Chapter 6

Employment Outcomes and the Role of Technology

Previous chapters have described and analyzed the disappointing labor market outcomes in Latin America during the 1990s. With some exceptions, Latin American countries generally suffered from stagnant wages, rising unemployment, and increasing wage inequality associated with rising returns to education. As mentioned in chapter 1, there are several (not mutually exclusive) hypotheses for these labor market phenomena. This chapter focuses on explanations associated with technological change.

The main conclusion that emerges from the analysis is that technology provides a good explanation for stagnant wages but not for rising unemployment. Wage growth has been low because productivity has barely increased in the region. Since over long periods of time productivity growth is associated mainly with technological change, it follows that wages have failed to increase as expected because of slow technological progress in the region. In other words, the problem is not that labor markets have allocated rents in a way that has hurt workers; it is that the economic system has failed to generate rents that can be allocated to workers.

This conclusion casts doubt on explanations that blame other labor market pathologies, such as rising unemployment, on technological change. Moreover, cross-country analysis clearly shows that high or rapidly growing productivity is not correlated with high or rapidly growing unemployment rates.

An additional conclusion is that the claim that rising returns to education are due to skill-biased technological change, perhaps caused by trade liberalization and other structural reforms, turns out to be surprisingly weak. This is not to dispute the validity of the more general notion that technological change must be skill biased in the long run; technological change must be skill biased to reconcile the long-term increase in the supply of skilled workers with the absence of a secular decline in the returns to education. The point is rather that it is difficult to find convincing evidence that technological change is the cause of the recent increase in the returns to education. The chapter does not reach a strong conclusion on this point, but instead warns the reader that more research is needed in order to understand the causes of the rising skill premium in the region. Moreover, even if skill-biased technological change were indeed the cause of this phenomenon, there is still much to be learned about the specific technologies (such as information technology and automated equipment) behind skill-biased technological change and the specific skills for which demand is rising.

Technology and Stagnant Wages

One point on which economists generally agree is that, in the long run, the main determinant of the wage level is labor productivity. This is clearly the case if the share of labor in GDP (that is, total wages paid as a proportion of total income) is constant over time; in this case, the rate of growth of the wage is equal to the rate of growth of productivity.[1] Moreover, if labor's share does not vary with income levels across countries, this would imply that richer countries pay higher wages because they have higher levels of labor productivity.

The constancy of labor's share has been one of the "stylized facts" of growth accepted by economists for many decades (Kaldor 1961). This is partly because of the remarkable stability of labor's share in the United States, where total wages and salaries paid as a fraction of total income remained at 60 percent from 1950 to 2002. Considering a more inclusive measure of labor compensation, which includes employers' contributions to social insurance and other labor income in addition to wages and salaries, leads to the conclusion that labor's share has increased slightly over this period, implying that wages have actually grown faster than labor productivity in the United States.

The constancy of labor's share has also been observed in East Asian countries, which have experienced fast rates of growth (Young 1995). Consistent with this finding, Gollin (2002) shows that labor's share does not vary systematically with income level across countries. Putting together all the available data across countries and time, he finds that labor's share clusters in a range from 0.6 to 0.85, with no tendency over time or across countries.

Unfortunately, the evidence is not as conclusive as these papers and findings suggest. For example, Blanchard (1997) shows that labor's share of national income declined during the 1980s and 1990s in several countries in Continental Europe. More generally, Harrison (2002) shows that, whereas labor's share appears to have no trend when all countries are taken together, this masks differences in experience among countries at different income levels. Her detailed analysis suggests that poor and middle-income countries have exhibited a negative trend in labor's share over 1960-97.

Labor saving technological progress might be a reason why labor's share could fall over time. Technological progress is said to be labor saving if it raises the demand for capital by more than it raises the demand for labor.[2] With flexible wages and a constant stock of capital, this would imply that wages do not rise as fast as output, and hence the share of income accruing to labor falls. Of course, it also implies that the returns to capital increase and hence in the long run the supply of capital would respond positively. This would lower the returns to capital and increase wages, allowing labor's share to remain constant. This is a good description of what happens in the long run in developed countries and perhaps even in less developed countries, but it may fail to capture relevant dynamics in the medium run, when the capital stock does not adjust fully. For example, Blanchard (1997) argues that the decrease in labor's share in Europe in the 1980s and 1990s was caused by labor saving technological change (itself the result of labor market rigidities and high labor taxes), which was not accompanied by an expanded supply of capital. Could this be happening in Latin America? Are stagnant wages a result of the decrease in labor's share in the region?

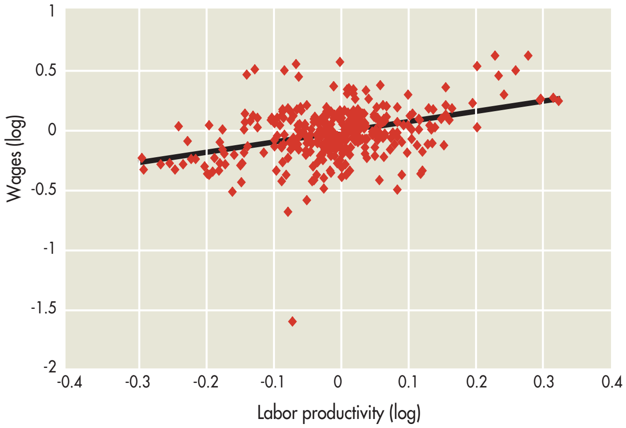
Before looking in detail at the data for Latin America, it is useful to look again at Harrison's findings. The negative trend in labor's share for countries in the middle and lower portions of the income distribution turns out to be small: labor's share falls by 1 percentage point each decade. This would contribute little to the explanation of stagnant wages in Latin America.

To look into this matter more directly, this chapter investigates the statistical relationship between wages and labor productivity across countries in Latin America using data on wages from the Inter-American Development Bank (IDB), Econom-

[1] To see this, note that if the wage (w) is a constant fraction of labor productivity (Y/L, where Y is total output and L is total workers), that is, $w = \alpha\ (Y/L)$, then total wages paid will be a constant fraction of total output or GDP: $\alpha = (wL)/Y$.

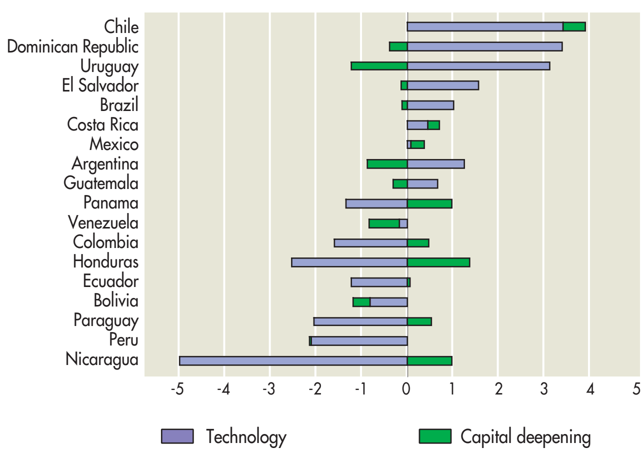
[2] Barro and Sala-i-Martin show that for there to exist a steady state in a neoclassical growth model, technological change has to be labor saving. Given that developed countries (such as the United States and the United Kingdom) have exhibited roughly constant growth rates for more than a century, steady-state growth is an attractive feature of growth models. This is a strong argument that technological progress must ultimately be labor saving.

Figure 6.1 Wages and Labor Productivity in Latin America



Note: Each point in the scatter corresponds to one Latin American country and one year.
Source: IDB calculations based on ILO data.

Figure 6.2 Labor Productivity Growth: Contributions from Technology and Capital Deepening, 1985-2000
(Percent)



Source: IDB calculations.

ic Commission for Latin America and the Caribbean (ECLAC), and International Labour Organization (ILO).[3] For the IDB and ECLAC data sets, the statistical analysis suggests that wages move more than proportionally with labor productivity. For the ILO data set, the estimated coefficient is 0.86, implying that when labor productivity increases by 1 percent, wages increase by 0.86 percent. But even in this case, the standard error of the regression is such that the analysis cannot reject the hypothesis that the true coefficient is equal to one. Figure 6.1 shows the corresponding partial correlation of labor productivity and wages (in logs) for the ILO data set. In general, the statistical analysis suggests that wages move one for one with labor productivity.

This analysis suggests that the failure of wages to grow rapidly is due to slow growth in labor productivity. As Figure 6.2 shows, the average annual growth rate of labor productivity in 1985-2000 was low in the region.[4] Out of 18 countries in the sample, nine exhibited negative growth rates. The simple average of the growth rate in the 18 countries was –0.03 percent, far below the U.S. growth rate of 1.95 percent in the same period. Thus, the general tendency has been one of stagnation in labor productivity in the region in the post-crisis period. Only four countries (Chile, Dominican Republic, El Salvador, and Uruguay) have shown rates of growth in labor productivity above 1 percent a year.

It falls outside of the scope of this Report to conduct a full analysis of the sources of low growth in labor productivity in the region.[5] Here the analysis is limited to an exploration of the role of technological change in this phenomenon. Since technological change cannot be measured directly, the conventional approach entails looking at the growth of output that cannot be explained by increases in inputs (this is commonly referred to as total factor productivity, TFP) as an indirect measure of technological change.[6] In this way, growth in

[3] Formally, a regression was run of the log of the wage level on the log of labor productivity, using year and country dummies. The regression used PPP labor productivity numbers from the Heston, Summers, and Betina (2002) database. Three sources of wages were used to perform three exercises. The first used average wages from the household surveys (IDB database). The second used data from ECLAC (PADI database) on average real wages in the manufacturing sector in the countries of the region. The third used data for manufacturing real wages from the ILO.

[4] The data come from the Heston, Summers, and Betina (2002) database.

[5] See Loayza, Fajnzylber, and Calderón (2002), for a thorough analysis.

[6] This is a good approach for the long run; for example, it is not disputed that the source of growth for developed countries over the long run has been technological change. Over shorter periods, however, TFP growth may be induced by factors other than technological change, for instance, a better allocation of resources across sectors, or a reallocation of resources away from rent seeking and into productive activities. Moreover, TFP growth is affected by the business cycle: in a downturn, capital utilization decreases, and this is usually not captured in capital input measures, so that it would lead to an underestimation of TFP growth.

labor productivity can be broken down into two components: a contribution from technological change and a contribution from capital deepening (see Figure 6.2).[7]

During 1985-2000, technological progress contributed nothing to growth in labor productivity in the region.[8] Whereas in the United States technology contributed 1.57 percent to growth in labor productivity, the average for the region was –0.1 percent. Technology contributed more than 1 percent to growth in labor productivity in only six of 18 countries in the study sample (Argentina, Brazil, Chile, Dominican Republic, El Salvador, and Uruguay).[9]

It is worth investigating whether the stagnation during 1985 to 2000 was due to negative results in the second half of the 1980s. To explore this possibility, the statistical analysis subdivides the whole period into three five-year subperiods: 1985-90, 1990-95, and 1995-2000. Appendix 6.2 describes the details of this analysis. The main result is that there is no statistically significant difference in the rate of growth of labor productivity across the three subperiods. Analysis of the contribution of technology to the growth in labor productivity across the three subperiods yields the same result. The only statistically significant difference arises in the contribution of capital deepening to growth in labor productivity, which shows an improvement from a –1 percent in 1990-95 to 1.2 percent in 1995-2000.

The result that growth in labor productivity is not statistically greater in the first half of the 1990s with respect to the second half of the 1980s is surprising in light of the fact that growth in income per capita increased markedly across the two five-year periods. Indeed, a similar statistical analysis reveals that the growth rate of income per capita increased from –1.1 percent a year in 1985-90 to 1 percent in 1990-95. This improvement was not due to a higher growth rate in labor productivity, but rather to a significant increase in labor force participation: the contribution of this component went from a –0.7 percent in the second half of the 1980s to 0.9 percent in the first half of the 1990s. In the words of Paul Krugman, the growth spur in 1990-95 was more "perspiration" than "inspiration" (Krugman 1994).

Technological Progress and Employment

In the 1990s, growth in employment failed to match growth in the number of people looking for work. As chapter 1 showed, this led to rising rates of unemployment in several countries, particularly in South America. In popular discussions, a hypothesis that has been implicitly formulated to explain this phenomenon is that technological progress reduced the need for workers.

The idea that technological progress has a detrimental effect on employment growth is not new. But a casual look at economic history clearly rejects the idea. For example, there was fast technological progress and a high rate of growth in employment in Great Britain following the Industrial Revolution. This was also the case in the United States during the whole twentieth century, with an important intensification of both technological change and employment growth during the 1990s.[10] The reason for this, of course, is that output is not fixed and hence it is not the case that when an economy can use less labor to produce the same amount of output, then it will do so. Simply put, what happens is that technological change leads to rising output instead of rising unemployment.

Still, it is instructive to take a look at recent data. The best available indicator of technological change is TFP growth. Using TFP growth rates calculated by Klenow and Rodríguez-Clare (2003), it is possible to check the relationship between changes

[7] See Appendix 6.1 for an explanation of the decomposition of growth in Figure 6.2.

[8] This growth decomposition does not adjust for capacity utilization or human capital, but the results would only be strengthened if these adjustments were made (see Loayza, Fajnzylber, and Calderón 2002).

[9] Interestingly, of the four countries where labor productivity grew by more than 1 percent a year, only one experienced a positive contribution from capital deepening (Chile), and even there the contribution was barely more than 10 percent of the total growth in labor productivity. This result should not be surprising: it is well known in the literature that high growth of labor productivity is usually the result of high TFP growth rather than capital deepening (Klenow and Rodríguez-Clare 1997; Easterly and Levine 2001; Loayza and others 2002).

[10] Europe was an exception during the 1970s, 1980s, and 1990s, with slow employment growth, but it is not clear that this was due to rapid technological change.

in employment rates and TFP growth rates for a pool of countries for 1990-95 and 1995-2000. There is no statistically significant relation between the variables: it is not the case that countries with higher TFP growth rates suffer from declining employment rates.[11] A similar analysis, but with the increase in the number of personal computers per person instead of TFP growth as a measure of technological progress, yields similar results.[12]

A slightly different hypothesis holds that periods of high technological change go together with low employment rates (or high unemployment rates), although not necessarily decreasing employment rates. This alternative was explored by checking the statistical relationship between the employment rate at the end of the subperiod and the change in TFP over the subperiod for the two subperiods mentioned above. Again, the results show no statistically significant relationship between these variables. The same results arise when the change in computers per person rather than TFP growth is used as an indicator of technological progress.

A more sophisticated and subtle version of the "technological change is bad for jobs" hypothesis is framed in a cross-industry setting. The idea is that the industries that have been growing fast in the region are ones that have also experienced fast technological progress, and hence have generated low employment growth. More formally, the hypothesis is that fast technological change goes together with slow employment growth at the industry level. In theory, this would happen if the industry faced a steep (inelastic) demand curve: in that case, an improvement in technology (a rightward shift in the supply curve) would lead to a large decline in price and a small increase in output in the new equilibrium. Given the higher productivity associated with the improvement in technology, the small increase in output could actually be produced with a lower employment level. This could have aggregate implications—at least in the short run—if industries that experienced fast technological progress fired workers that were not rapidly absorbed by the rest of the economy. This would lead to higher unemployment during a transition period.

To check this "industry version" of the hypothesis, it is necessary to turn to cross-industry data. Although the focus is Latin America, it is helpful to start the analysis with the United States, which has high-quality data for the manufacturing sector at a disaggregate level. It turns out that, in contrast with the proposition above, there is a positive and statistically significant relation between TFP growth and employment growth at the industry level.[13] In other words, high technological progress goes together with higher rates of employment growth at the industry level.

Is this also the case in Latin America? Unfortunately, the data for Latin America are incomplete and available only at a higher level of aggregation. Thus, the exercise is less reliable than for the United States. However, the analysis yields a positive and statistically significant relation between TFP growth and employment growth at the industry level for a pool of seven Latin American countries for which the necessary data are available.[14] Thus,

[11] The regression was of the change in the log of the employment rate (employment over labor force) on the changes in the log of TFP in 1990-95 (48 countries) and 1995-2000 (32 countries). The estimated coefficient is positive but statistically insignificant.

[12] Data on personal computers per person are from World Development Indicators, World Bank.

[13] Formally, this result comes from running a regression of change in the log of industry employment on change in the log of industry TFP. The data come from the NBER-CES Manufacturing Industry Database maintained by Bartelsman, Becker, and Gray (http://www.nber.org/nberces/nbprod96.htm). This database provides information for each of the 459 1987 SIC four-digit industries. The period for which changes in the main variables are calculated is 1960-96. TFP is calculated using the five-factor TFP index developed by the National Bureau of Economic Research. The estimated coefficient is 0.36 with a standard error of 0.07. It can be shown that if there is unrestricted labor mobility across industries, then this estimated coefficient plus 1 is an unbiased estimate of the elasticity of substitution in demand between industry outputs (Klenow 1998). If there are restrictions on cross-industry labor flows, then this would establish a lower bound for the elasticity of substitution. Thus, this finding is consistent with an elasticity of substitution among goods greater than 1.

[14] The seven countries are Bolivia, Chile, Colombia, Ecuador, Mexico, Panama, and Venezuela. The data come from the UNIDO database for three-digit industries according to the ISIC classification. Thus, instead of 459 sectors, the data are for 32 sectors per country. $\ln TFP = \ln(Y_i/L_i) - \alpha_i \ln(K_i/L_i)$ is computed for each country, where i is a sector index, and α_i is the capital share in sector i. The industry capital stock was constructed using data on industry investment deflated by the country's investment deflator from the Penn World Tables. For α_i the capital share for each industry in the United States is used. The period of analysis is 1983-91. The regression uses country dummies and yields a coefficient on change in log of TFP equal to 0.1, with a standard error of 0.039 (t-statistic of 2.6).

similar to the United States, industries enjoying faster TFP growth exhibit faster employment growth, rejecting the subtle version of the hypothesis that technological change is bad for jobs.

In sum, the evidence presented in this section shows that it is difficult to make the argument that technological progress at the aggregate or industry level leads to an increase in unemployment. The next section turns to a more interesting possibility, namely that technological change may have different effects on different types of workers and, in particular, that it could lead to an increase in wages for skilled workers in relation to those of unskilled workers.

Technology and the Rising Skill Premium in Latin America

Chapters 1 and 3 presented evidence of a rising skill premium in Latin America. This, of course, is only a general trend; there are countries where the skill premium did not increase, but they are the exception.

The phenomenon of the rising skill premium has received a lot of attention in the region because of its effect on income inequality, which is already the highest in the world. Moreover, the expectation was that trade liberalization would lead to a reduction in wage inequality, so the fact that it has increased certainly calls for an explanation.

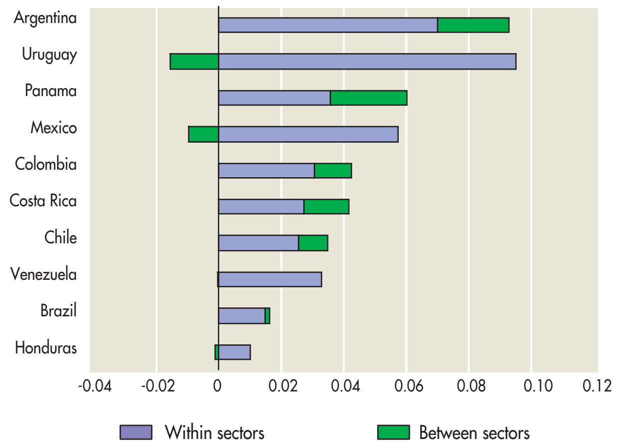
A simple explanation for the rising skill premium is that it is due to the large increase in the supply of workers with secondary education in most countries. In other words, this explanation posits that workers with tertiary education have become scarcer relative to workers with only secondary education, thereby allowing the former to command a higher relative wage. As discussed in chapter 3, this "supply-side" explanation is not sufficient because the supply of workers with tertiary education has declined only slightly relative to the supply of workers with only secondary education. Thus, it is necessary to explore an additional "demand-side" explanation for the rising skill premium. Indeed, chapter 3 showed the existence of a regional positive trend in the relative demand for workers with tertiary education of between 1.9 and 2.4 percent a year. What explains this rising relative demand for skilled workers?

At a general level, the increasing relative demand for skills could come from a between-sectors phenomenon or a within-sector phenomenon, or from a combination of both. Some sectors are more skill intensive relative to others. For example, the financial services sector is skill intensive in relation to the agricultural sector. If the financial services sector expands and the agricultural sector contracts, then the overall skill intensity increases, implying an increase in the relative demand for skills at the aggregate level. This is a between-sectors phenomenon because it arises as resources are reallocated between sectors. Alternatively, the increase in demand for skills at the aggregate level could come from a tendency for sectors to become more skill intensive, which would be a within-sector phenomenon.

The distinction between the within and between effects is important because it points to different sources of the increase in the relative demand for skilled labor. For example, the effect of trade liberalization on the skill premium should show up as an increase in the relative demand for skilled workers associated with a between-sectors effect. The effect of technological change on the relative demand for skills, by contrast, would be expected to arise through a within effect.

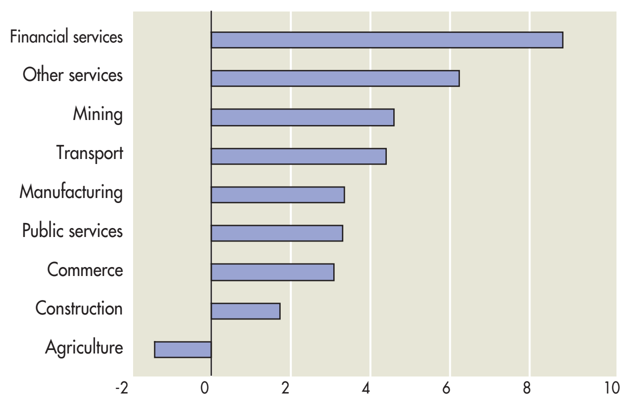
The most important between-sectors effect in the past decades has been associated with reallocation of workers from agriculture and manufacturing toward services. This reallocation has contributed to the increasing demand for skills because the services sector is more skill intensive than either the manufacturing or the agricultural sector. Indeed, if the skill intensity of a sector is defined by its share of college educated workers, the skill intensity of the services sector was 14.8 percent in Brazil in 1999, whereas the skill intensity of the agricultural and manufacturing sectors was only 7.4 and 8.1 percent, respectively. Similarly, in Chile in 1998, the skill intensity of the services sector was 28.5 percent, whereas it was only 5.1 and 17.6 percent in the agricultural and manufacturing sectors, respectively. This relation holds true for all

Figure 6.3 Decomposition of Change in Relative Demand for Skilled Labor, 1990s



Source: IDB calculations.

Figure 6.4 Increases in Skill Intensity Across Sectors in Latin America
(Percent)



Note: Financial services includes finance, insurance, real estate and business services. Other services includes community, social, and personal services. Mining is mining and quarrying. Transport includes transport and storage. Public services includes electricity, gas, and water. Commerce includes wholesale and retail trade, and hotels and restaurants. Agriculture includes agriculture, hunting, forestry, and fishing.
Source: IDB calculations.

countries and years for which the relevant data are available.

According to this analysis, the within effect explains most of the increase in the demand for skills in Latin America. For instance, Argentina's skill intensity increased by 9.2 percent because the share of workers with tertiary education increased from 22.9 to 32.1 percent in 1992-2000. Of the total increase, the within effect accounted for 7 percent, whereas the between effect accounted for 2.3 percent.[15] Figure 6.3 shows the decomposition of the total increase in the skill intensity at the aggregate level (all sectors combined) for the 10 countries for which data are available.[16] In three of the countries, the between effect goes in the wrong direction and therefore the within effect overexplains the increased skill intensity. In the other countries, the within effect accounts for most of the total increase in skill intensity.

This sector analysis leads to the additional conclusion that rising skill intensity is a phenomenon that is not concentrated in manufacturing, as has sometimes been presumed. On the contrary, the phenomenon is present in many sectors. To see this, it is useful to calculate the average increase in skill intensity in each sector for the 10 Latin American countries in the sample. According to this measure, the sector that experienced the strongest increase in skill intensity was finance, insurance, real estate, and business services. The sector with the second-highest average increase was community, social, and personal services. In general, all sectors experienced an increase in skill intensity, except for agriculture. Moreover, as shown in Figure 6.4, manufacturing experienced only a moderate increase in skill intensity.

A caveat of this analysis is that it is done at a high level of aggregation, in which the economy is grouped in nine large sectors, such as manufactur-

[15] This exercise uses data from household surveys, which provide the education level and sector of occupation for workers. Workers are classified in nine sectors: (1) agriculture, hunting, forestry, and fishing; (2) mining and quarrying; (3) manufacturing; (4) electricity, gas, and water supply; (5) construction; (6) wholesale and retail trade and hotels and restaurants; (7) transport and storage; (8) finance, insurance, real estate, and business services; and (9) community, social, and personal services. The economywide skill intensity is a weighted average of the skill intensity across sectors, with the weights given by the share of employment of each sector. For the decomposition, note that the change in this weighted average is equal to the sum of two components: the within effect, which is the weighted average of the change in skill intensity across sectors with weights given by the employment shares in the initial year, and the between effect, which is the sum across all sectors of the skill intensity in the final year multiplied by the change in the employment share for each sector.

[16] The periods of analysis vary across countries due to data availability: Argentina, 1992-2000; Brazil, 1988-99; Chile, 1990-98; Colombia, 1991-99; Costa Rica, 1989-2000; Honduras, 1992-99; Mexico, 1989-2000; Panama, 1991-2000; Uruguay, 1989-2000; and Venezuela, 1989-99.

ing and agriculture. Perhaps the increase in skill intensity for some of these broad sectors is itself caused by a between phenomenon across subsectors. For example, the increase in skill intensity in manufacturing could be caused by a reallocation of resources from apparel to machinery, which is more skill intensive. This issue has been explored in several recent papers for the manufacturing sector, which is the only sector for which the required data are available. The consistent finding in these studies is that the between effect is small (Berman and Machin 2000; Sánchez-Páramo and Schady 2003). Thus, most of the increase in skill intensity at the sector level is also caused by a within effect at the subsector level.

One explanation for this phenomenon at the subsector level that has been discussed in the literature starts with the accepted proposition that capital is complementary to skilled labor, and a substitute for unskilled labor. Thus, if a higher investment rate leads to capital deepening (as reflected in an increasing capital-output ratio), then it would be expected that the relative demand for skilled labor would increase. However, a problem with this hypothesis is that, for plausible elasticity parameters, capital deepening explains only a small part of the increase in the relative demand for skills (see Berman and Machin 2000). But more importantly, data from Heston, Summers, and Bettina (2002) for 1985-2000 show that there is a negative trend in the capital-output ratio in Latin American countries, so there is no capital deepening whatsoever.[17]

The discussion so far can be summarized in three statements. First, an increase in the relative demand for skills, and not a fall in the relative supply of skills, has caused the increase in the skill premium. Second, a within-sector effect rather than a between-sectors phenomenon has caused the increase in the relative demand for skills at the aggregate level. And third, the capital deepening explanation for the within effect is not consistent with the data.

An understanding of the causes of the rising skill premium requires an understanding of the causes of the rising relative demand for skills within sectors. A widely accepted explanation for this phenomenon is technological change that is biased in favor of skilled workers. This is commonly referred to as skill-biased technological change. The rest of this section is devoted to exploring this explanation of the rising skill premium in the region.

Exploring the validity of the skill-biased technological change (SBTC) hypothesis for the case of Latin America turns out to be important because a better understanding of the causes and characteristics of the rising demand for skills may prove valuable in designing better technology and education policies. For example, the ambitious study by de Ferranti and others (2003) puts forward an interesting argument, which begins with recent research arguing that trade liberalization, foreign direct investment flows, and other reforms have increased technology adoption in Latin America and the Caribbean. Coming from the rich, skilled-labor abundant countries, the argument goes, these adopted technologies are skill biased, so they have led to a rising demand for skills. In contrast to what has happened in other regions, however, Latin America's unresponsive and rigid education systems have not been able to match this rising demand for skills. According to this study, the result has been an increase in the skill premium and increased inequality. The bright side to this story is that the greater skill premium presents a golden opportunity to increase the supply of skills to match the greater demand and produce fast growth and prosperity with falling inequality.

This chapter explores the SBTC hypothesis as it applies to the Latin American and Caribbean region to understand whether these conclusions are warranted. In particular, what specific technologies has the region adopted recently? Are they specific to manufacturing or do they have broader relevance, like information technology? What has been the role of international trade in inducing and

[17] This statement comes from running a regression of the capital-output ratio on a time trend, using country dummies. The coefficient of the time trend in this regression is -0.0103, with standard error 0.002 (t-statistic -4.31). The decline in the capital-output ratio is due to lower investment rates in the 1980s and 1990s compared with the ones that prevailed in the 1960s and 1970s. The good news is that there was a trend to recuperate those high investment rates in the 1990s. The bad news is that this trend broke down in the late 1990s.

allowing technology adoption in the region? What are the skills whose demand has increased the most (engineers, information technology professionals, business administrators, accountants, or others)? These are, of course, difficult questions, but they provide the proper motivation to guide the investigation.

Although there has been some research conducted recently addressing these questions in the context of Latin America, most of the related research has been focused on the United States. The next section looks at this literature, which provides several useful clues for the analysis of Latin America and the Caribbean.

Skill-biased Technological Change in the United States

During the past two decades, and especially in the early 1980s, there was a marked increase in the skill premium in the United States (Card and DiNardo 2002). This led to a large literature exploring the causes of this phenomenon. Given that the rising skill premium coincided with a rising relative supply of skilled workers, the necessary conclusion was that the demand for skills was increasing.

Initially, increasing international trade with less developed countries received a lot of attention as a plausible explanation for the rising demand for skills because standard trade theory would predict this for a developed country like the United States. According to this view, opening up trade channels with less developed countries would lead a country abundant in skilled labor to specialize in goods intensive in skilled labor. This would increase the relative size of sectors producing these goods and thereby increase the aggregate demand for skilled workers. Soon, however, people realized that the reallocation of resources toward sectors intensive in skilled labor explained only a small fraction of the rising aggregate demand for skills. The new consensus became that the source of the increasing demand for skilled workers was at the industry or sector level, that is, the consensus was that it was a within-sector phenomenon, such as the one observed in Latin America.

The SBTC hypothesis has become the most widely accepted explanation of the rising skill premium in the United States because it provides a plausible explanation for the observed increasing intensity in skilled labor across a large set of industries or sectors. Exemplifying the way good science is done, the SBTC hypothesis soon began to be contrasted with the data in different ways. This section briefly reviews this literature in an effort to better understand the SBTC hypothesis and its plausibility for the Latin American case. The next section turns to the literature that specifically analyzes the hypothesis for Latin America.

Skill-biased technological change generally brings to mind two things: computers and equipment that displaces manual labor on the factory floor. Doms, Dunne, and Troske (1997) use plant-level data to examine the relationship between adoption of advanced production machinery and skill intensity. The data come from plant-level responses to a survey of manufacturing technology conducted by the U.S. Census Bureau. The survey asked firms whether they used any of 17 particular technologies that included computer aided design/computer aided manufacturing, networks, and robots. According to the study's authors, these technologies increase the level of automation in a factory:

> The primary way workers control these technologies is through keyboards, pointing devices, and video display terminals. At a minimum, workers using these technologies must be able to use such devices and thus have reasonable language skills, reading skills, and, in some cases, basic math skills. Thus, we expect that plants that are more automated will employ relatively more educated and skilled workers than plants that rely on more traditional technologies with mechanical interfaces (i.e., levers and switches). (Doms, Dunne, and Troske 1997, p. 260)

The Doms, Dunne, and Troske study finds that, indeed, firms that use more of these technologies also have a higher share of skilled workers, as measured by the share of workers that have at least a college degree. This applies both to production and nonproduction workers. But, surprisingly, when the study turns from cross-section to time-series analysis, firms do not become more skill intensive when they adopt more technology.[18] From these seemingly contradictory results, the study concludes that the relationship between factory floor automation technologies and skills does not match that which the SBTC hypothesis postulates (adoption of these technologies increases the relative demand for skills), but rather skill intensity leads to technology adoption: firms with more skilled workers are more likely to adopt advanced technology.[19]

Doms, Dunne, and Troske turn to computers as an alternative driver of skill-biased technological change. They perform a similar analysis and find that firms that invest more in computers and computer peripherals in relation to total investment do become more skill intensive, as measured by the share of nonproduction workers.

This last result corresponds to the notion that firms that increase their use of computers become more skill intensive. Moreover, it seems that there has been an increase in demand for people with knowledge about computers and software. However, wages for electrical engineers and people with computer science degrees relative to those with degrees in humanities and social sciences stagnated or decreased during the 1980s and early 1990s (Card and DiNardo 2002). Has a supply effect prevented prices from reflecting a change in demand? That is, was there a large increase in the supply of people with engineering and computer science degrees? According to data presented in Romer (2000), the fraction of engineers in the total U.S. labor force has remained constant since the early 1970s.

Perhaps this interpretation of the SBTC hypothesis is too narrow. As Bresnahan, Brynjolfsson, and Hitt (2002) argue, investments in computers and information technology go together with changes in organizational form and product mix that lead firms to increase their demand for a wide range of skills, not only computer-related skills. In their words:

> Firms do not simply plug in computers or telecommunications equipment and achieve service quality or efficiency gains. Instead they go through a process of organizational redesign and make substantial changes to their product and service mix. This raises the possibility that computers affect labor demand not only directly, as has been previously studied, but indirectly through other firm-level changes. That is, IT is embedded in a cluster of related innovations, notably organizational changes and product innovation. These three complementary innovations—a) increased use of IT, b) changes in organization practices, and c) changes in products and services—*taken together* are the SBTC that calls for a higher-skilled labor mix. (Bresnahan, Brynjolfsson, and Hitt 2002, p. 341)

The study confirms that the three elements of this particular version of the SBTC hypothesis vary together at the firm level, so that the data do not reject the proposition that falling prices of information technology equipment have led to organizational changes that in turn have led to greater relative demand for skills.

This could well be the most interesting and plausible version of the SBTC hypothesis. However, most of the increase in the skill premium in the United States occurred in the 1980s, whereas the effect of technological change led by information technology should have been felt during the 1990s. A possible explanation could be that the skill premium increased rapidly in the 1980s not because of

[18] It might be possible that firms *first* hire more skilled workers and then adopt the new technology. In this case, an empirical study looking for skill upgrading *after* technology adoption would find none. It is difficult to claim that the Doms, Dunne, and Troske (1997) study suffers from this problem, however, because it covers 1977-92 and most of the technologies considered became available after 1977. It seems unlikely that by 1977 firms had already adjusted their workforce in response to those skill-biased technologies.

[19] Doms, Dunne, and Troske (1997) alert the reader that this finding should be interpreted with care because it is only about the dynamics of individual firms. Technology adoption could still have aggregate implications if firms that adopted technologies grew faster or had a higher probability of survival: in that case, it would be expected that there would be an increase in the share of resources managed by firms that are more intensive in skilled labor. If this were the case, then there would be a process of increasing relative demand for skills caused by technology adoption that would not be captured in the exercise performed by Doms, Dunne, and Troske.

a faster rate of increase in the relative demand for skills, but because of a slower rate of increase in their relative supply (Katz and Murphy 1992). But this explanation requires the rate of increase in the relative supply of skills to have risen during the 1990s, as this would be required to explain the considerable slowdown in the rate of increase in the skill premium. However, as Beaudry and Green (2002) show, this did not happen.

Beaudry and Green propose a different framework for thinking about this matter. The idea is that during the 1980s and 1990s, the U.S. economy was (and perhaps still is) in transition toward a new skill-intensive technology associated with information technology.[20] In this transition process, the old technology coexists with the new technology, and factor prices are affected by both the evolution of the stock of factors of production (skilled labor, unskilled labor, and capital) and the rate at which the economy adopts the new technology. Given some plausible assumptions about the intensity with which the old and new technologies use the factors of production, Beaudry and Green show that—contrary to what has been emphasized in the literature—an increase in the relative supply of skills *increases* the skill premium. Moreover, an increase in the capital stock *decreases* the skill premium, in spite of the fact that skills are complementary to capital in the new technology.

The explanation for these surprising results rests on the notion that changes in factor supplies are accompanied by changes in the adoption of the new technology. Thus, an increase in the relative supply of skills leads to faster adoption of the new skill-biased technology; in turn, this increases the relative demand for skills and thereby prevents the skill premium from falling. Were it not for the introduction of capital into the model, this would imply that changes in the relative supply of skills do not affect the skill premium.[21]

Beaudry and Green introduce capital into the model and make two reasonable assumptions. First, the new technology exhibits capital-skill complementarity in the sense that the capital-labor ratio in the new (skill-intensive) technology is higher than in the old technology. Second, the new technology is capital efficient relative to the old technology in the sense that fewer units of capital are required to produce one unit of output with the new technology than with the old technology.[22] Under the first assumption, adoption of the new technology leads to a higher demand for capital. In turn, with constant capital stock, this leads to a higher rental rate for capital, and—under the second assumption—this increases the skill premium.

Beaudry and Green show that this framework is consistent with the U.S. data and provides an explanation for the evolution of the skill premium in the United States during the 1980s and 1990s. According to this explanation, rather than ongoing skill-biased technological change, the behavior of the skill premium has been determined by imbalances in the accumulation of skills and capital. During the 1980s, the skill premium increased because the supply of capital failed to match the increase in educational attainment; the skill premium stopped increasing toward the end of the 1980s and in the 1990s thanks to faster capital accumulation in relation to the rate of increase in educational attainment.

What are the implications for Latin America? In broad terms, it is clear that technological progress must have been skill biased during the twentieth century in the United States. There is no other way to explain the stability of the skill premium in spite of the significant increase in the relative supply of skilled labor during this period.[23] When it comes to explaining the recent increase in the skill premium in the United States, the simple SBTC hypothesis is not sufficiently informative and is even inconsistent with recent experience because it fails to explain the slowdown in the rising skill premium in the 1990s. Thus, perhaps a more appealing explanation is the one provided by Beaudry and

[20] Caselli (1999) explains this idea in depth. Beaudry and Green (2002) introduce capital and propose a coherent explanation for the U.S. experience since the mid-1970s.

[21] The intuition behind this result is the same as the intuition for factor price equalization in trade models.

[22] These two assumptions are consistent only when the share of skilled labor in the new technology is much higher than in the old technology, which is what Beaudry and Green (2002) implicitly assume.

[23] See Goldin and Margo (1992) and Acemoglu (2002).

Green, in which the evolution of the skill premium is determined by imbalances in the accumulation of skills and capital during the transition from the old to the new, general-purpose, skill-intensive technology, such as information technology.

Skill-biased Technological Change in Latin America

The discussion about the determinants of the skill premium in the United States points to two related frameworks for thinking about this matter in Latin America. In both frameworks, the new technologies are associated with information technology and affect all sectors of the economy. The difference is that in the first framework (the exogenous SBTC hypothesis), the relative demand for skills is determined solely by exogenous skill-biased technological change, whereas in the second framework (the technology revolution hypothesis), the relative demand for skills is determined by a more complex process in which both the adoption of the new technology and the supply of skills and capital interact.[24]

According to the exogenous SBTC hypothesis, the skill premium increases when the relative supply of skills does not match the increase in the relative demand for skills caused by exogenous skill-biased technological change. In turn, skill-biased technological change in less developed countries can be seen as the result of the diffusion of skill-biased technologies developed for rich countries that are abundant in skilled labor (Acemoglu and Zilibotti 2001). By contrast, the technology revolution hypothesis posits that the skill premium increases when educational attainment increases faster than the supply of capital (Beaudry and Green 2002).

This section begins with an exploration of these ideas using the available household survey data for Latin America. It then moves on to analyze several specific questions. First, which technologies are behind the increasing relative demand for skills? Second, has trade liberalization caused the adoption of skill-biased technologies? And third, which skills are most in demand?

The Aggregate Data

The exogenous SBTC hypothesis suggests that the skill premium is determined by the relative supply of skilled labor and a time trend that captures rising relative demand for skills caused (presumably) by ongoing skill-biased technological change. It is instructive to follow Katz and Murphy (1992) in running a regression of the relative wage of skilled workers on the relative supply of skilled workers and a time trend for the region for the 1990s.[25] The estimated coefficient on the time trend is positive and statistically significant, but—contrary to the results in Katz and Murphy—the estimated coefficient on the relative supply of skilled workers is not statistically different from zero.[26] This should not be surprising in light of Beaudry and Green's (2002) results, which show that the Katz and Murphy results no longer hold in the United States when implemented for a period that includes the 1990s.

To deal with some econometric problems with this exercise, an alternative approach, also proposed by Katz and Murphy, involves using standard estimates of the relevant elasticities to derive the implied relative demand for skills from data on relative supply and relative wages, as explained in

[24] This discussion does not explicitly address a third framework, proposed by Acemoglu and others (see Acemoglu 2002), in which skill-biased technological change is itself caused by the increased relative supply of skills in developed countries. This endogenous SBTC hypothesis is interesting and relevant for the discussion in developed countries, but does not help much beyond the exogenous SBTC hypothesis from the point of view of understanding the recent experience in Latin America.

[25] This exercise follows the literature in thinking of skilled workers as workers with complete tertiary education and unskilled workers as those with complete secondary education. This is appropriate because, as mentioned in chapters 1 and 3, it is the wage of workers with tertiary education relative to workers with only secondary education that has been increasing in the region. All the data come from the IDB's collection of household surveys for Latin American countries. The supply numbers come from the surveys restricted to workers between 25 and 49 years of age, and who work at least five hours a day. The relative wages relate only to males, to avoid compositional effects. The regression is done for an unbalanced panel for Latin America with country dummies.

[26] The coefficient of the log of the relative supply is –0.106 with a t-statistic of 1.19. Not only is this coefficient not statistically different from zero, but it also implies an elasticity of substitution between skilled and unskilled labor of around 10, which is implausibly large. The coefficient of the time trend is 0.013 with a t-statistic of 3.62. These results are similar to the results of Sánchez-Páramo and Schady (2003).

Table 6.1 Evolution of the Relative Demand for Skills in Latin America

Variable	(1)	(2)	(3)
Trend	0.017 (2.05)**	0.018 (2.22)**	0.102 (2.65)**
GDP per worker (log)	0.359 (0.74)		
Total factor productivity (log)		0.227 (0.37)	
Computers per capita (log)			–0.359 (2.08)**
Number of observations	70	70	52
R^2	0.87	0.87	0.90

** Significant at 5 percent.

Note: The dependent variable is relative demand for skilled labor, with elasticity –2. All regressions use country dummies (not reported). Absolute values of t-statistics are in parentheses.

Source: IDB calculations.

Appendix 6.3. The intuition is that the evolution of the skill premium and the relative supply of skills must imply an increase in the relative demand for skills. But by how much does demand increase? This is determined by the relevant elasticities, which are obtained from standard estimates in the empirical literature.

This approach yields the implied relative demand for skills for all the countries and years for which relevant data are available from the household surveys. A simple statistical analysis of the derived relative demand for skills shows the existence of a positive trend in the region from the mid-1980s to the end of the 1990s. This is suggestive of skill-biased technological change, but requires further analysis. In particular, if the rising relative demand for skills is caused by skill-biased technological change, it is natural to expect that countries whose labor productivity or TFP has grown faster should have experienced a larger increase in the relative demand for skills.[27]

The statistical analysis reveals that this is not true: a regression of the relative demand for skills on productivity variables (labor productivity or TFP) and a time trend yields an estimated coefficient for the productivity variable that is not statistically different from zero (Table 6.1). Instead, using the number of computers per capita as a way to capture the diffusion of information technology, the coefficient becomes statistically significant, but of the wrong sign: the regression implies that countries where the diffusion of personal computers has been faster have experienced a lower rate of increase in the relative demand for skills (Table 6.1).

The next step should be to explore the empirical relevance of the technology revolution hypothesis, in which, instead of exogenous skill-biased technological change, there is a transition from old to new skill-biased technology. Unfortunately, lack of data prevents a thorough exploration of such an alternative framework. At most, the data would allow for exploring a crude approximation of Beaudry and Green's framework, by running a regression of the skill premium on the ratio of the supply of skilled workers to the capital stock (the Beaudry and Green ratio) plus a time trend. According to this framework, the coefficient on the time trend should be close to zero, whereas the coefficient on the Beaudry and Green ratio should be positive. The results generated by a simple regression

[27] This assumes that the degree to which technological change is biased toward skilled labor is exogenous to less developed countries, as in Acemoglu and Zilibotti (2001). Thus, if a country adopts technology at a faster pace than another, it is natural to expect both faster TFP growth and a higher rate of increase in the relative demand for skills.

do not match these predictions: the estimated coefficient on the time trend is positive and statistically significant, whereas the estimated coefficient on the Beaudry and Green ratio is negative, although statistically not different from zero.

These results show that there is no simple model that fits the available data for Latin America. Perhaps this should not be surprising: it would be quite remarkable if a simple framework such as any of the ones mentioned here could consistently explain the Latin American experience of the past two decades. The rest of this section adopts a more eclectic approach, in which the two major technological explanations for the rising skill premium (exogenous skill-biased technological change and the technological revolution) have some relevance for recent experience in Latin America.

Rising Relative Demand for Skills

Doms, Dunne, and Troske (1997) analyze plant-level data to explore the relationship between adoption of production automation technologies and skills upgrading. The authors conclude that although increased skills lead to technology adoption, it is not the case that technology adoption leads to increased demand for skills. Is there some evidence on this matter for Latin America?

Pavcnik (2002) follows a similar strategy to the one implemented by Doms, Dunne, and Troske using Chilean plant-level data.[28] As proxies for technology adoption, Pavcnik uses indicator variables for whether a plant receives foreign technical assistance, pays for patent use, or imports a portion of its materials. She finds basically the same result as Doms, Dunne, and Troske derive for the United States. Unfortunately, Pavcnik did not have data on information technology investment to check whether this kind of investment led to increases in skill intensity.

The results of this study are certainly not definitive, but do call into question the conclusion that technologies adopted recently in the manufacturing sector have led to an increase in the relative demand for skills. More importantly, given the small size of the manufacturing sector, it is unlikely that this, by itself, could have had a large aggregate effect. Perhaps a more appropriate interpretation is that investment in information technology has, as in Bresnahan, Brynjolfsson, and Hitt (2002), led to increased relative demand for skills (college graduates) of a wide variety, not only engineers and information technology professionals, and that this has happened not only in manufacturing but also in services and other sectors.

Trade Liberalization

In some studies, including de Ferranti and others (2003), the SBTC hypothesis is accompanied by a second hypothesis that states that the adoption of technologies intensive in skilled labor has been fueled in part by trade liberalization. What is the evidence for this claim?

A large literature discusses the role of trade in the diffusion of technology. In the extreme, trade is essential because new technologies almost always require imported equipment and other inputs. Thus, closing off trade completely surely would have a significant effect on reducing technology diffusion. But the relevant question is whether trade liberalization, *of the magnitude experienced in Latin America*, has led to faster technology diffusion.

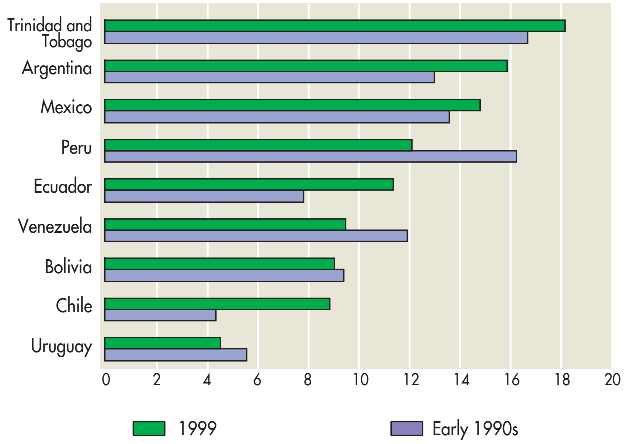
To investigate this matter, it is instructive to start by examining the evolution of tariffs on capital goods in Latin America during the 1990s. As shown in Figure 6.5, there is no significant trend toward a reduction in these tariffs. In fact, in many countries, tariffs on capital goods increased during this period.

Given the well-known problems with tariff data, it is instructive to look directly at price data on capital goods and output to find out whether the relative price of capital goods has fallen in the region. Data on the price of capital goods relative to output for most of the countries in Latin America are from Heston, Summers, and Bettina (2002). In a regression of this relative price on a time trend, using country dummies, the estimated coefficient turned out negative and significantly different from zero.[29]

[28] This is the only study that uses appropriate data with appropriate econometric techniques. What is crucial is that the econometric identification comes from the time-series dimension of a panel, as opposed to the cross section, where endogeneity problems may be severe.

[29] The coefficient is −0.0059 and the standard error is 0.0017, with t-statistic −3.4.

Figure 6.5 Import Tariffs on Capital Goods
(Percent)



Source: UNCTAD database.

Thus, the hypothesis that there is a negative time trend in the relative price of capital goods in Latin America cannot be rejected.

Is the declining relative price of capital a consequence of trade liberalization? To explore this, note that there is a long-run trend in the United States of decline in the relative price of investment (Greenwood, Hercowitz, and Krusell 1997). It is natural to expect that this trend, which is surely due to faster technological change at the level of investment goods than general output, would also benefit Latin America because technology diffuses from developed to less developed countries. Thus, even without trade liberalization, a decline in the relative price of capital in the region would be expected. In a regression of the relative price of capital in Latin American countries against the same price in the United States, the hypothesis that the coefficient is 1 cannot be rejected.[30] Thus, the entire decline observed in the relative price of capital in the region could be due to the general trend in developed countries that has existed for many decades.

Since it is commonly understood that investment goods are more tradable than consumption goods, it is important to examine how the real exchange rate (RER) has affected the relative price of investment goods. Given that the RER is a good indicator of the relative price of tradable goods in terms of nontradable goods, it would be expected that a lower (appreciated) RER would lead to a lower relative price of investment. In a regression of the price of investment relative to output on the corresponding price in the United States and the RER in each country, together with country dummies, the coefficients for both independent variables turn out significantly different from zero and of the expected sign: the coefficient on the relative price of investment in the United States is positive and statistically not different from 1, and the coefficient on the RER is positive.[31] The regression was also run including the index of trade reform developed by Lora and Barrera (1997) and updated by Lora and Panizza (2002). This index goes from 0 to 1, with 1 being the most liberal trade regime in the region in the period under consideration (mid-1980s to 2000). If trade reform led to cheaper prices for investment goods, then trade reform would have a negative coefficient. In fact, the coefficient is positive, although it is not significantly different from 0 at the 10 percent level of confidence.

The analysis so far casts doubt on the idea that trade liberalization has led to a decrease in the relative price of investment and, hence, an increase in imports of capital goods, which in turn has led to an increase in the relative demand for skilled labor. As a final check on this idea, the analysis evaluates whether there has been an increasing share of imported capital goods in the total capital stock in Latin American countries. A series was constructed on the total capital stock and the part of that stock that is composed of imported capital goods.[32] A regression of the imported capital component on a

[30] The regression used country dummies and was conducted for 1985-2000 (or until the last year for which data were available). The resulting coefficient is 0.82, with standard error 0.38 (t-statistic 2.15).

[31] The coefficient for the relative price of investment in the United States is 1.39 and the standard error is 0.54 (t-statistic 2.59); the coefficient for the RER is 0.0025 and the standard error is 0.00066 (t-statistic 3.79).

[32] To do this, both series were computed using the permanent inventory method with a depreciation rate of 6 percent. For the initial year, 0 was used as the value of the capital stock for both series. For total capital stock, the initial year was 1950, and the investment data are from Heston, Summers, and Bettina (2002). For the imported capital goods, the data are from the ECLAC Yearbook (table 295) and the initial year was 1960. Since the analysis is on the period from the mid-1980s onward, the value of the capital stock in the initial year is irrelevant. The ratio of stock of capital imported over total capital is obtained by dividing these two series.

time trend shows that there is a positive time trend.[33] A new regression of the imported capital component on Lora and Panizza's (2002) index of trade reforms (with country and year dummies) is run to examine whether this positive time trend is a result of trade liberalization. The coefficient on trade reform is basically 0. The same exercise, but using tariffs on capital goods instead of the index of trade reform, yields a similar result.

Thus, the analysis so far does not provide evidence for the hypothesis that trade reform has led to imports of capital goods, which in turn have increased the relative demand for skilled labor. But perhaps trade reform has led to skill-biased technological change that is not associated with more imports of capital goods. This idea hinges on the notion that trade liberalization leads to technological change. On this matter, there is strong disagreement among economists, and it is not the place here to review this literature (see Rodrik 1995). Suffice it to say that there is no consensus that trade liberalization has led to faster technological progress in the region. It is safe to say that trade liberalization, together with a set of "right conditions," would indeed lead to faster technological progress, but that unfortunately those right conditions have not prevailed in many countries in Latin America in the 1990s.[34]

Two recent papers that study the direct link between trade liberalization and skill-biased technological change are relevant here. Sánchez-Páramo and Schady (2003) obtained data on imports and the relative demand for skilled workers for a group of manufacturing industries in Chile, Colombia, and Mexico. They regress the relative demand for skilled workers on import penetration, using country-sector specific dummies, and find a positive and statistically significant coefficient. This is consistent with the results in Pavcnik and others (2002) for Brazil; they show that the sectors where import penetration increased more rapidly were also the ones where the share of skilled workers increased the most. These results must be interpreted with caution, however, because they use industry data to get at what is in essence a plant-level phenomenon. Thus, the results admit different interpretations. It could well be, for instance, that increasing import penetration goes together with contraction of the domestic sector. If contraction occurs through the exit of low-productivity firms or through reduced plant size, then this by itself could cause the observed increase in the relative demand for skilled workers.

To avoid these problems, instead of import penetration it is better to use more exogenous measures of trade liberalization, like tariffs. Pavcnik and others (2002) do this and find no statistically significant relationship between tariff reduction and rising relative demand for skilled workers. Examination of data for Mexico leads to similar results.[35]

Which Skills Are Most in Demand?

The appropriate policy response to increases in demand for skilled workers caused by technological change is to facilitate the appropriate supply response, which requires knowledge about the skills whose demand is increasing the most. Some commentators have implicitly or explicitly assumed that technological change has increased the demand for engineers and scientists. Is this true?

Data availability limits the study of this issue, but some knowledge can be gained from household surveys. In particular, for the case of Mexico, these surveys contain information about the supply and wages of college educated workers by educational attainment for two broad categories: scientists and engineers, and other professionals.[36] Figure 6.6

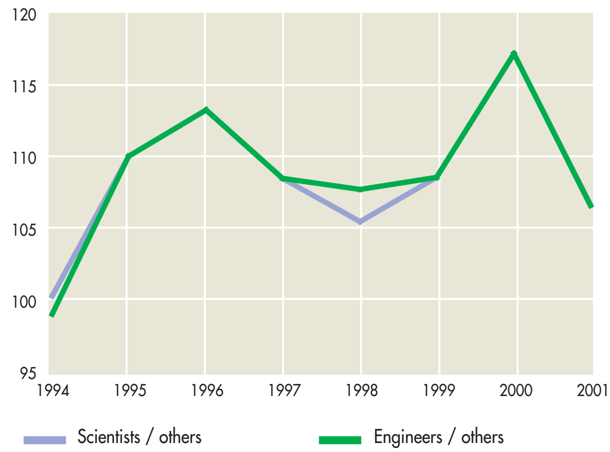
[33] This regression included country dummies. The coefficient on the time trend is 0.001, with standard error 0.00009 and t-statistic 10.3.

[34] Beyond the right macroeconomic conditions and appropriate education levels, there is debate about the "right conditions." For some, they are an effective national innovation system (de Ferranti and others 2003). For others, they are the right institutions (Rodrik, Subramanian, and Trebbi 2002). Others would argue that what is required is a cluster-based policy toward certain sectors.

[35] Using the data described in López-Córdoba (2003), a regression of plant-level skill intensity (measured as production to total workers in each plant) on industry-level import penetration and year dummies was run for 1994-2000. The estimated coefficient on import penetration turned out negative (increasing import penetration implies *less* skill intensity), but statistically indistinguishable from 0.

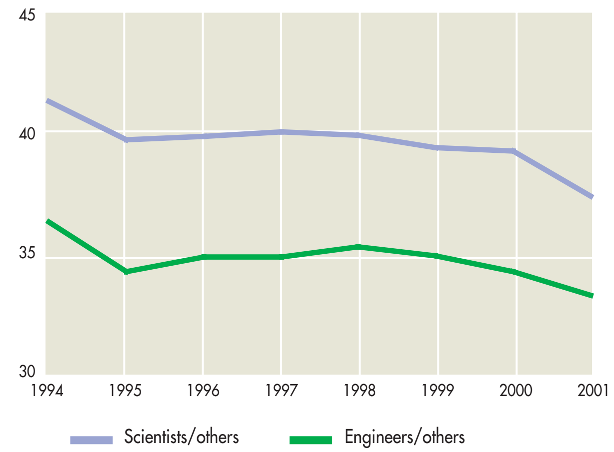
[36] Scientists and engineers include four subcategories: (1) physicists, chemists, and related professionals; (2) mathematicians, statisticians, and related professionals; (3) computing professionals; and (4) architects, engineers, and related professionals. Other professionals include five subcategories: (1) business professionals; (2) legal professionals; (3) archivists, librarians, and related professionals; (4) social and related science professionals; and (5) writers and creative and performing artists.

Figure 6.6 Evolution of Relative Wages of Scientists and Engineers in Mexico
(Percent)



Source: IDB calculations based on household surveys.

Figure 6.7 Evolution of Relative Supply of Scientists and Engineers in Mexico
(Percent)



Source: IDB calculations based on data from Encuesta Nacional de Empleo Urbano Mexico.

shows the evolution of wages for scientists and engineers relative to those for other professionals for 1994–2001.[37] The figure reveals significant swings from one year to the next, so it is difficult to infer a clear trend. Figure 6.7 shows that the relative supply of workers with technical degrees has been falling, which is contrary to what would be expected in the presence of increasing relative demand for workers with technical degrees. From these figures, it is difficult to infer an increasing relative demand for workers with technical degrees.

For the rest of the countries, there are no available data on wages and labor supply according to educational degree, but there are data classified according to occupation.[38] Figures 6.8 and 6.9 show the evolution of the wages and share of workers in technical jobs relative to those in other jobs for the countries for which household and labor survey data are available. From Figure 6.8, it is difficult to draw the conclusion that the relative wages of workers in technical occupations have increased; the only countries for which this appears to be true are Mexico and Panama. Is this due to an increase in the relative supply of workers in technical areas, which has compensated for an increase in the relative demand for such workers? Experience has varied across countries for workers in technical occupations:

- In Argentina, Brazil, and Uruguay, the relative wage fell and the relative supply increased. Thus, there is no clear conclusion about the relative demand for technical workers.
- In Panama, the relative wage increased and the relative supply decreased. Thus, there is no clear conclusion about the relative demand for technical workers.
- In Colombia, there was a slight fall in the relative wage, while relative supply also dropped. This suggests a decrease in the relative demand for technical workers.
- In Mexico, the relative wage increased and relative supply was constant. This suggests an increase in the relative demand for technical workers.

In sum, there is no clear evidence of an increase in the relative demand for technical workers in the countries in Latin America for which data are available.

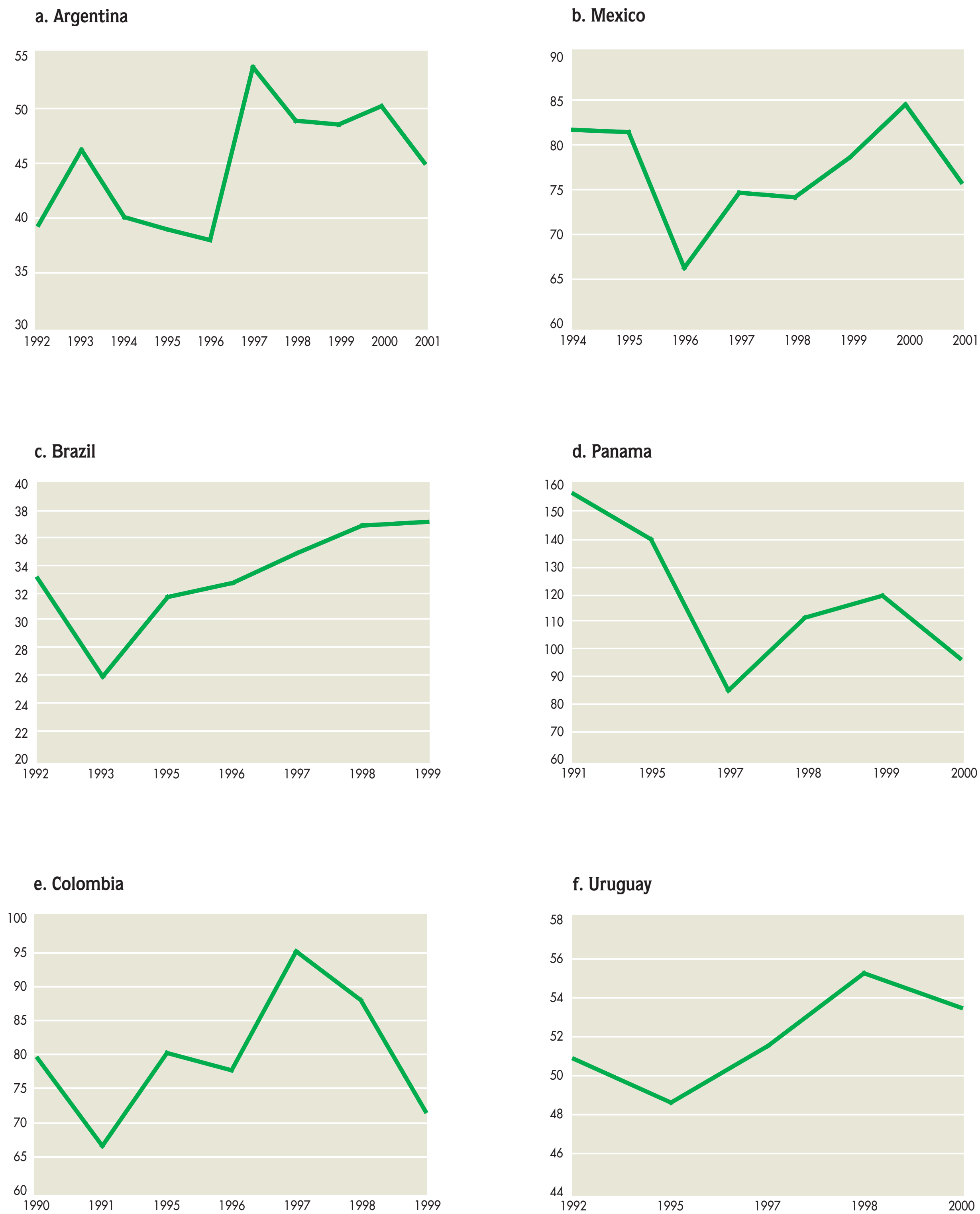
[37] Unfortunately, there are no consistent data for a longer period (there was a change in codification in 1994).

[38] The analysis focuses on data for hourly wages for males, although the implications are similar for other variables (monthly income and females).

Figure 6.8 **Evolution of Relative Wages of Technical Workers**
(Percent)

Note: Sample includes only salaried workers.
Source: IDB calculations based on household surveys.

Figure 6.9 **Evolution of Relative Supply of Technical Workers**
(Percent)



Note: Sample includes only salaried workers.
Source: IDB calculations based on household surveys.

Conclusion

This chapter has discussed the role of technology in labor markets in Latin America. In particular, it has considered the validity of the claims that technology is responsible for stagnant wages, rising unemployment, and the rising skill premium in the region. The data reviewed support the first claim in the sense that stagnant wages appear to be a result of stagnant productivity, which itself could well result from a slow pace of technological change.

The second claim, namely that rising unemployment is the consequence of technological progress, is clearly rejected by the data: it is not the case that countries with high TFP levels have lower employment rates, nor is it true that countries experiencing faster TFP growth have lower or declining employment rates. The same conclusion emerges if the number of personal computers per capita is used (instead of TFP) as the indicator of technological level.

The evidence and literature reviewed in regards to the third claim, namely that skill-biased technological change is responsible for the increasing skill premium in the region, are mixed and inconclusive. However, a clear conclusion that emerges is that the simplistic notion that trade liberalization has allowed firms to import production automation equipment that has replaced unskilled labor, and that this has led to the rising relative demand for skilled workers (especially in technical areas) is clearly wrong.

First, it is not clear that trade liberalization has caused an intensification in the adoption of skill-biased technologies. Trade barriers for importing equipment have not been removed in a significant way because they were already low. Moreover, it is not true that countries that have engaged in stronger trade liberalization have experienced a faster increase in imported capital as a share of total capital. And the empirical evidence is not clear on whether trade liberalization has led to faster technological adoption through other mechanisms (such as increased competition).

Second, the evidence rejects the notion that adoption of production automation technologies in manufacturing plants has led to an increase in skill intensity in those plants. More importantly, given the small and declining size of the manufacturing sector in the region, it is difficult to make the case that something specific to this sector is responsible for the increasing relative demand for skills in the whole economy. This conclusion is strengthened by data showing that all sectors, not just manufacturing, have experienced increased relative demand for skills. A more reasonable hypothesis is that the increasing penetration of information technology has caused the rising skill intensity in all sectors of the economy. But this hypothesis awaits clear confirmation in the region.

Third, the evidence does not support the claim that the relative demand for skilled workers is concentrated in workers with technical skills, as opposed to more general skills. Data from various countries show that the relative wages of workers with technical degrees or in technical occupations have not increased, and that this is not due to rising relative supply keeping their relative wages stagnant. The implication of this conclusion is important because it suggests that it would be wrong at this point to push for greater emphasis on engineering and scientific areas in the education efforts of the countries in the region.

Without a clear understanding of the specific causes of the rising skill premium, it is difficult to draw specific policy recommendations to deal with this phenomenon. But this should not be the main issue regarding technology and labor markets in the region. Of much greater importance than the rising relative wage of workers with tertiary education is the fact that wages have stagnated for workers with lower education levels. The finding that this is most likely caused by a slow pace of technological progress in the region should receive much more attention.

This is not the appropriate place to discuss in detail the policies that governments could follow to improve along this dimension (see de Ferranti and others 2003). However, countries should devote more energy to develop higher education systems that respond rapidly and effectively to the productive sector's demand for labor. Just as education policies by themselves are not the solution to the labor market problems affecting the region (as discussed in chapter 3), it is also true that without strong universities graduating high-quality professionals that respond to the needs of the private sector, it is doubtful that the region would improve its track record in terms of technology adoption and innovation. Moreover, a more responsive higher education system could prevent relative wages from deviating much in the medium term.

Given that the education sector is plagued by market imperfections, the role of the government is crucial. But public intervention in this area has not necessarily done much good: it is common to find governments transferring large sums of money to public universities that end up allocating these resources without placing adequate weight on private sector demand. As long as governments continue to transfer resources to public universities (and there are arguably good reasons for continuing to do so), it is important to make sure that these resources have a high social rate of return.

In this area, small changes could go a long way. For example, governments could slow the rate of growth of these transfers and allocate the freed-up resources toward projects in which universities collaborate with the private sector in terms of curriculum design, teacher training, investment in equipment, and research. This would help in promoting closer cooperation between universities and private sector associations at the sector level, so that the training provided by the universities would closely match the needs of firms. This collaboration should extend to national training institutes and technical schools.

Beyond public universities, governments should pay attention to improving the functioning of the higher education market. It is crucial to establish a system to improve information flows and decisionmaking regarding education choices. Prospective students should have better information about the labor market conditions (wages and the probability of employment) for various careers and universities. They should have better information regarding the quality of public and private universities, through a system of voluntary certification of universities and educational programs. And they should have access to loans in order to act on this information. These are all areas where government intervention could foster high returns.

Appendix 6.1 Decomposition of Growth in Labor Productivity

This appendix explains the analysis behind columns (2) and (3) in Appendix Table 6.1. As is customary in the literature, the analysis assumes a Cobb-Douglas production function in which labor's share is two-thirds: $Y = K^{1/3} (AL)^{2/3}$, Y is output, K is the capital stock, L is the quantity of workers, and A is a variable that captures the level of technology. This production function can be rearranged so that: $Y/L = TFP(K/L)^{1/3}$, where $TFP = A^{2/3}$. Taking logs and differentiating with respect to time yields the usual growth decomposition equation:

$$g = g\,(TFP) + (1/3)g(K/L)$$

where g is the growth rate of labor productivity, $g(TFP)$ is the growth rate of TFP, and $g(K/L)$ is the growth rate of the capital-labor ratio.

The problem with this approach is that part of the growth of the capital-labor ratio could be due to technological change. To see this, note that the rate of return to capital is $(1/3)A^{2/3}(K/L)^{-2/3}$, which is the marginal product of K in the production function above. As A increases, the rate of return to capital increases, and the natural consequence is more capital accumulation. It is natural to assume that in equilibrium the rate of return to capital is constant; for this to be the case, an increase in A requires a proportional increase in the capital-labor ratio. Thus, the decomposition above attributes to capital deepening what is really a contribution of technology.

There is another way to see this same point. Consider a model in which A and L grow at constant and exogenous rates g_A and g_L, respectively. Given the usual equation for the accumulation of capital ($\dot{K} = I - \delta K$, where $\dot{K}$ is the time derivative of K and δ is the rate of depreciation of capital), it can be shown that the capital-output ratio is given by:

$$\frac{K}{Y} = \frac{s}{g_A + g_L + \delta}$$

where s is the investment rate, assumed constant here. If the savings rate does not increase, the capital-output ratio does not increase. But the capital-labor ratio depends on both A and the capital-output ratio: $K/L = A(K/Y)^{3/2}$. Thus, even with a constant investment rate, an increase in A would lead to an increase in the capital-labor ratio.

This argument suggests a different decomposition, which comes from noting that $Y/L = A(K/Y)^{1/2}$. This leads to the following growth decomposition:

$$g = g\,(A) + (1/2)g(K/Y).$$

The benefit of this second approach is that, in contrast to the capital-labor ratio, the capital-output ratio does not depend on A. For instance, if all that happens is that A increases by 10 percent, then it would be expected that the capital-labor ratio would also increase by 10 percent. In the traditional decomposition, the increase in labor productivity is explained by both growth in TFP and growth in the capital-labor ratio. In this alternative decomposition, all the growth would be accounted for by growth in A.

This decomposition is shown in columns (2) and (3) in Appendix Table 6.1, where $g(A)$ is labeled technology and $g(K/Y)$ is labeled capital deepening.

Appendix 6.2 Growth in Labor Productivity across Countries and Time

This appendix explains the statistical analysis to uncover differences across countries and subperiods in the growth rates of labor productivity and its two components (technology and capital deepening). The analysis assumes that the growth rate of labor productivity in each country in each subperiod is the result of three elements: a country-specific element that is common across the three subperiods, a subperiod-specific element that is common across all countries, and a country and subperiod-specific element.

In other words, the analysis assumes that:

$$g_{ct} = \alpha + \gamma_c + \gamma_t + \varepsilon_{ct}$$

where g_{ct} is the growth rate of the variable of interest (labor productivity, the level of technology, or the capital-output ratio divided by two), subscript c denotes the country and subscript t denotes time (subperiod), and γ_c and γ_t are country and subperiod dummies. The associated regression was run imposing the constraints that both the sum of the country dummy coefficients and the sum of the subperiod dummy coefficients equal 0. In this way, the coefficients of the country and subperiod dummies can be interpreted as deviations from the sample means.

The results of this exercise reveal that only Chile and the Dominican Republic have rates of growth of labor productivity that are statistically higher than the sample mean, whereas Nicaragua has a growth rate of labor productivity that is statistically lower than the sample mean. For Chile and the Dominican Republic, the higher-than-average growth rates are due to statistically higher-than-average contributions from technology, not capital deepening. The reverse is true for Nicaragua.

The results for the subperiod dummies are interesting. Appendix Table 6.1 shows that there are no statistically significant differences across subperiods in the growth rate of labor productivity or the contribution from technology. Capital deepening made a statistically negative contribution in 1990-95 and a statistically positive contribution in 1995-2000.

Appendix Table 6.1 Subperiod Effects on Growth in Labor Productivity, 1985–2000

Subperiod	Labor productivity	Technology	Capital deepening
1985–90	–0.005	–0.004	–0.001
	(0.004)	(0.006)	(0.005)
1990–95	0.001	0.007	–0.010
	(0.004)	(0.006)	(0.005)**
1995–2000	0.003	–0.002	0.012
	(0.004)	(0.006)	(0.005)**
F tests of differences across subperiods			
1985–90 vs. 1990–95	0.67	1.04	1.28
1985–90 vs. 1995–2000	1.19	0.03	2.54
1990–95 vs. 1995–2000	0.07	0.71	7.43**

** Significant at 5 percent.
Note: t-statistics are in parentheses.
Source: IDB calculations.

Appendix 6.3 The Implied Relative Demand for Skills

Is there a generalized trend in the demand for different skill groups? Consider N skill groups and M countries. Output is produced according to the following CES production function:

$$Y_{jt} = \left(\sum_{i=1}^{N} (A_{ijt} L_{ijt})^{\sigma} \right)^{1/\sigma}$$

where L_{jit} is the quantity used of labor type $i = 1, 2, \ldots N$ in country $j = 1, 2, \ldots M$ at time t, and where the elasticity of substitution among labor types is $\varepsilon = -1/(1 - \sigma)$ with $\sigma < 1$. Equality of supply and demand for labor type i at time t implies the following:

$$w_{ijt} = Y_{jt}^{1-\sigma} A_{ijt}^{\sigma} L_{ijt}^{\sigma-1}.$$

Dividing the wage of labor type i by the wage of labor type 1 and taking logs gives the following:

$$\ln\left(\frac{w_{ijt}}{w_{1jt}}\right) = \sigma \ln\left(\frac{A_{ijt}}{A_{1jt}}\right) - (1 - \sigma) \ln\left(\frac{L_{ijt}}{L_{1jt}}\right).$$

Assuming a particular value for σ, say 0.5 (so that $\varepsilon = -2$) or 1/3 (so that $\varepsilon = -1.5$), and using data for the left-hand side of the equation and the second term on the right-hand side, the implied $\ln(A_{ijt}/A_{1jt})$ for each skill group/country/year triplet can be calculated.