines fully depreciate after a year and the marginal cost of producing each machine is constant and equal to $(1-\beta)^2$. This implies that $\chi^U = (1-\beta)$. There is a monopolist in the developing country that can copy US technologies at a small cost ξ.

Assuming that $(1-\beta)\theta^j q_s^U(i) > q_s^j(i)$ for all $s = h, l$ and j and i, firms in developing countries will use US technologies.[27] This result implies that (1) $\widetilde{q}^j(i) = \theta^j q_s^U(i)$, (2) the domestic monopolist will set χ^U (the monopolist price), and (3) there will be no R&D in developing countries in the future, so the developing country will always adopt US technologies.

Substituting χ^U in (9) and the demands in the production function, I get:

$$Y_s^j = \left(p_s^j\right)^{\frac{(1-\beta)}{\beta}} \widetilde{Q}_s^j S^j, \text{ for } s = h, l; \text{and } S = H, L; \tag{10}$$

where $\widetilde{Q}_s^j = \int_0^1 \widetilde{q}_s^j(i)\,di$, for $s = h, l$. Notice that (10) is equivalent to a linear technology, where the productivity of each unit of labor is proportional to the state of technology ($\widetilde{Q}_s^j$) and to product prices.[28]

Computing the marginal productivity of labor, using the fact that $\widetilde{q}^j(i) = \theta^j q_s^U(i)$, the skill premium in this economy is:

$$\omega^j = \left(p^j\right)^{\frac{1}{\beta}} \frac{Q_h^U}{Q_l^U}.$$

Using (7), (8), and (10) implies that the relative price is:

$$p^j = \left[\left(\frac{1-\gamma}{\gamma}\right)^{-\varepsilon} \frac{Q_h^U}{Q_l^U}\frac{H^j}{L^j}\right]^{-\frac{\beta}{1+\beta(\varepsilon-1)}}. \tag{11}$$

[26] Assuming that $\lambda > (1-\beta)^{\frac{(1-\beta)}{\beta}}$.

[27] This assumption implies that it is more efficient to use US technologies even if the US monopolist sells the machine at the monopolist price and the domestic monopolist sells the machine at the marginal cost.

[28] Expression (10) is equivalent to the CES aggregate production function implicit in the derivation of (1) if $A_s^j = \left(p_s^j\right)^{\frac{(1-\beta)}{\beta}} \widetilde{Q}_s^j$ and $\alpha = 0$.

Therefore, the skill premium is:

$$\omega^j = \left[\left(\frac{1-\gamma}{\gamma} \right)^{-\varepsilon} \frac{H^j}{L^j} \right]^{-\frac{1}{1+\beta(\varepsilon-1)}} \left(\frac{Q_h^U}{Q_l^U} \right)^{\frac{\beta}{1+\beta(\varepsilon-1)}}. \tag{12}$$

This expression highlights the positive relationship between technological bias in the US and the skill premium in developing countries and the negative effect of the domestic relative supply on the skill premium.

Finally, I determine the equilibrium skill bias of technology in the US to find a closed-form for the skill premium in the US. I will not present all the derivations to save space, but I use the following two results from Acemoglu (2003a):

$$\left(p^U\right)^{\frac{1}{\beta}} \frac{H^U}{L^U} = \Theta\left(\frac{z_h}{z_l}\right), \text{with } \Theta'\left(\frac{z_h}{z_l}\right) > 0. \tag{13}$$

$$\frac{Q_h^U}{Q_l^U} = \left(\frac{1-\gamma}{\gamma}\right)^{\varepsilon} \left(\frac{H^U}{L^U}\right)^{\beta(\varepsilon-1)}. \tag{14}$$

The first result is the basic prediction of the theory of induced technical change of Acemoglu (2002b). Relative research effort toward skilled labor increases if the relative price increases (the price effect) or the relative supply of skilled labor increases (the market size effect). Given that there is a relationship between both forces as highlighted by (11), the second expression presents the reduced-form relationship between the relative supply of labor in the US and the relative bias of technology. Notice that in this model the relative bias of technology in all the countries is completely determined in the US.

These expressions, jointly with the previous structure described in the model, lead to proposition 1 in Acemoglu (2003a):

$$\omega^U = \left(\frac{1-\gamma}{\gamma}\right)^{\varepsilon} \left(\frac{H^U}{L^U}\right)^{\beta(\varepsilon-1)-1}, \text{ and} \tag{15}$$

$$\omega^j = \left(\frac{1-\gamma}{\gamma}\right)^{\varepsilon} \left(\frac{H^U}{L^U}\right)^{\frac{(\beta(\varepsilon-1))^2}{\beta(\varepsilon-1)+1}} \left(\frac{H^j}{L^j}\right)^{-\frac{1}{\beta(\varepsilon-1)+1}}. \tag{16}$$

Finally, substituting (15) in (16) and taking logs I get:

$$\ln \omega^j = a \ln\left(\frac{1-\gamma}{\gamma}\right) + b \ln\left(\omega^U\right) + c \ln\left(\frac{H^j}{L^j}\right), \tag{17}$$

where $a = \frac{\beta(\varepsilon-1)-2}{\beta(\varepsilon-1)-1}$, $b = \frac{(\beta(\varepsilon-1))^2}{(\beta(\varepsilon-1))^2-1}$,and $c = -\frac{1}{\beta(\varepsilon-1)+1}$.

Two basic results can be derived from (17):

- A positive relationship between the skill premium in the US and in countries that use technologies developed in the US. Moreover, b is expected to be greater than 1.

- A negative impact of the domestic relative supply on the skill premium.[29]

Finally, this model also implies that periods of trade openness in the US create additional incentives to produce skill-biased technologies. The basic intuition of this result comes from expression (13). If $\frac{H^U}{L^U} > \frac{H^j}{L^j}$for all countries j, then periods of trade openness in the US increase the relative price of skilled-intensive goods in the US on impact. This creates an incentive to increase the relative effort in developing new machines to be used in the production of skilled-intensive goods. Thus, in the new steady-state equilibrium, there is an increase in the degree of bias of the new technologies.[30] The main implication for my paper is that, in addition to the relationships highlighted by (17), I expect a positive correlation between skill premium in Chile and trade openness in the US. I take this as a more exigent test of the model I will be testing in a semi-structural way in what follows.

4.2 Time Series Evidence

I study whether the Chilean macro time-series support the theoretical predictions of equation (17): a positive correlation between the skill premium in Chile and the US. In addition, I also test whether an increase in trade openness in the US should increase the skill premium in Chile, which is a more demanding test of the model in Acemoglu (2003a).

The model outlined in section 4 is highly stylized. Therefore, I extend the model to include other (potentially competing) determinants of the relative demand for skilled labor in the empirical analysis. I include a group of determinants that have been studied in other papers in the main estimating equations of this section. The other variables are:

- A proxy for the relative price of goods intensive in unskilled labor to capture potential Stopler-Samnuelson effects. In particular, I use a wholesale price index

[29] Equation (16) suggests the alternative empirical implication that the relative supply in the US should be positively correlated with the wage premium in Chile. Unfortunately, the relative supply of skilled labor in the US is empirically hard to distinguish from a deterministic trend, so time series exercises using this variable are hard to interpret.

[30] This theory also predicts that along the BGP the relative price of skill-intensive goods remains constant in the US. This result is supported by the empirical literature. See Acemoglu (2003a) for more details.

of textile goods in Chile as a proxy for the relative price of unskilled-labor intensive goods (Beyer et al., 1999).[31]

- Proxies for policy reforms (Behrman et al., 1997). Namely, I use a structural reform index and the subindices of trade and financial liberalization constructed by Morley et al. (1999) and Lora (2001).[32]

- The evolution of (the log of) real minimum wage to control for labor market regulations (Autor et al., 2005). I use and extend data from Bravo and Contreras (1999).

- Finally, the output gap to capture the potential effect of short-run fluctuations on the skill premium (Autor et al., 2005). I use the Hodrik-Prescott filter to construct my measure of output gap.[33]

A transformation of equation (17) is the basic specification for the empirical analysis I develop here using time-series methods. In particular, I focus on analyzing the relative demand for skilled labor, i.e. $D^j \equiv \ln \omega^j - c \ln \left(\frac{H^j}{L^j}\right)$. To implement this I assume $c = \frac{1}{1.5}$–i.e., the same assumption I use to compute relative demand in equation (2).[34]

My basic estimating equation is therefore:

$$D_t = \alpha_1 + \alpha_2 t + \alpha_3 cycle_t + \alpha_4 \log(w_{\min t}) + \alpha_5 SR_t + \alpha_6 \log(p_t) + \alpha_7 \log(\varpi_t^{US}) + \varrho_t, \quad (18)$$

where D is the relative demand obtained from (2) at time t, $cycle$ is the output gap, $w_{\min}$ is the real minimum wage, SR is an index of structural reforms, p is an index of the relative price of unskilled goods, ϖ^{US} is the skill premium in the US (I use the estimates reported in Autor et al., 2005), and ϱ is an error term.

I estimate equation (18) using both levels and first differences because of the known limitations of unit root tests.[35] In this case, for instance, Phillips-Perron tests are

[31] Notice that my model suggests that including the relative price of skill-intensive goods and the relative labor supply is redundant. In a more general model, however, both variables could be included.

[32] My procedure to construct a structural reform index that covers the complete period in my sample is as follows. First, I extend the Morley et al. (1999) index to cover the 1996-1999 period using the Lora (2001) index. Second, I extend the combined index to cover the 1960-1969 and 2000-2002 periods. To do that, I run a regression of the combined index on trade openness and financial depth. I use the predicted coefficients and observed variables to extend the index. Data on trade openness and financial depth come from Diaz et al. (2005).

[33] Using the unemployment rate instead of the output gap yields similar results.

[34] Notice that using a CES production function, as I do in (2), or the Acemoglu (2003a) model, as I do in (17), produces exactly the same relative demand as long as $c = \sigma$. If instead of using my estimate of $\sigma = 1.5$, I use an estimate of c using data from the US, my empirical estimates are roughly equivalent, see footnote 37 below.

[35] In the case of first-difference equations I include an $MA(1)$ to control for potential over-differentiation of the series if the true process is $I(0)$.

inconclusive because they suggest that D has either a unit root or is stationary around a deterministic trend.

The results of estimating equation (18) are presented in columns (1) of tables 5 and 6. All the estimated coefficients are in line with the previous literature, but the only coefficient that is statistically significant at the conventional levels is the skill premium in the US.[36] Notice that the fact that both level and first-difference equations report very similar results suggesting that spurious correlation between the skill premium in the US and the relative demand in Chile is not driving the results. An additional way of testing whether results could be driven by spurious correlation is using Granger-causality tests. I can not reject the hypothesis that the relative demand in Chile does not Granger-cause the relative skill premium in the US (p-value=0.47), *but* I reject the hypothesis that the skill premium in the US does not Granger-cause the relative demand in Chile (p-value=0.03).

The estimated coefficient of the skill premium in the US is positive and significant and implies that a 1% increase in the skill premium in the US increases the relative demand in Chile by between 2.1 and 2.4%. This is consistent with the prediction of equation (17) that this elasticity should be bigger than one. More importantly for my semi-strcutural testing of the model, I cannot reject that the magnitude is equal to the value predicted by equation (17) (with p-values of 0.17 and 0.14 for first-difference and level estimates, respectively), given the available estimates of $\beta(\varepsilon-1)-1$ for the US. The coefficient $\beta(\varepsilon-1)-1$ captures the long-run relationship between the relative supply and the skill premium in the US (see equation 15). I find an estimate for this variable of 0.15 for the US (Acemoglu, 2003a reports an estimate of 0.13). Thus, I cannot reject that $\frac{\partial D}{\partial \log(\varpi_t^{US})} = \frac{\left(\widehat{\beta(\varepsilon-1)}\right)^2}{\left(\widehat{\beta(\varepsilon-1)}\right)^2-1}$, where $\beta(\widehat{\varepsilon-1})$ comes from estimates of the long-run relationship between the relative supply and the skill premium in the US. Thus, I take this as empirical support for the model I am using to interpret the results: my results do not only present the correct sign, but also, and more importantly, present a size which is consistent with the theoretical model.[37]

I test the second implication of the model in section 4: the level of trade openness in the US should positively affect the relative demand for skilled labor in Chile. In

[36]Results do not change significantly if I replace the structural reforms index by indices of trade and financial liberalization.

[37]If instead I use an estimate of $c=\beta(\varepsilon-1)$ to construct my measure of D in equation (17), results of the effect of wage premium in the US on the relative demand in Chile are roughly equivalent to those presented in column 1 of Tables 5 and 6. (the estimate in Table 5 changes to 2.14–with a standard error of 0.83– and the estimate in Table 6 becomes 2.49–with a standard error of 0.71.

column (2) of Tables 5 and 6, I replace the skill premium by a proxy of trade openness in the US–the ratio of the sum of real exports and imports to GDP. Results support this theoretical prediction: an increase in trade openness in the US increases the skill premium in Chile. As discussed in section 4, the intuition of this result is that in periods of trade opening in the US, the price of skill intensive goods increases, which creates an incentive to produce technologies that are biased towards skilled labor.

Finally, for completeness I present estimates including both the wage premium in the US and trade openness in the US in columns (3) of Tables 5 and 6–notice that in the model, the wage premium in the US is determined by trade openness in the US so these estimates have no clear theoretical interpretation. Both variables are positive and (marginally) significant.[38]

The time series evidence suggests that the relative demand for skilled workers in Chile responds to the behavior of skill upgrading in the US. These effects are not only statistically significant, but also economically relevant. The skill premium in the US increased about 25 log points between 1980 and 2000. The estimated elasticity implies an effect of between 50 and 60 log points on the relative demand in Chile, which increased about 80 log points over the same period. Similarly, trade openness in the US increased about 80 log points over the last 20 years, and the estimated effect on the relative demand in Chile is above 100 log points.[39]

The timing of the evolution of the relative demand for skilled labor in Chile also supports the empirical results in this section. As Figure 6 shows, the big increase in the relative demand in the mid 1980s occurs at the same time as the increase in the relative wage in the US and the period of major trade openness in the US. As previously discussed, the 1980s was the period when skill upgrading was stronger in Chile.

[38] Other (non-reported) exercises include substituting total wages for predicted wages, including equipment imports, including dummies for 1972-1973, including measures of strikes, including alternative indices of institutions (such as democracy), and including interactions of the skill premium in the US and the supply of skills in Chile. Results were not significant. The last exercise is interesting because a model where technology adoption depends on skill intensity in Chile would suggest a higher correlation of demand and supply for skills as the economy becomes more skill intensive. The evidence does not support this view.

[39] As a comparison, if I use the point estimates in Tables 5 and 6 for the other variables, the improvement in the structural reform index and the drop in the relative price labor-intensive goods from 1980 to 2000 explain an increase in the relative demand of about 5 and 30 log points, respectively. Obviously, the confidence intervals around these values are huge, given that the point estimates are not statistically significant.

5 Conclusions

This paper studies the evolution of the skill premium in Chile over the last 40 years. I use macro and sectoral evidence to analyze the behavior of the skill premium and to test implications of the skill-biased technical change hypothesis in a country that uses technologies developed abroad.

Macro evidence suggests that, after some fluctuations in the 1960s and 1970s, the skill premium increased in the 1980s and has remained roughly constant since then. Specifically, the skill premium has increased significantly from about 82 log points in the 1960s to an average of 120 and 123 log points in the 1980s and 1990s, respectively. I use a CES aggregate production function a la Katz and Murphy (1992) and Krusel et al. (2000) to decompose the evolution of skill premium into supply and demand factors. The relative supply of skilled workers has increased from 0.14 in the 1960s to 0.21 and 0.31 in the 1980s and the 1990s, respectively. Therefore, the relative demand for skilled workers increased significantly in the latter period.

Results using the CES framework also suggest that differences in the relative supply can completely explain the differences between Chile and the US in the level of the skill premium. This is a first piece of suggestive evidence supporting the theory I present to explain the technological bias in Chile. In my model, the relative bias of the technology in Chile should be the same as in the US (as representative of developed countries technologies). This piece of evidence supports that claim.

Next, I present sectoral evidence that supports the view that most of the skill upgrading in Chile over the last 40 years has taken place in all the sectors of the economy (i.e., within-sector skill upgrading). I provide macro and sectoral evidence of a close relationship between patterns of skill upgrading in the US and Chile. Results using sectoral data, in turn, present the same conclusion: skill upgrading in Chile is correlated with skill upgrading in the US, after controlling for sector and time effects. The sectoral evidence also suggests that this effect is relatively stronger in the tradable sectors and in sectors that are intensive in imported capital. Namely, my estimates imply that skill upgrading in the US explains about 103% and 60% of skill upgrading in Chile in the tradable and nontradable sector, respectively.

Next, as predicted by my model, macro time-series regressions imply that a proxy for the relative demand for skilled labor in Chile is significantly correlated with skill premium and trade openness in the US, after controlling for the traditional determinants presented in the literature. Moreover, the point estimates I find for Chile are not statistically different from the estimates the model imply. Consistently with these results, my time series estimates imply that the evolution of the skill premium in the US can explain between 60 and 75% of the increase in relative demand in Chile from 1980 to 2000.

6 Appendix A: Construction of Economic Sectors using the University of Chile Employment Survey

The University of Chile survey allows me to construct 21 2-digit ISIC sectors that are comparable over the complete period. The detailed definitions of the sectors come from DECON(undated). Using this information, I follow Robbins (1994b) and exclude from my sample the agriculture, mining, and public administration and military sectors. Table A.1 presents the sectors included in the analysis.

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Table 1: College/High School Wage Premium (in log points)

Middle East and North Africa		East Asia and Pacific		Developing Europe and Central Asia		Latin America and the Caribbean		High Income	
Mean	0.48	**Mean**	0.53	**Mean**	0.29	**Mean**	0.62	**Mean**	0.37
Median	0.48	**Median**	0.52	**Median**	0.27	**Median**	0.59	**Median**	0.36
Kuwait	0.23	Vietnam	0.24	Hungary	0.22	Peru	0.41	Italy	0.14
Egypt	0.39	Hong Kong	0.31	Yugoslavia	0.24	Costa Rica	0.43	Norway	0.20
Tunisia	0.40	Indonesia	0.35	Estonia	0.27	Honduras	0.47	Netherlands	0.26
Iran	0.58	Sri Lanka	0.35	Poland	0.35	Dominican R.	0.47	Australia	0.27
Morocco	0.79	Malaysia	0.47	Russian Fed.	0.36	Venezuela	0.47	Israel	0.28
Sub-Saharan Africa		Nepal	0.49			Uruguay	0.49	UK	0.30
Mean	0.49	Thailand	0.58			Argentina	0.52	Germany	0.30
Median	0.48	China	0.61			Bolivia	0.54	Denmark	0.30
Ethiopia	0.16	Philippines	0.63			Paraguay	0.58	Canada	0.32
Zimbabwe	0.28	Singapore	0.66			Ecuador	0.59	Belgium	0.33
Uganda	0.30	Korea	0.68			Nicaragua	0.61	Austria	0.36
Cameroon	0.30	Taiwan	0.95			Brazil	0.61	Spain	0.36
Ghana	0.44	**South Asia**				Panama	0.69	Finland	0.37
Sudan	0.47	**Mean**	0.53			Chile	0.69	Switzerland	0.38
Burkina Faso	0.48	**Median**	0.51			Colombia	0.70	Greece	0.38
South Africa	0.51	Sri Lanka	0.35			El Salvador	0.70	Portugal	0.43
Zambia	0.53	Nepal	0.49			Mexico	0.70	Sweden	0.46
Kenya	0.57	India	0.53			Guatemala	0.75	France	0.50
Cote d'Ivoire	0.66	Pakistan	0.77			Jamaica	1.44	USA	0.50
Tanzania	0.69							Cyprus	0.61
Botswana	0.96							Japan	0.66

Source: Author's calculations using data from Contreras (2002) for Chile; Autor et al. (2005) for the US; and Acemoglu (2003b), Banerjee and Duflo (2005), and Caselli and Coleman (2006) for other counties.

Table 2: Skill Upgrading in Chile, Sectoral Evidence

	Total (1)	Between (2)	Within (3)	Within Share (3)/(1)
	Panel A: All Sectors			
1970 – 1961	0.58%	0.15%	0.44%	75.90%
1980 – 1970	0.65%	0.07%	0.58%	89.30%
1990 – 1980	1.34%	0.18%	1.17%	87.61%
2000 – 1990	0.84%	0.07%	0.77%	92.04%
	Panel B: Tradable Sectors			
1970 – 1961	0.13%	-0.01%	0.14%	108.85%
1980 – 1970	0.64%	0.06%	0.59%	91.81%
1990 – 1980	1.98%	0.11%	1.89%	95.50%
2000 – 1990	0.36%	0.00%	0.35%	99.56%
	Panel C: Non-Tradable Sectors			
1970 – 1961	0.75%	0.21%	0.56%	73.85%
1980 – 1970	0.56%	-0.02%	0.58%	103.68%
1990 – 1980	1.15%	0.24%	0.93%	81.00%
2000 – 1990	0.88%	-0.01%	0.89%	100.91%

Table 3: Share of Developed Economies in Imports of Non-Transportation Machinery and Equipment

	US	OECD
1962		
Machinery and Equipment	50.01%	98.50%
Data Processing Machines	31.23%	99.26%
1970		
Machinery and Equipment	44.68%	94.33%
Data Processing Machines	24.12%	80.21%
1980		
Machinery and Equipment	38.23%	86.29%
Data Processing Machines	45.23%	91.58%
1990		
Machinery and Equipment	25.23%	83.27%
Data Processing Machines	46.97%	77.64%
2000		
Machinery and Equipment	38.79%	74.28%
Data Processing Machines	55.91%	67.56%

Sources: Author's calculations using Feenstra et al. (2005)

Table 4: Sectoral Evidence, including the Wage Bill in the US

	Panel A			
Sample:	Full Sample	Full Sample	Full Sample	Non-tradable Sectors
	(1)	(2)	(3)	(4)
Skilled Labor Share in the US	1.584**	0.643	1.272*	0.643
	(0.738)	(0.833)	(0.714)	(0.912)
Skilled Labor Share in the US × Dummy for AMIC		1.740		3.012***
		(1.533)		(0.946)
Skilled Labor Share in the US × Dummy for tradable sector			0.828	
			(2.001)	
Year Dummies	Yes	Yes	Yes	Yes
Sector Dummies	Yes	Yes	Yes	Yes
Observations	100	97	100	52
R^2	0.780	0.783	0.788	0.854

	Panel B			
Sample:	Full Sample	Full Sample	Full Sample	Tradable Sectors
	(1)	(2)	(3)	(4)
Skilled Labor Share in the US	1.508*	0.066	0.965	1.807
	(0.835)	(0.653)	(0.789)	(2.419)
Skilled Labor Share in the US × Dummy for AMIC		2.084		
		(1.912)		
Skilled Labor Share in the US × Dummy for tradable sector			0.793	
			(2.461)	
FDI stock	0.003	0.009	0.005	-0.005
	(0.004)	(0.005)	(0.004)	(0.010)
FDI stock × Dummy for AMIC		-0.012		
		(0.009)		
FDI stock × Dummy for tradable sector			-0.011	
			(0.010)	
Tariffs				-0.103
				(0.370)
Year Dummies	Yes	Yes	Yes	Yes
Sector Dummies	Yes	Yes	Yes	Yes
Observations	94	92	94	45
R^2	0.770	0.793	0.789	0.591

Notes: Standard errors clustered at the sector level in parenthesis. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Dummy for AMIC is a dummy variable equals to 1 when a country is above median of imported capital (AMIC). Tariffs is equal to Tariff ×1,000.

Table 5: Time-Series Evidence: Estimation in Levels

Dependent variable: Relative Demand			
Variable	(1)	(2)	(3)
Wage Premium in the US	2.081		1.874
	(0.828)		(0.750)
Openness in the US		1.331	1.353
		(0.421)	(0.570)
Output Gap	0.674	0.454	0.563
	(0.458)	(0.553)	(0.465)
Real Minimum Wage	-0.294	-0.346	-0.499
	(0.199)	(0.198)	(0.220)
Structural Reforms	0.371	0.243	0.941
	(0.465)	(0.330)	(0.401)
Price of unskilled goods	-0.275	-0.254	-0.329
	(0.186)	(0.146)	(0.178)
Trend	0.001	0.019	-0.051
	(0.012)	(0.876)	(0.023)
N	38	40	38
R^2	0.853	0.876	0.883
ADF-test	-4.629	-4.604	-5.677

Notes: Newey-West HAC standard errors in parenthesis.

Table 6: Time-Series Evidence: Estimation in First Differences

Dependent variable: Relative Demand			
Variable	(1)	(2)	(3)
Wage Premium in the US	2.397		2.142
	(0.877)		(0.062)
Openness in the US		1.597	1.381
		(0.447)	(0.590)
Output Gap	0.721	0.438	0.538
	(0.560)	(0.550)	(0.443)
Real Minimum Wage	-0.345	-0.388	-0.531
	(0.250)	(0.213)	(0.233)
Structural Reforms	0.478	0.390	1.036
	(0.370)	(0.338)	(0.405)
Price of unskilled goods	-0.317	-0.245	-0.365
	(0.207)	(0.219)	(0.179)
Trend	-0.006	-0.034	-0.058
	(0.013)	(0.017)	(0.024)
N	38	40	37
R^2	0.252	0.293	0.482

Notes: Newey-West HAC standard errors in parenthesis.

Figure 1: The Wage Premium in Chile

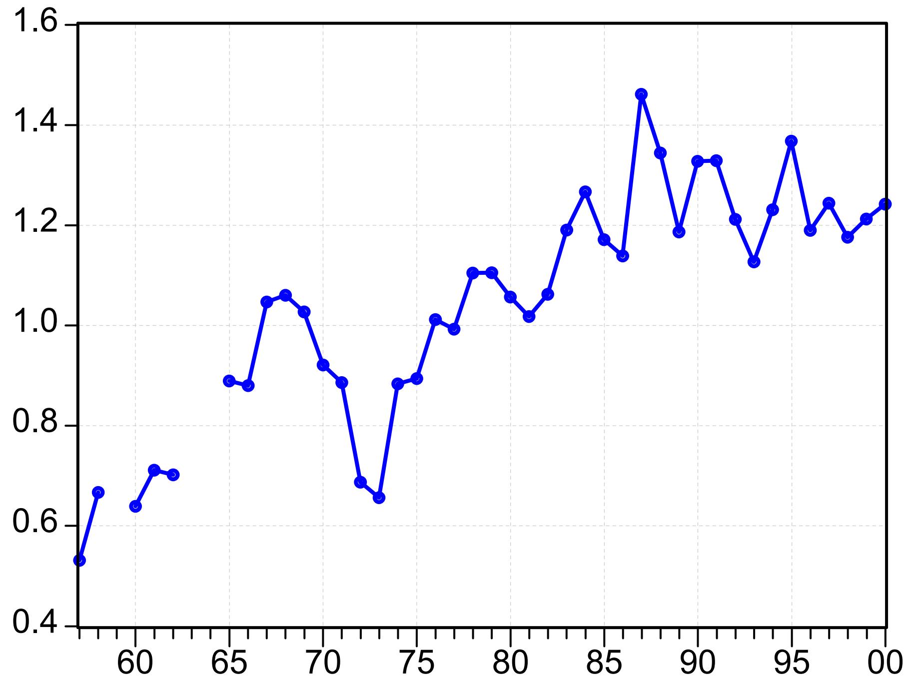


Figure 2: Relative Supply in Chile

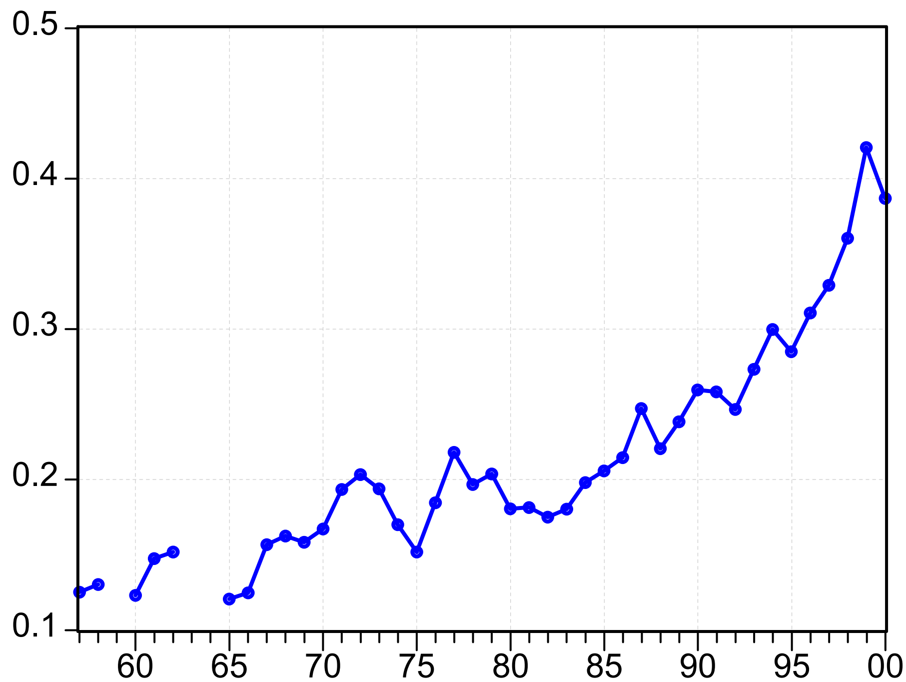


Figure 3: Relative Demand in Chile

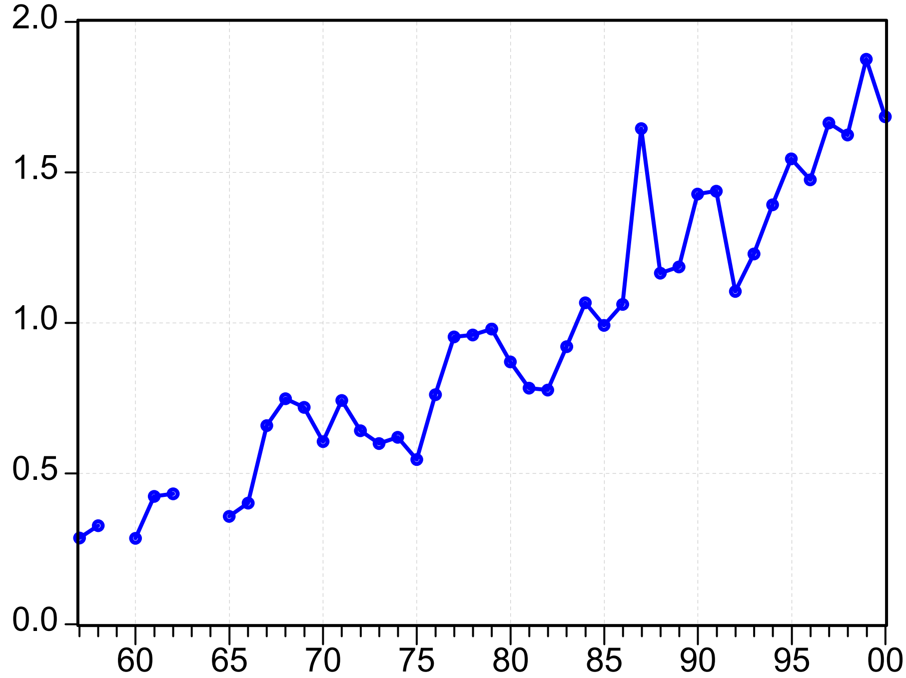


Figure 4: Equipment Capital per Skilled Labor

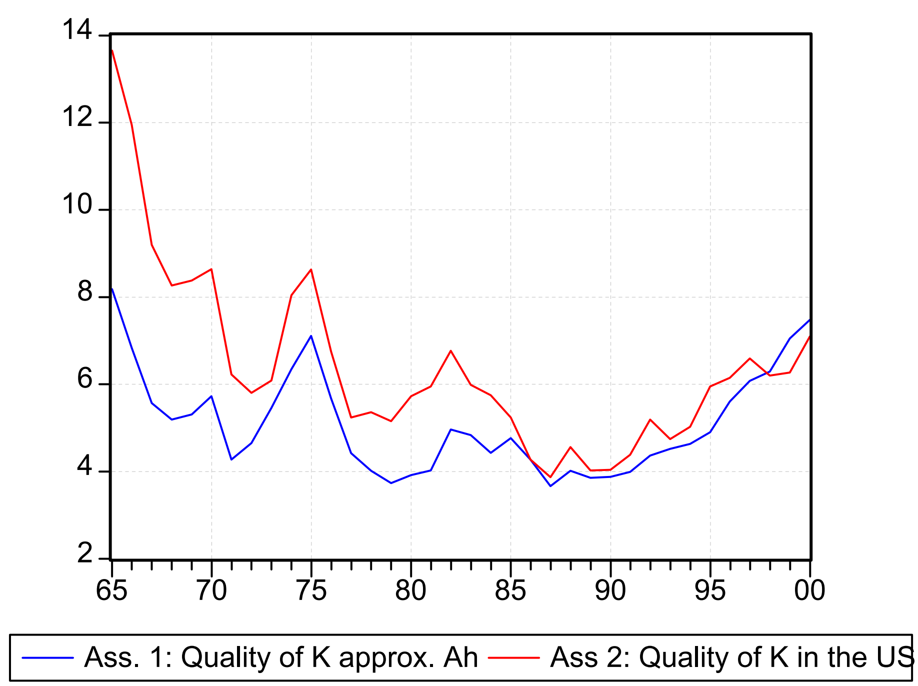
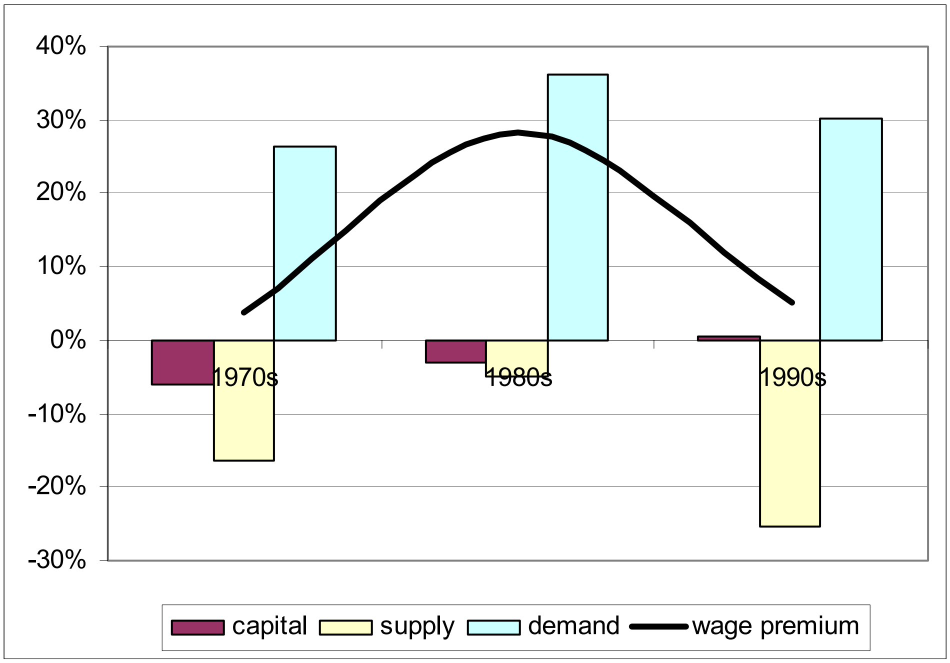


Figure 5: Decomposing Wage Premium Growth, by Decade

Panel A: Assumption 1: Quality of Capital equal to A_h



Panel B: Assumption 2: Quality of Capital in the US

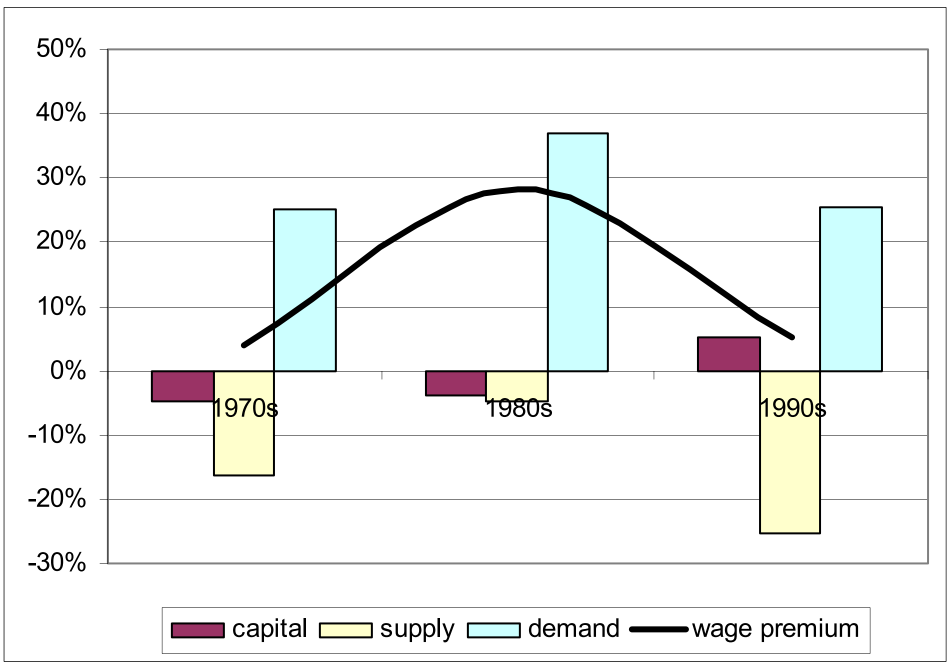


Figure 6: Skill Premium in Chile and the US

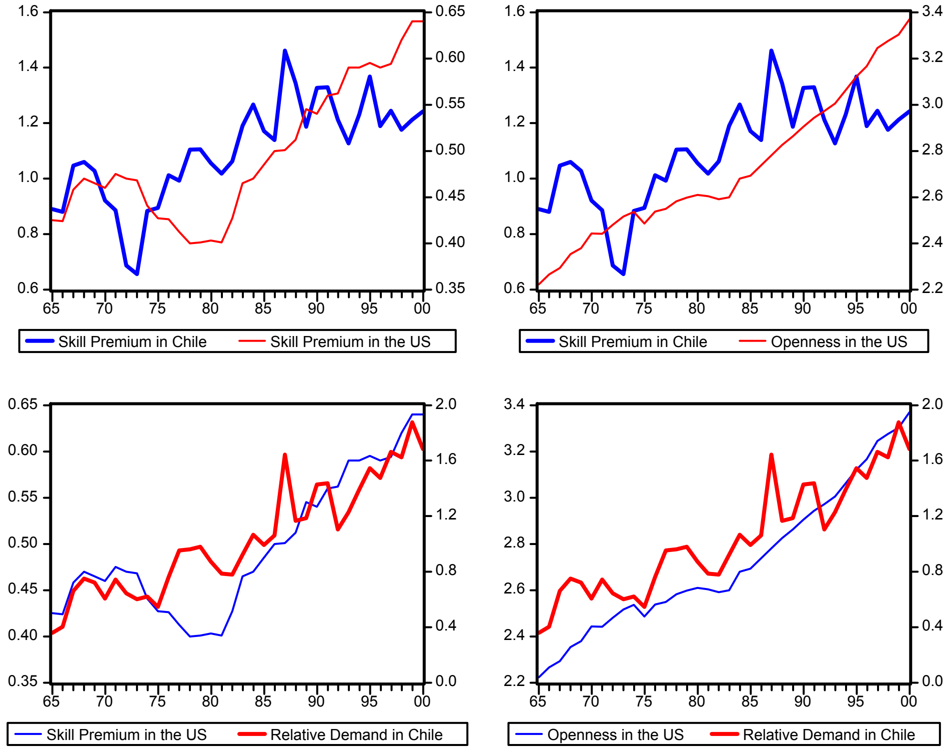


Table A.1: Two-Digit Industries

Manufacture of food products, beverages, and tobacco products
Manufacture of textiles, dressing, and leather products
Manufacture of wood and wood products
Manufacture of paper and paper products, publishing and printing
Manufacture of chemicals and chemical products, plastics and rubber products, petroleum products
Manufacture of other non-metallic mineral products
Manufacture of basic metals
Manufacture of fabricated metal products, machinery and equipment
Other manufacturing industries
Construction
Wholesale and retail trade
Hotels and restaurants
Financial intermediation and real estate
Personal service activities
Education and health services
Sanitation services
Other community and social services
Transportation
Communications
Electricity, gas, steam and hot water supply
Collection, purification and distribution of water

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