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ABBREVIATIONS AND ACRONYMS

CIMO	Program of Integral Quality and Modernization
CNCM	Computerized Numeric Controlled Machinery
CONACYT	National Science and Technology Council
EIA	Annual Industrial Survey
ENESTYC	National Survey of Employment, Wages, Technology and Training
FIDETEC	Fund of Research and Development for Technical Modernization
GDP	Gross Domestic Product
INEGI	National Institute of Statistics, Geography and Information Technology
NAFTA	North American Free Trade Agreement
NCM	Numeric Controlled Machinery
OECD	Organization for Economic Co-operation and Development
PAIDEC	Program to Support Research and Development Projects
PMT	Program of Technological Modernization
PROVINC	Program to Support Academic Sector Links
R&D	Research and Development
SBTC	Skill-biased Technological Change
S&T	Science and Technology
TA	Technology Adoption
TFP	Total Factor Productivity

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Gladys López-Acevedo (LCSPE) wrote this report; Joseph S. Shapiro and Erica Soler provided valuable research and editorial assistance. Volume I of this report summarizes the background papers in Volume II. The team benefited from comments received at the international Conference on "Innovation and Technology for Human Development" held by the United Nations Development Program (UNDP) jointly with the Mexican government on July 11, 2001. The team also received valuable feedback from government officials, particularly from the Ministry of Economy, the Ministry of Labor, and the INEGI, while writing this report. The findings from this report gave support to some of the government policies envisioned in the forthcoming National Development Technology Plan. We want to express appreciation for the close collaboration and report comments offered by Miguel Cervera, Abigail Durán and Alejandro Cano (INEGI headquarters), the General Direction of Labor Statistics, Policies and Studies at the Ministry of Labor (STPS), the General Direction for Science and Technology Policy at the National Science and Technology Council (CONACYT), and the Direction of Technology and Quality at the Ministry of Economy (SE). We are grateful to William F. Maloney (LCSPP) and Hong W. Tan (WBIHD) for their comments as peer reviewers. The lead Economist for Mexico, Marcelo Giugale, provided overall guidance. This study was carried out under the general direction of Mr. Olivier Lafourcade (Director, LCC1C).

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EXECUTIVE SUMMARY

This report examines two components of new technology adoption (TA) by Mexican manufacturing firms. First, adoption of new technology in particular circumstances has different impacts on the performance of different types of firms. We ask: what firms, what circumstances, what performance? We use productivity, wages, and net employment of a firm to measure its performance. In relation to this, we also ask whether technological change disproportionately helps workers of certain skill levels. Second, a firm adopts new technology when the circumstances are ripe. Here we ask: which firms, what circumstances, and which technologies? These questions allow us to distinguish the effects of adopting new technology. They also let us explain the extent to which a firm uses a particular *kind* of technology. Our data comes from the National Survey of Employment, Wages, Technology, and Training (ENESTYC), and the National Industrial Survey (EIA), for 1992, 1995 and 1999. Both surveys are conducted by the National Institute of Statistics, Geography, and Information (INEGI). This main volume summarizes the three technical papers in Volume II, which offer detailed discussion of relevant literature, methodology, and results.

Answers to these questions clarify when new technology improves performance and what factors determine whether a firm uses new technology at all. Generally, technology improves firm performance, and outperforming firms speed economic growth. However, different circumstances improve performance by different amounts, and inspire particular firms to adopt technology. By knowing what circumstances best improve the performance of a particular firm type, government can better encourage adoption of efficacious technology. By knowing the circumstances that inspire firms to adopt new technology, government can design policies to increase TA.

In this report, we offer six extensions to previous findings of the Bank and others. First, we consider the *type* of technology that a firm adopts. Our data allow us to distinguish between the adoption of a robot and the adoption of a numeric controlled machine, and thereby to see which factors influence the adoption of a particular type of technology. Second, we consider the effects of state technology variables, such as government spending on research and development

(R&D) and on firm TA. This consideration puts us in a better position to recommend public policies to influence private sector behavior. Third, we also consider the effect of union on firm TA. Fourth, we use precise firm performance measures such as wage growth, job creation, job destruction, net employment, total factor productivity (TFP), productivity, and value-added, whereas previous studies have tended to use either a single measure of performance or aggregated measures as proxies for firm performance. Since different measures give different pictures of firm performance, use of these measures gives a more detailed picture of performance. Fifth, we examine the timing of the benefit. This is in order to understand how the time of TA relates to the time of training, hiring, and salary raises. Finally, whereas most studies just look at whether a firm adopts new technology, we also ask to what extent the firm integrates the technology. In combination with data on technology type, this technological intensity analysis proxies the usefulness of a particular technology to a particular firm.

Results

Analysis of data from about 6,000 manufacturing firms in Mexico in the 1990s suggests several conclusions. First, firms that adopt new technology perform better. All metrics of firm performance that we use – worker wages, firm productivity, job creation, job destruction, net employment, and value-added – support this finding. However, this finding does not imply that new technology increases performance of *all* firms—a firm only adopts a new technology if it has reason to think that technology will improve its performance. Moreover, we find that the effect of technology on the performance of firms varies across firms of different size and located in different regions. However, we do find that investments in human capital magnify technology-driven productivity gains. A firm that pursues worker training in conjunction with TA increases its productivity benefit from new technology. Firms may already be aware of these results, since employee training precedes and positively correlates with TA.

Second, in our sample of manufacturing firms, technological change is skill-using for skilled workers but skill-replacing for unskilled workers. It may be that computers let skilled workers function more efficiently, but that machines replace unskilled workers. Perhaps because of skill-replacement, we also find that TA increases wage inequality. Although TA causes average wages to rise, wages of skilled workers rise much more than wages of unskilled workers.

Third, the likelihood of TA varies markedly by time period, firm, industry, and technology type. Specifically, TA in the 1995-99 period was more prevalent and more effective than TA during 1992-95. In general, the firms most likely to adopt new technology are large, have a high proportion of skilled labor, train workers, operate on a high proportion of foreign capital, have large R&D budgets, and are located in the North. It may be that proximity to the U.S. increases competition, and that competition encourages firms to adopt technology, so a firm's proximity to the U.S. encourages it to adopt technology. Firms adopting the most *complex* technology frequently train workers and have large R&D budgets. Also, a firm that trains workers or adopts new technology in one year is highly likely to do so in following years. The complexity of the technology that a firm is likely to adopt correlates with both the firm's size and the skill level of its workers, as large firms adopt more complex technology than small firms, and firms with many skilled workers adopt more complex technology than firms with more unskilled workers.

Fourth, training and R&D increase the intensity in the use of more complex technologies such as automatic equipment, NCM and CNCM, while they reduce the intensity in the use of more simple technologies such as manual equipment and machinery tools.

Policy Recommendations and Conclusions

The OECD (2000) emphasizes that governments can improve the effectiveness of R&D expenditure by supporting proliferation of venture capital and credit institutions. Public/private partnerships with selective participation also maximize the value of government R&D expenditure. These partnerships could take the form of shared seminars, working groups, or regular discussion meetings. Inviting private sector representatives to policy planning meetings offers a good way of integrating public priorities with private needs. Additionally, public research expenditure should focus on basic knowledge and broad findings that can aid a wide variety of industries.

Melo (2001) also identifies the following main areas of action for current technology policies in Mexico, Brazil, and Argentina: promoting R&D efforts by the private firms themselves, strengthening cooperation between public sector research institutions and private firms, and creating or strengthening the informational infrastructure necessary for the success of R&D activities by the firms.

On balance, this study shows that new technology improves performance in certain circumstances. Most firms know their customers and competition, so they are likely to have a good sense of when a technology will improve performance. However, these firms may lack knowledge of existing technologies in the marketplace. Therefore, government technology policy should be twofold. First, policy should spread knowledge of existing technology, facilitate inter-firm linkages, offer consultations to firms to recommend technologies, and encourage shared information of efficacious technology. Second, government should facilitate TA in firms that are likely to benefit from new technology while avoiding incentives for TA among firms simply seeking government money. Ideally, the first prong of government policy will let firms likely to benefit from technology self-identify, so government can offer financing, loans, grants, or consultations, to encourage only these firms to adopt new technology and thereby improve their performance. Given the results which emerged from this report, future research should address specific policy questions such as: What is the impact of collective bargaining agreements, rules on training, output and technology adoption? What is the impact of minimum wages, or mandatory severance pay on training, output and technology adoption?.

Nevertheless, new technology in Mexican manufacturing in the 1990s worsened wage inequality and disproportionately benefited skilled workers. Integration of advanced machines into maquiladoras, for example, may increase firm performance but may replace some workers and relatively diminish the wages of others. Ideal development in Mexico would be inclusive, but expanding use of new technology may in some cases exclude unskilled workers from the benefits of economic growth. Policymakers should not take this caveat as a reason to discourage TA, but rather a reason to encourage equal wage growth in conjunction with technology. Lessons from other countries show that government could encourage training through levy-grant systems, tax credits, and training subsidies. Gill, Fluitman, and Dar (2000) review the effectiveness of these schemes. Training workers of all skills in conjunction with TA is a cost-effective way for firms to improve performance while benefiting all workers.

The change in the effect of technology that occurred between 1992-95 and 1995-99 suggests another set of policy measures. The first change between these periods was the integration of the North American Free Trade Agreement (NAFTA) in 1994, which opened borders and intensified pressure on Mexican firms. Second, the 1994 crisis increased interest and inflation rates, diminished the buying power of firms and workers, and lessened investor confidence in lending. Both events increased the competition that Mexican firms faced, and it appears that both also increased the effectiveness of TA. To further increase the value of new technology to firms, the government should continue liberalizing the Mexican economy. Allowing free flow of goods, individuals, and ideas between borders and demarcating the public from the private sector by selling public corporations and limiting market interference – the golden oldies of improved performance – form an ideal environment for efficient TA.

Furthermore, the Mexican government should continue increasing its funding of R&D but also encourage private R&D funding. Mexico has a relatively low level of R&D spending, but it is growing fast. Maintaining this growth will promote the quality of future technology developed in Mexico. Since the private sector may know its technological needs better than the public sector, government might also encourage the private sector to expand its own R&D expenditure by such means as a R&D tax credit.

1. Introduction

Technological change has been an engine of growth for industrialized countries and remains an opportunity for the growth of developing countries. By analyzing firms in Mexico, our goal is to understand more fully in what circumstances new technology improves performance and what factors determine whether a firm uses technology at all. We examine the marginal value of technology by considering cases of TA, where a firm first integrates a new technology. Adding firm-, region-, and industry-specific variables to our analysis allows us both to consider the effect of these variables on the likelihood of TA, and also to determine the effect of TA in the performance of firms while controlling for these variables.

Why ask these questions? A successful firm offers workers a well-paying, long-lasting job and a high quality of life that allows them to build families and communities. These companies also build human capital and achieve recognized development goals. In part, our goal is academic: we seek to understand further the processes by which TA occurs, and correspondingly, the processes by which firms become successful. However, another goal is material: we hope that a better understanding of technology will facilitate more jobs with higher wages for Mexican workers. Ultimately, our goal is to improve the quality of Mexican manufacturing jobs. A thorough understanding of how technology distributes its benefits between highly skilled and unskilled workers is a potent tool to facilitate shared growth through TA.

This understanding should be valuable to researchers, policymakers, and private sector decision-makers. Generally, technology can improve firm performance and outperforming firms can speed up economic growth—on these points researchers disagree little. Nevertheless, different circumstances improve performance by varied amounts, and inspire particular firms to adopt technology. By knowing what circumstances best improve a particular type of firm's performance, government can better encourage adoption of efficacious technology. By knowing the circumstances that inspire firms to adopt new technology, government can design policies to increase TA.

As support for the World Bank's current Country Assistance Strategy, this study builds on important contributions. The Bank's Knowledge and Innovation Loan (World Bank 1998) was based on the premise that for Mexico to achieve higher growth in total factor productivity (TFP) and thereby higher income and wage growth, firms would have to adopt more new technology. The Bank later found that high-technology workplaces and highly skilled labor correlate with export and productivity growth (World Bank 2000b).

This volume contains seven sections that develop this knowledge, beginning with the Introduction. Section II outlines issues pertinent to the Mexican experience, including trade liberalization, the 1994 crisis, and the science and technology (S&T) sector. Section III reviews relevant literature on the benefits of new technology, the skill-biased technological change (SBTC) hypothesis, and determinants of TA. Section IV describes the data used for this research. Section V explains the methodology used and expected results. Section VI discusses research findings for the impact of TA on firm performance, and for determinants of TA. Section VII offers conclusions and suggests policy implications.

2. The Mexican Experience

To understand Mexico-specific technology findings, we need to understand the economic and technological circumstances in which firms adopt new technology. This section discusses Mexico's trade liberalization, the 1994 crisis, and the condition of the S&T sector in Mexico.

2.1. Liberalization

While Mexico was protected from international trade, the technical ability of firms received little policy attention. Since trade liberalization began in the 1980s, however, the technological capability of Mexican firms has risen to the forefront of policy concerns. Liberalization began in 1984 and accelerated when Mexico joined the General Agreement on Tariffs and Trade in 1986. In 1989, the government began radical policy reforms to reduce government regulation and liberalize trade. The adoption of NAFTA with the U.S. and Canada in 1994 intensified liberalization.

Because of this international openness, technology now lies at the heart of Mexican economic activity. Globalization-induced competition has made firms increase the speed and efficiency of TA. It has also inspired firms to increase R&D budgets (OECD 2000).

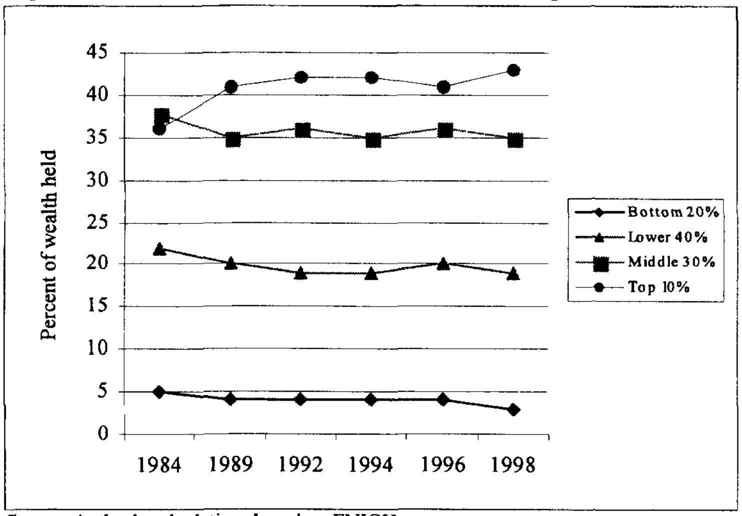
However, along with liberalization Mexican wage equality has worsened. The Gini coefficient, which measures income inequality and is especially sensitive to changes around the population median, rose from 0.47 in 1984 to 0.53 in 1998 (Table 1). While the poorest quintile lost 1.3 percent of its income during this period, the richest decile increased its wealth by 7.7 percent. In relative terms, all strata except the richest lost income during this period (Figure 1). Chile experienced a similar worsening of wage inequality, but in the early 1990s this trend reversed (Gill and Montenegro, forthcoming). This reversal may have occurred because Chile's government has pushed strongly education and training programs to help the poor sectors reap some of the benefits of economic growth.

Table 1. Inequality in Mexico, Measured by Gini Coefficient

Year	National	Urban	Rural
1984	0.47	0.44	0.45
1989	0.52	0.50	0.44
1992	0.53	0.50	0.43
1994	0.53	0.51	0.42
1996	0.52	0.49	0.45
1998	0.53	0.495	0.48

Source: Author's calculations based on ENIGH.

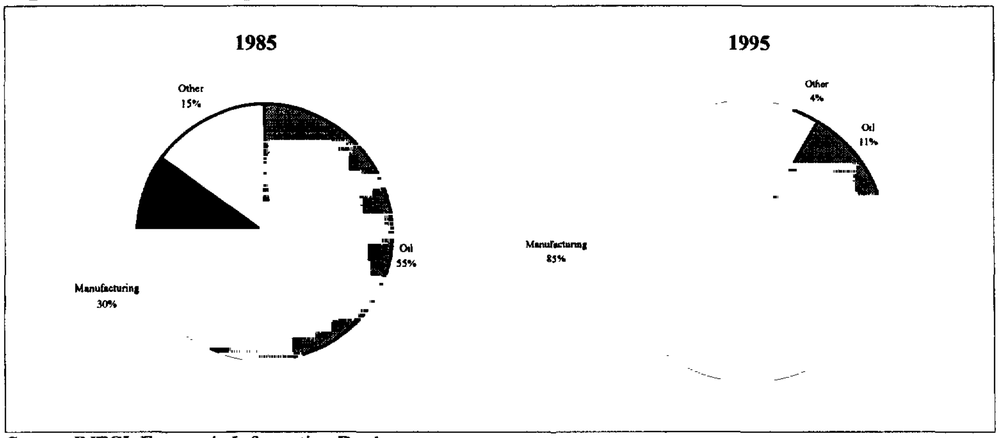
Figure 1. Wealth Distribution among Mexican Population



Source: Author's calculations based on ENIGH.

Liberalization also restructured the Mexican economy. After 1994, the composition of exports shifted: in 1985, oil accounted for more than 55 percent of total exports; in 1995, the share had fallen to under 11 percent. Correspondingly, manufacturing increased from 30 percent of total exports in 1985 to 85 percent a decade later (Figure 2).

Figure 2. Mexican Export Composition, 1985 versus 1995



Source: INEGI, Economic Information Database.

Growth was pronounced in export industries. The best manufacturing export performers during 1994-2000 were the textile, clothing, and leather industry, with 284 percent growth, and the metallic products, machinery, and equipment industry, with 207 percent growth. Many other manufacturing industries had export increases in this period of over 100 percent. The most significant of all the increases was in "metallic products, machinery, and equipment," which represented 15 percent of all Mexican exports in 1991 and 19 percent in 2000.[1] In 1991, export plants (maquiladoras) accounted for 37 percent of exports; in 2000, they represented almost 48 percent of all Mexican exports. From 1994 to 2000, maquiladora exports grew by 202 percent while non-maquiladora exports grew by 151 percent. However, some non-maquiladora manufacturing industries such as metallic products, machinery, and equipment grew even faster (263 percent) than the maquiladora sector.[2]

[1] INEGI, Economic Information Database.
[2] Ibid.

2.2. The 1994 Crisis

At the height of liberalization, Mexico underwent a severe currency crisis. In December 1994, the Mexican peso sharply devalued against the dollar and a rapid outflow of Mexico's foreign currency reserves began. The following month, a $48.8 billion stabilization package was announced by the U.S. ($20bn), the International Monetary Fund ($17.8bn), and the Bank for International Settlements ($10bn), to prevent further devaluation and default on Mexico's short-term debt.

The package succeeded in preventing global spread of the crisis, but failed to prevent a local recession. Real Mexican wages fell and did not return to their previous levels until 1998. In 1995, gross domestic product (GDP) dropped by 6.2 percent and inflation jumped from 7 percent to 52 percent.

Regulatory reforms adopted in response to the crisis focused mostly on the banking sector. Government loosened restrictions on foreign ownership of Mexican banks and developed short-term lending instruments. Since most analysts thought that the Mexican economy was properly liberalizing and increasing efficiency and that the crisis was mainly financial, regulatory reforms generally excluded the manufacturing sector.

Nonetheless, changes in the economy caused by the crisis had a great impact on the manufacturing sector. The crisis itself caused a short-term 30 percent drop in growth of exports to the U.S., which included mostly manufactured goods (Gould 1996). The increased cost of borrowing due to high interest rates also impeded manufacturing plant growth and business development. This pressure may simply have magnified the effects of liberalization, but in doing so it forced firms to become more efficient (Health 1999).

Since the crisis and NAFTA's implementation occurred in the same time period, and since both forced manufacturing firms to increase efficiency, distinguishing between their effects is difficult. However, the distinction may be unnecessary. Whether a change in firm behavior was caused by either NAFTA or the crisis is unnecessary to determine that the change was associated with pressure toward firm efficiency.

2.3. Science and Technology

Since technology can play a key role in these economic fluctuations, it is a key issue for development (OECD 2000). Usually, domestically developed S&T is the source of technologies that firms adopt; this is not the case in Mexico. Due to a lack of technical innovation in Mexico, many technologies used in Mexico come from abroad, so profits from their use do not remain in Mexico.

Research has identified four weaknesses of the Mexican S&T sector (World Bank 1997, 1998; OECD 1999, 2000; CONACYT, *Programa de Ciencia y Tecnología 1995-2000*). First, S&T institutions are experiencing market failure. There is a gap between the targets of Mexican government research and the needs of private sector companies, yet 70 percent of Mexican R&D is government-funded. In R&D intensive countries such as Japan, Korea, and the U.S., business is the major source of R&D. Furthermore, the quantity and quality of Mexican engineers produced by universities has failed to meet demand by Mexican firms (Table 2).

Table 2. Researchers per Ten Thousand Labor Force

	1993	1995
Mexico	4	6
United States[1]	74	..
Canada	50	56
Australia[2]	60	64
Korea	..	48
Turkey	6	7
European Union[1]	46[3]	49

1. 1993 data is from 1992.
2. 1995 data is from 1994.
Source: OECD (2000).

Second, S&T investment is insufficient. Although Mexico may rely on imported technology, it must invest substantially in human capital and infrastructure to ensure effective absorption of this technology (OECD 1997). For example, Mexico spends 0.3 percent of its GDP on R&D, the lowest share in the entire OECD (Table 3). It is a good sign that today Mexico and Turkey show the highest annual growth rates of R&D expenditure (OECD 1998). This may be simply a statistical phenomenon, however, countries further away from the mean demonstrate relatively larger growth.

Table 3. R&D Expenditure as Percentage of GDP

	1993	1995	1996	1997
Mexico	0.2	0.3	0.3	0.3
United States	2.6	2.6	2.7	2.7
Canada	1.6	1.6	1.6	1.6
Australia[1]	1.5	1.6	1.6	..
Korea	2.2	2.5	2.6	2.7
Turkey	0.4	0.4	0.5	0.5
European Union	1.9	1.8	1.8	1.8

1. 1995 data is actually from 1994.
Note: Figures represent percentages of GDP.
Source: OECD (2000).

The effectiveness of S&T research depends on the productivity of researchers and relevance of output to social and economic development—in other words, knowledge output per unit of research input, and the value of this output to research goals. Measured in terms of annual scientific publications, Mexican productivity remains low among OECD countries and international standards at a share of 0.4 percent of total OECD research (Table 4). Human capital, which is necessary to effectively use technology, also remains low. Mexico produces fewer Ph.D.s per year than comparable countries (OECD 2000). Of those aged 25 to 34, 90 percent have at least upper secondary education in the Czech Republic, Japan, Korea and Norway, but less than 30 percent do in Mexico (OECD 2000).

Table 4. Number of Scientific Publications per 100,000 population

	Annual average, 1995/97	Annual growth (%) 1987-97
Canada	70.1	0.0
Mexico	1.9	7.8
United States	65.3	-0.1
Australia	64.6	2.0
Korea	8.7	22.2
Turkey	3.0	17.5
European Union	43.6	2.2

Source: OECD (2000).

The third challenge facing the Mexican S&T sector is the lack of technological support institutions. Finally, there is a regional disparity in S&T capacity, which is particularly weighted toward Mexico City. Severe disparity in S&T capacity causes some regions to advance while others stagnate, causing S&T infrastructure to locate disproportionately in Mexico City. Over half of the National System of Researchers is located in Mexico City, and more than three-fourths of all doctoral degrees are awarded by colleges in the Mexico City area (CONACYT, 2000).

3. Technology Literature

3.1. Benefits

Previous research has established that economic growth needs a sufficient level of technology. Bell and Pavitt (1992) found that the technology Mexico adopts comes not from Mexican research but from technological knowledge developed in other countries. It seems reasonable to assume that much of the future technology used in Mexico will be developed abroad. Mexico's technological ability, then, will be crucially shaped by its ability to utilize foreign technology, or its absorptive capacity (Audretsch 1995; Cohen and Levinthal 1989). To develop meaningful absorptive capacity, Mexico must achieve a threshold level of knowledge and technological development (OECD 1997; Dosi, Pavitt, and Soete 1990).

Indeed, other countries have experienced major benefits from TA. In the U.S., manufacturing plants that adopt technology exhibit superior performance (Doms, Dunne, and Roberts 1995). In The Netherlands, R&D and skilled labor investments also improve firm performance (Audretsch and others 2001).

On a broader level, the *Human Development Report 2001* stresses that technology is both a tool for development and that development advances technology. Technology directly reduces infant mortality and expands life expectancy.

3.2. Skill Bias

Technology is a valuable tool for development but also a tool that can cause employment and wealth restructuring. Technology increases the relative wages and employment share of skilled labor, thereby increasing a country's income dispersion. Generally, we can explain increased inequality by changes in a population's level of education or a shift in the return to education. The World Bank's "Earnings Inequality after Mexico's Economic and Educational Reforms" shows that inequality in Mexico has worsened, but that changes in education levels are insufficient to explain inequality, so the value of education in Mexico must have changed. Three possible theories – change in minimum wage, integration of technology, and liberalization – can explain a change in the value of education. As an explanation for the worsening of earnings inequality in Mexico, the minimum wage is unimportant, but liberalization and technology are highly important (World Bank 2000a). Furthermore, Acosta and Montes (2001) show that technological change is more important than trade in explaining the increase in skill premium in Argentina and Mexico.

There is a large body of research for industrialized countries on this hypothesis, deemed the skill-biased technical change hypothesis (SBTC). However, there is little research assessing SBTC in developing countries. Currently, the Bank is financing small research groups evaluating this hypothesis in developing countries, such as Brazil, India, and Malaysia. Tan (2000a) finds that Malaysian manufacturers increase skilled labor employment and wages in conjunction with adoption of information technology. Berman, Bound, and Machin (1997) find that excepting Belgium, the twelve countries with the highest gross national product per capita increased skilled labor employment in conjunction with TA. Berman, Bound, and Griliches (1994) examine four possible explanations for increased wage inequality in the U.S. in the 1980s and conclude that SBTC is the primary cause. Bruinshoofd and Weel (1998) report similar findings for the Netherlands, as do Haskel and Heden (1998) for the U.K. Sanguinetti and others (2001) show that trade liberalization has worsened wage inequality in Argentina but not in Uruguay. After controlling for liberalization, industry, firm, and labor demand shock, they find that SBTC explains a significant portion of this inequality. Acosta and Montes (2001) find a constant increase in skill premium in Mexico during the 1987-1993 period, but a deceleration during the 1994-99 period and a decline after 1997. These authors contend that the former may be caused by between industries differences.

The World Bank (2000a) shows that demand increases for a more educated labor force within the economic sectors explain the increase in their premium when compared to the demand shifts for less educated workers between economic sectors. Acosta and Montes (2001) show that there is a constant increase on skill premia during the 1987-1993 period, but there is a decelaration during the 1994-99 period and a decline after 1997. These authors contend that the former may be caused by between industries differences.

Most of this research focuses on TA at the macro level, but a thorough understanding of TA at the firm level is necessary to design effective policy. More specifically, we need to understand in what circumstances TA improves performance. Several studies have tried to measure TA at the firm level, but only a handful link TA to firm performance.[3] These empirical studies show close correlation between TA and productivity (Audretsch and others 2001; Tan 2000a, 2000b; Aw and Batra 1999; Doms, Dunne, and Roberts, 1995). Several authors also find that TA raises demand for more skilled workers and so reduces demand for physical labor (Katz and Murphy 1992; Davis and Haltiwanger 1991; Krueger 1993; Mincer 1991).

3.3. Determinants of New Technology Adoption

A large body of literature asks what types of firms and circumstances increase TA likelihood most. Blomstrom, Kokko, and Zejan (1992), in an analysis of Mexico, find that local competition most encourages subsidiaries of multinational firms to import technology. Firm size is perhaps the most widely recognized determinant of TA. Studies find that, all things being equal, larger firms are more likely to adopt new technology than their smaller counterparts (Mansfield 1961; Davies 1979, Romeo 1975; Globerman 1975).

By increasing the pressure under which local firms operate, trade liberalization may also increase TA likelihood (Iscan 1998). A firm, of course, only adopts the technologies that it concludes will help its performance. If no such technologies are available, the firm is less likely to adopt new technology. Therefore, the availability of appropriately complex technology is another determinant of TA likelihood (Lapan and Bardhan 1973; Cantwell 1989; Haddad and

[3] See technical papers 1 and 2 of this report for a more thorough review.

Harrison 1993). Torres (2000) also finds that the scientific ability of a firm's region influences absorptive capacity. To capture all these influences, we use a wide range of variables in the TA determinants estimations.

4. Data

Our data comes from three sources. First, INEGI conducted the National Survey of Employment, Wages, Technology, and Training (ENESTYC). The Ministry of Labor co-designed the questionnaire, which gathered rich information on manufacturing firms and their technologies. The government conducted the survey in 1992, 1995, and 1999, but its questions on technology ask whether the firm adopted technology in the periods 1989-92, 1994-95, or 1997-99, respectively. Subsequent references to the time of TA mention only the final year of the period (e.g. 1992 rather than 1989-92). Data from the 1992 survey includes 5,071 manufacturing firms, data from the 1995 survey includes 5,242 manufacturing firms, and data from the 1999 survey includes 7,429 manufacturing firms.

ENESTYC allows us to identify the same firm in different years. Nevertheless, this valuable feature makes us exclude firms that did not exist in all three years, thereby biasing our sample to surviving enterprises, which tend to be large and old (Audretsch 1995). While random observation selection should not cause bias in our resultant estimations, surviving firms are not randomly selected. Darwinian selection of extant firms means that the firms in our sample tend to be more efficient and have better performance than a truly average Mexican firm.

Second, INEGI conducts the EIA, which covers 6,500 Mexican manufacturing plants. Since the survey attempts to cover most aggregate production but not most plants in all categories, our sample includes most large plants but very few small plants. To compare technology data with firm-specific characteristics, we linked the ENESTYC panels to firms in the EIA. The 1992-95 panel has 3,293 manufacturing firms, the 1995-99 panel has 1,717 manufacturing firms, and the 1992-99 panel has 1,066 manufacturing firms.[4]

[4] Appendix B of Volume II shows the number of firms in each panel broken down by size and industry.

Third, we use state-level S&T variables from the National Council of Science and Technology (CONACYT). Inclusion of these variables allows us to relate regional context and public policy with technology effectiveness.

These surveys define several variable categories that we use for analysis. Although a detailed explanation of these variables appears in Appendix C of Volume II, we offer a brief description here. According to INEGI's definitions, a micro-size firm has 1-15 workers, a small firm has 16-100 workers, a medium-size firm has 101-250 workers, and a large firm has 250 or more workers. We consider nine manufacturing industries, according to the National Accounts definitions: (1) food, beverages, and tobacco; (2) textiles, clothing, and leather; (3) wood and wood products; (4) paper, paper products, printing, and publishing; (5) chemicals, oil derivatives, and coal; (6) non-metallic mineral products; (7) basic metal industries; (8) metal products, machinery, and equipment; and (9) other manufacturing industries.

We measure foreign capital in absolute terms; if foreign investment in the firm exceeds 50 percent of total investment in the firm, we consider it as a foreign capital firm. We use a similar measurement for exports; if over 50 percent of a firm's total sales come from outside the country where it has headquarters, we consider it to be an export oriented firm. Similarly with technology, if the firm adopts new technology we give it a point, and if not, it receives no weight in our calculations. We consider the adoption of six different technology types: manual equipment, automatic equipment, machinery tools, numeric controlled machinery (NCM), computerized numeric controlled machinery (CNCM), and robots. We also use dummies to indicate if the firm is in the maquila sector, if the firm is a subsidiary, and if the firm has a union. We measure R&D as the percent of the firm's total expenditures directed to R&D; we also use a variable that measures the percent of the firm's total expenditures directed to technology transfer. We measure training as an all-or-nothing variable, so it is impossible to distinguish between a firm that trains annually and a firm that trains weekly.

Definitions of Regions	
North	Baja California, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo Leon, Sinaloa, Sonora, Tamaulipas, and Zacatecas
Center	Aguascalientes, Colima, Guanajuato, Hidalgo, Jalisco, Mexico, Michoacan, Morelos, Nayarit, Puebla, Queretaro, San Luis Potosi, and Tlaxcala
South	Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz, and Yucatán
Capital	Distrito Federal

We measure wages in real pesos, and productivity as units of output divided by the number of workers. For value-added we use INEGI's calculations, which measure value-added as the difference between the production value and the cost of the production factors. We estimate total factor productivity (TFP) as the residual in a production function.

5. Methodology and Hypotheses

We include here a cursory methodology section; thorough discussion appears in the technical papers. For each set of estimations, this section presents methodology then expected results.

5.1. New Technology and Firm Performance

A. Firm Performance

For the wage, net employment, job creation, job destruction, and productivity measures we use random and fixed effects models. In these models, after controlling for industry, a firm's characteristics and its status of having adopted new technology or not in the given period predict the firm performance measure. We run separate models for each measure of performance, and also the sample is restricted only to firms of a particular size or located in a particular region. However, we are interested in analyzing not only the correlation but also the causality amongst TA and firm performance, therefore, we also run a joint estimation for wage performance and TA determinants. For this joint estimation we use a three-stage least squares method. For the value-added metric of firm performance we use a fixed effects production function, in which capital, labor, TA and training, time of TA, and firm characteristics predict value-added, controlling for industry.

A firm adopts new technology if the firm concludes that the technology will improve its performance. By definition, technology is a new tool or means of converting inputs to outputs. Few sensible employers would adopt less efficient technology than their existing one, so it seems reasonable to hypothesize that new technology increases productivity. In cases where the benefit of this increased productivity exceeds the cost of adopting new technology, the firm's performance should improve. Therefore, we hypothesize that rational firms adopt new technology in cases where this benefit exceeds the cost, so technology will improve firm performance in all metrics.

B. Wage Inequality

To understand the effect of new technology on wage inequality, we also use a fixed effects model. The model controls for firm size, firm age, worker skill, and status as a maquiladora. We use the logarithm of the ratio of wages of skilled workers to the wages of unskilled workers as dependent variable. We run two regressions: one for the logarithm of the ratio of highly skilled workers' wages to unskilled workers' wages, and another for the logarithm of the ratio of semi-skilled workers' wages to unskilled workers' wages.

For detailed reasons, we expect TA to increase wage inequality. The reasons are the following: we can distinguish three functions of technology. First, *skill-replacing* technology eliminates firm need for unskilled labor but leaves highly skilled labor. A mechanized quality-control system, for example, might replace monitoring employees but leaves other employees' marginal value of labor unaffected. Skill-replacing technology decreases demand for unskilled labor but leaves wages unaffected. Since a firm employing such technology can decrease labor costs while maintaining output constant, skill-replacing technology increases firm profits and productivity while leaving average wages constant and decreasing net employment. The adoption of skill-replacing technology should affect employment but not relative wages.

Skill-augmenting technology allows skilled labor to co-opt the production of unskilled labor without additional effort. A manager, for example, who acquires a device that records memos no longer requires a secretary to transcribe memos. With the device, the manager has acquired an additional skill. The memo-recorder allows the manager to do the work of a secretary without expending additional labor time. Skill-augmenting technology increases the marginal value of skilled and highly skilled labor, it increases the wages of skilled labor and decreases demand for and the wages of unskilled labor. In effect, it worsens wage inequality.

Skill-creating technology gives skilled workers new and previously nonexistent tools. Such technology does not affect either absolute wages or employment of unskilled labor, but increases the marginal value of skilled labor. A researcher with a new computer program, for example, might be able to pursue analysis which was previously impossible. This analysis was never the responsibility of either unskilled or skilled labor; it is a skill created precisely by technology. Skill-creating technology increases the wages of skilled labor, but leaves labor demand and unskilled labor unaffected. Although the wages of unskilled labor do not fall, their wages relative to skilled labor do.

Firms that only adopt skill-replacing technology may exhibit no changes in wage inequality, whereas firms adopting skill-augmenting and skill-creating technology will have worse wage inequality. Some technologies are both skill-replacing and skill-augmenting, but many are not. On balance, firms adopt all three kinds of technology, and skill-augmenting and skill-creating technology tend to worsen wage inequality.

C. Skill Shares

To measure the relation of technology with wages and employment, we use fixed effects models with value-added, firm capital assets, the wages of highly skilled relative to unskilled workers, TFP, the wage-share of the examined skill group in the firm's total wages, and the unemployment rate (used as a control for macroeconomic shocks) as independent variables. We measure TFP as the residual of the production function with capital and labor. For similar reasons as described above, we hypothesize that technology increases wages and employment, but increases the relative demand for skilled labor over unskilled labor.

D. Time of Benefit

To understand how the time of TA relates to the time of training, hiring, and salary raises, we use a fixed effects model with independent variables for firm and industry characteristics, the unemployment rate, and a series of dummy variables, τ, that represent the time of adoption. We define that $\tau = 0$ for every period that a firm does not adopt technology. For a firm that adopts technology, $\tau = 0$ in the time period of TA, $\tau = 1$ the period after adoption, and $\tau = -1$ the period before adoption. Since we have data for three time periods, the range of τ is $[-2 < \tau < 2]$, but for a particular firm τ only takes on three consecutive values. We predict that salaries will rise and firms will train their workers after TA, but it is difficult to predict how these variables will change before TA.

5.2. Determinants of New Technology Adoption

The question of TA likelihood is one of influence – what are the conditions that most encourage a firm to adopt new technology? We use two separate methods to answer this question. First, we use cross-sectional models for 1992 and 1999, which give us snapshots of the levels of influence that different variables have on TA at different times. We estimate two different cross-sectional models: a simple logit for each new technology type, and a multinomial logit which takes into account at the same time all the different types of new technologies. In these models, we include independent variables for factors specific to the firm, industry, and region (see Table 5).

Our second method uses panel estimation. Whereas cross-sectional estimations give snapshots to fill a photo album, panel estimation gives continuous coverage that shows us rates of change from 1992-95, from 1995-99, and from 1992-99. To estimate the influence of the factors in Table 5 on TA, we use a probit random effects model for each new technology type with adoption as the dependent variable, and a vector of firm-, region-, and industry-specific characteristics as independent variables. We expect that panel results will corroborate the cross-sectional results discussed above. We also use a tobit random effects model to analyze what factors determine the intensity in the use of a specific type of new technology.

In accordance with the literature, we expect that larger firms, older firms, firms located in the North, and firms with close tights with foreign and other firms will have the highest likelihood of TA. It may be that proximity to the U.S. increases competition, and that competition encourages firms to adopt technology, so a firm's proximity to the U.S. encourages it to adopt technology.

Table 5. Technology Types and Possible Determinants of Technology Adoption

Technology type	Firm-specific	Industry-specific	Region-specific
No new technology	Size	Food, beverages, tobacco	North
Any kind of new technology	Age	Textiles, clothing, leather	Center
	Foreign capital	Wood and wood products	South
Manual equipment	Subsidiary	Paper and paper products	Capital
Automatic equipment	Workforce skill-level	Chemical products	
Machinery tools	Training	Non-metallic mineral products	Science degrees per capita
NCM	R&D	Basic metal industries	Graduates per capita
CNCM	Status as maquila	Metal products, machinery	Researchers per capita
Robots	Export oriented	Other manufacturing ind.	Government R&D
	Union presence	R&D	expenditure per capita
	Joint activities	Exports	

Note: Detailed variable explanations appear in Appendix C of Volume II.

6. Results

The first part of this section refers to the relation between technology and firm performance. The second part considers what factors determine TA and the type of the technology that a firm adopts.

6.1. New Technology and Firm Performance

A. Firm Performance

We use several performance measures —wages, productivity, net employment, job creation, job destruction, and value-added— to assess the impact of TA on firm performance. These measures may suggest different conclusions—for example, a firm could increase productivity by reducing employment, so productivity would indicate superior performance but employment would suggest inferior performance (Baily, Bartelsman, and Haltiwanger 1996). Despite this possibility, the measures generally indicate consistent trends.

> Technology most improved performance of firms:
> - In the 1995-99 time period
> - Located in the North or the Capital
> - Of large size
>
> Technology most improved the wages of skilled workers.

On balance, firms that adopt new technology exhibit superior performance in the first three metrics – wages, productivity, and net employment. Firms that adopted technology in the 1992-99 sample paid workers higher wages, employed more total workers, and are associated with 26 percent higher productivity than firms that did not adopt technology.

We find a marked change in the influence of technology between 1992-95 and 1995-99 (Table 6). In almost every division of firms, the relation between technology and productivity performance was greater in the later period than in the earlier period. The exception was for small firms where no significant relation was found in the later period. The only two cases where a firm-type performed better in the earlier than the later period were the performance of wages for firms located in the Central and Southern regions. However, for the employment measure we find a positive relation with technology in the 1992-95 period while no significant relation shows in the 1995-99 period.

Table 6. Relation between Technology Adoption and Firm Performance, 1992-95 versus 1995-99

Sample	Firm Performance Measure					
	Wage		Productivity		Net Employment	
	1992-95	1995-99	1992-95	1995-99	1992-95	1995-99
All firms	0.506**	0.559**	0.055**	0.536**	0.338*	0.113
By size:						
Small firms	0.228**	0.276*	0.077**	0.375	0.174	
Medium firms	0.271**	0.470**	0.084	0.378**	0.495	-0.262
Large firms	0.380*	0.530**	-0.544	0.412**	0.024	0.274
By location:						
North	0.258**	0.583**	-0.037	0.709**	0.554	0.050
Center	1.119**	0.558**	0.095**	0.463**	-0.047	0.382
South	2.129**	0.466**	0.002	0.496	-1.697	-0.231
Mexico City	0.362**	0.649**	0.038	0.487**	0.563*	-0.240
	Job Creation		**Job Destruction**			
All firms	0.1846**	0.2189**	0.1040**	-0.0277		

* Significant at 10% level; ** Significant at 5% level.
Note: Figures are regression coefficientsfor the TA indicator variable, which in these models can be interpreted as elasticities.

The positive relation of technology with job creation, measured as the number of new hires in a given year, is higher for the 1995-99 period than for the 1992-95 period. Moreover, technology is positively associated with job destruction, measured as the numbers of dismissals in a given year, in the 1992-95 period, while there is no significant relation in the 1995-99 period.

The effectiveness of technology also increases with a firm's size. In the 1992-99 period, while a medium-size firm received a 20 percent productivity benefit associated to technology, large firms received a 23 percent productivity benefit. It also appears that the change between 1992-95 and 1995-99 improved technology's effectiveness more for large firms than for small firms.

In the latter period, the more Northern a firm is, the larger the effect of technology associated with its performance tends to be. In terms of productivity in the 1995-99 period, firms in the North are associated with a 71 percent benefit from technology, firms in the Capital are associated with a 49 percent technology benefit, and firms in the Center are associated with a 46 percent technology benefit. Other performance measures indicate similar trends.

Although it appears that technology influences wages, it may be that wages also influence TA. Therefore, we conducted a joint estimation using a three-stage regression for the TA determinants and the wage performance equations. The results for this joint estimation present expected findings: technology increases wages by quite large amounts in all three time periods. However, we find that this increase is larger for the 1992-95 period than for the 1995-99 period. We also find that larger firms paid higher wages than smaller firms during the later period, though in the first period (1992-95) smaller firms appeared to pay higher wages than large firms.

Technology is associated with a greater impact on wage performance for differently skilled workers in the 1995-99 period than in the 1992-95 period (Table 7). We find that the effect of technology increases with the workers' skill level and with firm size.

Table 7. Relation between TA and Firm Wage Performance by Skill Level, 1992-95 versus 1995-99

Sample	Firm Wage Performance					
	Highly skilled		Semi-skilled		Unskilled	
	1992-95	1995-99	1992-95	1995-99	1992-95	1995-99
All firms	0.282**	0.527**	0.498**	0.587**	0.286**	0.427**
Small firms	0.133	0.251	0.224**	0.243	0.239**	0.326*
Medium firms	0.302**	0.437**	0.227**	0.466**	0.215*	0.395**
Large firms	0.527	0.553**	0.444	0.497**	0.069	0.424**

* Significant at 10% level; ** Significant at 5% level.
Note: Figures are regression coefficients for the TA indicator variable, which in these models can be interpreted as elasticities.

For the value-added performance measure, we find that combining adoption of certain types of new technology (automatic equipment, machinery tools, and CNCM) with worker training increases the value-added of firms (Table 8). On average, training increases technology's productivity benefit by five percent. These results indicate the importance of complementary investments in worker training in order to achieve the productivity potential of technology.

Table 8. The Value-Added of Training with New Technology Adopted, 1992-99

TA and Training	Value-Added
Automatic equipment	0.064*
Machinery tools	0.079**
CNCM	0.067*
Robots	-0.004

* Significant at 10% level; ** Significant at 5% level.
Note: Figures are regression coefficients for the TA and training indicator variables, which in these models can be interpreted as elasticities.

B. Wage Inequality

Technology has exacerbated the wage gap between semi-skilled and unskilled workers by about eleven percent over seven years, controlling for the relevant variables. Additionally, the higher the overall skill level of a firm, the larger the gap between skilled and unskilled workers. We also find that maquiladoras have a wider wage inequality than other firms, and that smaller firms have a worse wage inequality than large firms. We find that skilled workers receive a much higher wage and employment benefit from TA than unskilled workers do.

C. Skill Shares

By distinguishing the wages and hiring of different skill-levels of workers, we examine the effect of performance on particular groups of firm employees. On the whole, technology biases a firm towards skilled workers, so technology is skill-using for highly skilled workers but skill-replacing for unskilled workers. Technical change is also skill-using for male and female highly skilled workers but skill-replacing for male semi-skilled production workers. Tan (2000a) finds that in Malaysia technical change is skill-using only for male highly skilled workers. Our results also show that capital and highly skilled workers are complements, while capital and semi-skilled workers are substitutes. This result is consistent with Tan (2000a).

D. Time of Benefit

We find that the share of highly skilled workers changes little in proportion to the time of TA. The share of highly skilled workers among total firm employment is fairly small. Although we observe an increase in the number of highly skilled workers hired after TA, the increase is also small in proportion to the total number of workers in the firm. For the semi-skilled workers we find that their share in the firm's total employment increases before and after TA. By the second period after TA, the share of semi-skilled workers has risen considerably. In contrast, the share of less-skilled workers is actually larger before TA, but falls post-adoption.

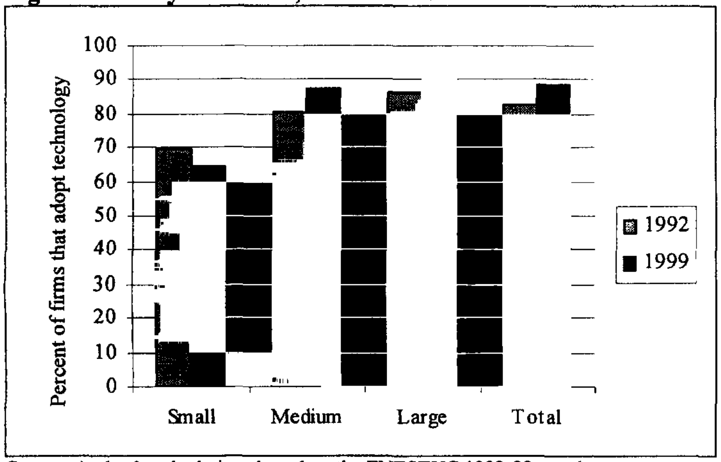
The productivity of technology firms is relatively low before TA, but after TA, it increases markedly. Technology increases firm productivity and presumably firm profits. Nevertheless, how do changes in worker's wages relate to increases in firm profits? Wages demonstrate similar trends to productivity, as it appears that employers share productivity gains from technology with all the skills of the workers. However, skilled workers receive significantly more benefit than unskilled workers. Wages at all the skill-levels of the workers begin rising two periods before TA, and continue rising until two periods after TA. Furthermore, the growth rates of the wages of all skill groups jump after TA.

6. 2. Determinants of New Technology Adoption

A. Levels of New Technology Adoption

First we investigate what kind of firms adopt new technology in what circumstances. Overall, TA rates for the firms included in the 1992-99 panel increased from 1992 to 1999 (Figure 3). Medium firms had the greatest increase in TA, with 9 percent more firms adopting new technology in 1999 than in 1992. However, small firms had a decrease in TA between the same period, falling from 69 percent in 1992 to 65 percent in 1999. Dividing firms by sector rather than size still shows the TA increase during 1992-99. Except for textiles, clothing, and leather, firms in every sector increased their rates of TA during this time (Table 9).

Figure 3. TA by Firm Size, 1992 versus 1999



Source: Author's calculations based on the ENESTYC 1992-99 panel.

Table 9. TA by Sector, 1992 versus 1999

Sector	Firms adopting technology (%) 1992	1999	Percent Increase, 1992-99
Food, beverage, tobacco	79.3	90.3	13.9
Textiles, clothing, leather	82.1	80.6	-1.8
Wood and wood products	77.8	89.5	15.0
Paper and paper products	84.2	84.4	0.2
Chemical products	86.8	91.4	5.3
Non-metallic minerals	76.1	93.2	22.5
Basic metal industries	69.4	92.3	**33.0**
Metal products, machinery	85.6	89.1	4.1
Other manufacturing	88.2	100.0	13.4
Total	82.6	88.6	7.3

Source: Author's calculations based on the ENESTYC 1992-99 panel.

As Figure 3 shows, TA likelihood strongly correlates with firm size. In every period, larger firms were more likely than smaller firms to adopt technology, large firms achieving a 92 percent TA rate in 1999. Since we measure TA by an absolute zero-one variable rather than a continuous variable, the fact that a single large firm might adopt *more* new technology than a single small firm has no effect on our results; regardless of the amount of technology adopted, a firm's size influences its TA patterns. A better explanation is that larger firms can exploit economies of scale to maximize efficiency from production. A small firm integrating an internal network, for example, may pay high fixed costs to cover only a few employees, thereby incurring high cost for the productivity benefit of only a few employees. Nevertheless, a large firm's intranet may allow a thousand workers to increase efficiency and diffuse a high fixed cost over many more employees—for a large firm, technology offers a better productivity benefit per worker.

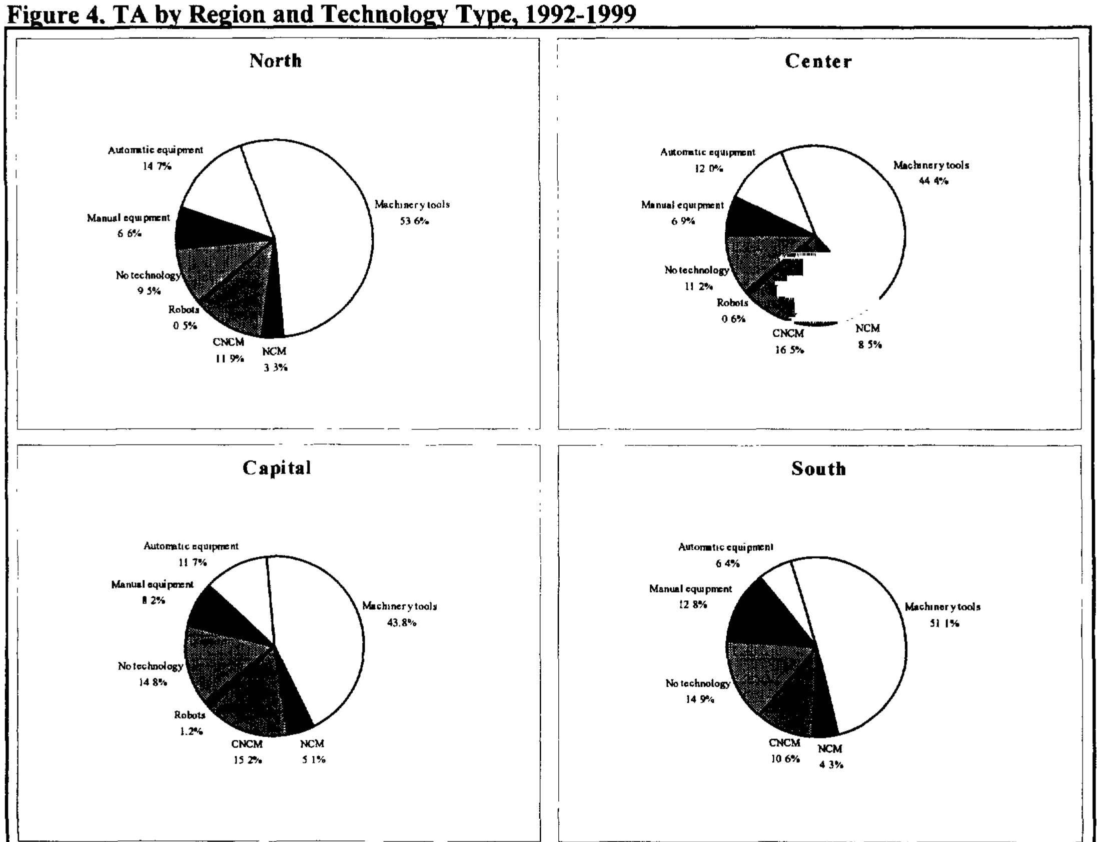
Firms located in the North had the greatest increase in TA, with 12 percent more firms adopting technology in 1999 than did in 1992 (Table 10). Over 90 percent of the firms located in the North adopted some kind of new technology in 1999. The Capital region shows the lowest increase (3.5 percent) in the TA rates between 1992 and 1999.

Table 10. TA by Region, 1992 versus 1999

Region	Firms adopting technology (%) 1992	Firms adopting technology (%) 1999	Percent Increase, 1992-99
North	80.7	90.5	12.1
Center	83.7	88.8	6.1
South	80.8	85.1	5.3
Capital	82.3	85.2	3.5
Total	82.6	88.6	7.3

Source: Author's calculations based on the ENESTYC 1992-99 panel.

Figure 4. TA by Region and Technology Type, 1992-1999



Source: Author's calculations based on the ENESTYC 1992-99 panel.

Figure 4 shows the adoption of different new technology types by region. We observe that more than 25 percent of the firms in the Central region adopted more complex new technology (NCM, CNCM, and robots). In the South only 15 percent of the firms adopted more complex technology. The most prevalent type of new technology in all regions is machinery tools.

B. Prolonged Activity

Generally, we find consistency in export, training, and technology activities over time—a firm that received over half of its sales from exports, trained its workers, or adopted new technology in 1992 was quite likely to pursue the same activity in 1999. Training of workers also precedes and strongly correlates with TA. A firm that did not adopt technology but did train its workers in 1992 has an 89 percent probability of adopting new technology in 1999. The same phenomenon appears with exports: a firm that exported but did not adopt technology in 1992 has a 79 percent chance of adopting new technology in 1999.

C. Determinants of New Technology Adoption

TA likelihood varies according to firm, industry, and location. Specifically, the likelihood of TA positively correlates with firm size, a larger firm being more likely to adopt technology. Additionally, firms hiring skilled labor introduce more new technology and tend to be more innovative.

> The firms most likely to adopt technology are:
> - large
> - located in the North
>
> And have:
> - a high proportion of skilled labor
> - a high proportion of foreign capital
> - worker training
>
> Firms adopting the most complex technology:
> - are large
> - have large R&D budgets
> - train workers

To relate a variable to new technologies of different complexity, we estimate multinomial logit models for 1992 and 1999. These estimations include six types of new technology: manual equipment, automatic equipment, machinery tools, NCM, CNCM, and robots. We can order these new technology types from simple manual technology to highly complex CNCM and robots. From these results, it can be appreciated the increasing importance of firm size and skilled workers with the increased likelihood of adopting more complex new technology (Table 11).

Table 11. Skill Shares as Determinants of TA, 1992 and 1999.

Share of labor:	Manual equipment	Automatic equipment	Machinery tools	NCM	CNCM	Robots
1992						
Semi-skilled	-0.003	0.008**	0.012**	0.017	0.004	-0.132
Unskilled	0.003	0.005	0.010**	0.009	-0.003	-0.136
1999						
Semi-skilled	0.000	0.013**	0.012**	0.001	0.012	0.074
Unskilled	0.006**	0.008**	0.009**	0.003	0.003	0.075

* Significant at 10% level; **Significant at 5% level.
Note: The comparison group is no adoption of new technology.

We observe from the panel probit results (Table 12) that, in the overall, TA likelihood also correlates with the share of foreign capital in the firm, and with the presence of worker training.[5] Firms located in the North are more likely to adopt new technology than firms located in other regions. To distinguish which factors affect which technologies are adopted, we present more detailed results below.

Firm factors:

Size. For the 1992-99 period, medium and large firms are 57 percent and 66 percent respectively more likely than micro and small firms to adopt some type of new technology. Large firms are 43 percent more likely to adopt new machinery tools and 93 percent more likely to adopt new CNCM. Medium-size firms are also more likely than micro and small firms to adopt new machinery tools and new CNCM. For the 1992-95 period, firm size negatively correlates with TA, while in the 1995-99 period the correlation is positive. This result may have arisen because NAFTA and the economic crisis of 1994 encouraged medium and large manufacturing firms to acquire technology to compete globally.

Age. Adoption of machinery tools positively relates to firm age, while adoption of new automatic equipment negatively relates to firm age. One reason for this is that our sample only includes firms that survived through the entire period. Surviving small firms may be more flexible than surviving large firms.

[5] See Technical Paper 3 of this report for the cross-section results.

Table 12. Determinants of New Technology Adoption by Technology Type, 1992-99 (Random Effects Model)

Explanatory Variables	Any type of technology		Automatic equipment		Machinery tools		CNCM		Robots	
	Coeff.	Marg. Ef.	Coeff.	Marg. Ef.	Coeff.	Marg. Ef.	Coeff.	Marg. Ef.	Coeff.	Marg. Ef.
Firm-specific										
Size: Medium	0.5677 **	0.0626	0.2373	0.0351	0.2987 **	0.0610	0.6368 **	0.0712	-0.1330	-0.0017
Large	0.6572 **	0.0583	0.0310	0.0037	0.4350 **	0.0682	0.9297 **	0.0843	-0.2672	-0.0026
Age	-0.0009	-0.0001	-0.0037 *	-0.0009	0.0041 **	0.0010	-0.0017	-0.0003	-0.0081	-0.0002
Foreign ownership	0.2797 **	0.0387	0.2369 **	0.0502	-0.0750	0.0000	0.0566	0.0076	0.2455	0.0055
Labor: Highly skilled	0.0109 *	0.0019	0.0063 *	0.0015	0.0022	0.0191	-0.0045	-0.0008	0.0112	0.0003
Semi-skilled	0.0003	0.0001	-0.0004 **	-0.0001	0.0001	0.0187	0.0001	0.0000	0.0003 *	0.0000
Low skilled	0.0004 *	0.0001	0.0002	0.0000	0.0001	0.0186	0.0001	0.0000	0.0000	0.0000
Training	0.2106 **	0.0058	-0.0678	-0.0025	0.1057	0.0221	0.4147 **	0.0103	4.3972	0.0197
R&D	0.0029	0.0006	0.0013	0.0003	0.0014	0.0190	0.0021	0.0004	0.0035	0.0001
Technology transfer	0.0774	0.0139	-0.1456	-0.0366	0.0138	0.0209	0.1262 *	0.0221	0.0289	0.0007
Maquila	-0.0944	-0.0114	-0.0803	-0.0160	0.0280	0.0257	0.0957	0.0142	-0.3871	-0.0061
Export oriented	0.0631	0.0106	-0.0993	-0.0234	-0.1565	-0.0159	0.2328	0.0396	-0.0895	-0.0017
Union	-0.1130	-0.0019	-0.1685	-0.0038	-0.1420	0.0155	-0.0275	-0.0005	4.9396	0.0123
Region:										
Central	-0.1264	-0.0112	-0.0158	-0.0018	-0.2335 **	-0.0077	0.1500	0.0129	0.1647	0.0018
South	-0.2131	-0.0387	-0.1804	-0.0421	-0.1246	-0.0077	0.0351	0.0063	-5.6082	-0.0226
Capital	-0.2012 *	-0.0310	0.0218	0.0042	-0.3380 **	-0.0403	0.2027	0.0277	0.3089	0.0057
Technology diffusion rate	0.0407 **	0.0087	0.5701 **	0.1411	0.0476 **	0.0300	0.0194	0.0034	-0.4093	-0.0081
Constant	-2.3784 **		-9.2729 **		-1.9412 **		-2.6713 **		-11.3325	
Log likelihood	-1016.1305		-837.4122		-1253.5804		-833.0133		-84.3751	

* Significant at 10% level; **Significant at 5% level.

Notes: 1. Dependent variable = 1 if the firm adopted some type of technology, 0 otherwise.

2. Skill shares are lagged one period.

3. Number of observations = 2,089; number of groups = 1,066.

Foreign ownership. For the 1992-99 period, foreign ownership increased the probability of adopting new automatic equipment and TA overall by 23 percent. For the 1995-99 period, foreign ownership increased the probability of acquiring new robots by 42 percent. For the 1992-95 period, foreign ownership had an important influence on the adoption of new CNCM.

Skill. Skilled workers and human capital tend to enhance the absorptive capacity of firms (Cohen and Levinthal 1989). We expect that the presence of skilled labor will encourage TA, but that unskilled labor will negatively relate to TA. Results show that, for the 1992-95 period, the number of highly skilled employees positively correlates with TA and, for the 1992-99 period, it positively correlates with the adoption of automatic equipment. The number of professionals, technical employees, managerial employees, and semi-skilled workers shapes a firm's TA patterns.

Training. Intuitively, training workers should enhance a firm's absorptive capacity. The positive and significant coefficient of the training variable in our regression suggests that training indeed does enhance absorptive capacity. For the 1995-99 and 1992-99 periods, training positively correlates with TA. For the 1992-99 period, a firm that trains workers is 20 percent more likely to adopt some type of new technology, and 41 percent more likely to adopt new CNCM than a firm that does not provide training. For the 1992-95 and 1995-99 periods, training positively correlates with the adoption of more complex new technology, such as CNCM.

R&D. Firm investment in R&D is also positively related to the adoption of new complex technology. Firm's investment in technology transfer also increases the probability of adopting new CNCM in the 1992-95 and 1992-99 periods, and the probability of adopting robots in the 1995-99 period.

Maquila. The technology performance of maquila firms differed between 1992-95 and 1995-99. We find that the probability of TA for maquila firms in the earlier period is 10 percent higher than for non-maquila firms. However, in the later period, it is 32 percent lower than for other firms.

Exports. For the 1992-95 period, a firm's status as an export-oriented firm is positively associated with TA, and specifically with new automatic equipment. However, we observe a negative relationship between exports and the adoption of new machinery tools for the 1995-99 period. The 1992-99 period had no significant relations between export-oriented firms and the adoption of different types of technology.

Subsidiary and Union. Subsidiary firms and firms with a union strongly increase the likelihood of TA in 1999. Moreover, we find that subsidiary firms increase the likelihood of adopting automatic equipment in 1999, while in 1992 these firms were less likely to adopt automatic equipment.

Regional factors:

For the 1992-99 period, firms in Mexico City seem less likely than firms in the North to adopt some type of new technology. A similarly strong relationship exists for the adoption of machinery tools. Surprisingly, for the 1995-99 period, firms in the Central and Southern regions were more likely to adopt new CNCM than firms in the North. For the 1992-95 period, firms in the Southern and Capital regions were less likely to adopt new technology than firms in the North. We can conclude that, in general, firms located in the North are more likely to adopt new technology than firms located in other regions. It may be that proximity to the U.S. increases competition, and that competition encourages firms to adopt new technology, so a firm's proximity to the U.S. encourages it to adopt new technology.

Technology diffusion rate:

The effect of the technology diffusion rate is positive for the adoption of any type of new technology, automatic equipment, and machinery tools, suggesting that a firm is more likely to adopt any type of new technology if other firms are using the technology.

D. Technological Intensity

Another measure of TA involves not just whether a firm adopts technology, but the degree to which it uses this technology. We refer to this degree as the *intensity* in the use of new technology. We measure technological intensity as the share of production equipment that the technology accounts for.

From the panel tobit estimations for the 1995-99, and 1992-99 periods, we find that intensity in the use of more complex technologies is positively correlated with firm size. For the 1992-95 period, we find the opposite relation: larger firms are negatively correlated with the intensity in the use of more complex technologies. For the 1992-99 period, the share of semi-skilled and unskilled workers reduces the intensity in the use of NCM, for the 1995-99 period, it reduces the intensity in the use of manual equipment, and for the 1992-95 period it increases the intensity in the use of machinery tools.

For the 1992-99 period, training increases the intensity in the use of automatic equipment and CNCM. For the 1992-95 and 1995-99 periods, training is positively correlated with the use of more complex technologies, while it reduces the use of more simple technologies. We find the same patterns with investments in R&D, for all the three periods, R&D increases the intensity in the use of more complex technologies, while it reduces the intensity in the use of more simple technologies such as manual equipment and machinery tools.

For the three periods, export oriented firms are positively correlated with the intensity in the use of robots, while the presence of a union reduces the intensity in the use of machinery tools. The fact that a firm has joint activities has no effect in the technological intensity. Finally, firms located in the North use automatic equipment with more intensity, and machinery tools with less intensity than the other regions.

7. Conclusions and Policy Implications

This section first reviews existing government policies relating to TA, then presents four key results and suggests policy implications to be drawn for each result.

Existing policies

The Mexican government currently operates a handful of programs aimed at increasing firm productivity and worker training. The Program of Integrated Quality and Modernization (CIMO) subsidizes worker training and technical assistance for micro, small, and medium enterprises. It seeks to increase worker productivity, improve human resource management, promote inter-firm linkages, and tie training to private sector needs. CIMO has existed since 1988; in the first half of 2000, it trained 200,000 workers in 80,000 firms. It operates through a distributed network of local associations that actively seek out potential participants (Tan 2001). Micro enterprise participants receive a 60 percent subsidy (50 percent for small and medium enterprises) for their training and consulting expenditures. CIMO's 2001 budget is US$ 21.9 million, which represents 0.1 percent of the total programmable government expenditure.

CONACYT oversees another organization, the Program of Technological Modernization (PMT), which seeks to increase the productivity of competitiveness in small and medium enterprises (16-500 employees). Participant firms receive a 50 percent subsidy on permitted costs. These costs include process optimization, system design, industrial engineering, benchmarking, environmental measures, technical training, and a preliminary evaluation of technical needs.

The Program to Support Academic Sector Links (PROVINC) attempts to improve the responsiveness of academic research to private sector needs. In part, it encourages cooperation between private sector and university researchers. Ultimately, PROVINC seeks to increase the supply of technology to meet demand. It offers courses to public and private individuals on these themes. PROVINC offers up to US$20,000 to support research meeting its goals.

CONACYT, which funds both PROVINC and PMT, also supports three initiatives that promote research into new technologies. The Program to Support R&D Projects (PAIDEC) supports 50 percent of research into new technology, to a maximum of US$250,000. The Fund of R&D for Technical Modernization (FIDETEC) supports research at a pre-sale stage, and seeks to increase innovation in Mexico. The CONACYT Registry of Technical Consultants offers consulting services to firms and supports their R&D efforts. Although these research programs are noteworthy, our focus is on the adoption of existing technology rather than the production of new technology.

The Ministry of Economy also supports several programs aimed at increasing firm's productivity by providing training and technical assistance to micro, small, and medium-size firms (Table 14). *Marcha hacia el sur* is a program directed to promote job creation in the Southern states.

Table 13. The Ministry of Economy Programs

Program	Description	Programmable expenditure for 2001 US$ millions	Share of total programmable expenditure for 2001
FIDECAP	Promotion for the Integration of Productive Networks	17.8	0.08
PCDES	Program of Distribution Centers in the U.S.	3.2	0.01
CETRO - CRECE	Center for the Development of Competitiveness and Regional Centers for Competitiveness.	21.6	0.09
Marcha hacia el sur		19.0	0.08

The ongoing World Bank "Training Mechanisms Reform Study" is reviewing the training and technical education systems in Mexico. Preliminary results from this study and other Bank reports indicate that, first, Mexico is providing insufficient on-the-job human capital accumulation and second, that the vocational and technical systems in Mexico are not providing new entrants with the appropriate skills.

Gill, Fluitman, and Dar (2000) extensively examine training reform programs around the world. The countries analyzed have different government initiatives to promote worker training, such as levy-grant schemes, tax credits, or training subsidies. The authors carefully assessed the effectiveness of each one of these initiatives.

This study has already influenced government policy—INEGI has added several policy-relevant questions to its 2001 ENESTYC survey. In addition, the findings from this study gave support to some of the government policies envisioned in the forthcoming National Development Technology Plan. Nevertheless, the breadth of empirical data contained here suggests further actions to improve job quality in Mexico. The OECD (2000) argues that governments can improve the effectiveness of R&D expenditure by supporting the proliferation of venture capital and credit institutions. Public/private partnerships with selective participation also maximize the value of government R&D expenditure. Inviting private sector representatives to policy planning meetings offers a good way to integrate public priorities with private needs. Additionally, public research expenditure should focus on basic knowledge and broad findings that can aid a wide variety of industries.

Box 1. A TA story.

In 1995, Ing. Ramón A. Báez Acta founded Micro Casting de México, S.A. in Monterrey. Micro Casting produces metal parts, plastic parts, and molds for maquiladoras and other firms. In 1999, Micro Casting applied to the Technological Modernization Program of CONACYT for a MX$950,000 project to automate production, develop and implement a company-wide information system, create new products, and improve quality monitoring. CONACYT agreed to pay half of the cost for a digital monitoring system for all parts of production. The system improved precision in metal die casting and helped Micro Casting secure contacts with U.S. and Taiwanese companies (CONACYT).

Conclusions and future policies

This study unequivocally shows that adoption of new manufacturing technology improves performance in certain circumstances. However if anything, our results show that no categorical statements about technology benefits can capture the reality of technology in Mexico. This conclusion suggests that government should encourage TA, but only for a firm that reasonably concludes that new technology will improve its performance. An incentive system that facilitates TA but keeps some financial burden on companies – so they only have the incentive to adopt technology when it is highly likely to improve performance – seems the best policy to emerge from these results. It may be that firms are unaware of existing technologies or unsure of their effectiveness, so government can perform this by fostering intra-industry communication through industry groups and conferences, or by offering firms free consultations on potentially valuable technology.

Our results also show that technology worsens wage equality. Since more highly skilled workers may be better prepared to benefit from advanced technology, this robust finding should seem unsurprising. However, government can take an active role to prevent technological change from leaving unskilled workers behind. By offering training to unskilled workers and continuing to ensure a strong education system for all students, government can extend the benefits of technology to all Mexicans.

Chile is a good example of a country that has lessened wage inequality. Gill and Montenegro (forthcoming) find that wage distribution in Chile worsened until 1990, but improved in the early 1990s. Chile's government promoted strongly education and training as a means of helping the poor segments reap some of the benefits of economic growth.

A third result is that the effect of technology changed markedly between 1992-95 and 1995-99. Either NAFTA or the 1994 crisis may have influenced this change. Nevertheless, both increased the competition that Mexican firms faced—NAFTA by the increased competition from foreign firms, and the 1994 crisis by shrinking domestic demand and increasing interest and inflation rates. Therefore, to maximize the benefit that firms receive from technology, the

Mexican government should continue liberalizing the Mexican economy. Allowing free flow of goods, individuals, and ideas between borders and differentiating the public from the private sector by selling public corporations and limiting market interference – the golden oldies of improved performance – an ideal environment for effective TA is created.

Finally, we find that R&D funding from whatever source increases the probability of adopting technology. This finding, too, should also be unsurprising. R&D may allow a firm to integrate a technology better. It may increase the human capital of involved researchers. It may broaden public knowledge about existing technologies, and it may discover cheaper ways to access already-existing technology. Mexico has a relatively low level of R&D spending, but a high rate of R&D spending growth. Maintaining this growth will promote the quality of future technology developed in Mexico. Since the private sector may know its technological needs better than the public sector may, government might also encourage the private sector to expand its own R&D expenditure by means such as a large R&D tax credit. In Mexico, firms can deduct from their income tax 86 percent of their expenditures on national R&D.

This volume began with two simple questions. First, we asked how firm characteristics and the circumstances of technology adoption affected firm performance. Second, we asked what firms and what circumstances encourage technology adoption. Rich empirical data from INEGI has allowed us to thoroughly answer these questions, and to understand better both the causes and the effects on firms of TA.

Two interesting lines of research emerge from this report. One is to expand our analysis to the service sector. Most analyses have focused on the manufacturing sector, and even technology does affect performance in the service industry, it may do so in different ways. The second line is to investigate further how the effect of technological change on skill labor shares varies across sectors and skill groups. Moreover, given the results which emerged from this report, future research could address specific questions such as: What is the impact of collective bargaining agreements, rules on training, output and technology adoption? What is the impact of minimum wages, or mandatory severance pay on training, output and technology adoption?.

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Minutes of Meeting with Government Officials to Discuss the ESW, Mexico - Technology, Wages, and Employment

A meeting to discuss the green cover report, "Mexico - Technology, Wages, and Employment" was held in Mexico City on Tuesday, October 9, 2001. The meeting was organized by Mr. Roberto Grijalva (Subcoordinador de Documentación y Formación Laboral, STPS), and was chaired by Mr. Jaime Domingo López Buitrón (Coordinador General de Políticas, Estudios y Estadísticas del Trabajo, STPS). The Bank's delegation was led by Mr. Marcelo Giugale (Sector Leader and Lead Economist). A list of participants is enclosed.

Meeting Format. Mr. Roberto Grijalva called the meeting to order and proposed the agenda for discussion. Mr. Marcelo Giugale followed with an introductory statement on the importance of participatory economic and sector work in the Bank's assistance program. The task manager Ms. Gladys López-Acevedo (Economist) summarized the background and main findings of the report. Participants then introduced themselves and presented comments, which the Bank team subsequently addressed. The remainder of the meeting took place in a seminar format.

The report was very well received by the participants of the meeting, who called it "substantive," "determinant," and "tremendously important," giving rise to an animated and constructive discussion, with most participants emphasizing the value of the report's content and conclusions. It was agreed to publish the report in gray cover. The only change requested was to explain that the relevant constraints imposed by the data used in the analyses were made explicit. A review of vocabulary and definitions will also be added to increase the report's accessibility. The other main points discussed with government officials are summarized below.

Region-specific variables. On the question of which region-specific variables were used in the analyses, it was explained that the Annex in background paper II indicates the region-specific variables from CONACYT's *Indicadores de la Actividad Científica y Tecnológica* and the National Employment Survey (ENE) included in the database. This Annex would also be included in the Main Volume. The region-specific variables such as university research, the presence of engineers and scientists were used in order to assess their impact on the likelihood of new technology adoption. Technical Paper 3 in Volume II shows that firm- and industry-specific variables were more important than those variables in explaining the adoption of new technologies.

Training. On the issue of the effect and magnitude of not providing training on firm's value-added, it was explained that it is not possible to estimate this effect due to insufficient observations. However, the estimations carried out in Technical paper two presents an interactive term for technology adoption and training to see if, in fact, training increases the returns to technology adoption. This interactive term captures the hypothesis that the adoption of new technology is different between training and no-training firms. This variable turned out to be positive and significant, which indicates the importance of complementary investments in worker training to carry out the productivity potential of technology.

Skill bias. On the question of why technical change has not benefited unskilled workers, since unskilled labor is abundant in Mexico, a plausible explanation is that there is a quality standard that must be met by firms in order to export products or grow. Thus, firms will require skilled labor in order to comply with quality standards.

Firm size. It was mentioned that the Ministry of Labor (STPS) uses different definitions of firm size. In fact, what is considered a large firm in the report, is a medium-size firm according to the STPS definition. However, the report uses INEGI's definitions.

Employment. On the question of the effect of technology on job creation and destruction, and whether there were systematic differences before and after 1995, separate estimations for job creation and destruction were carried out and presented in Technical Paper 1. The results from this exercise are summarized in the Main Volume.

Region. On the issue of why firms located in the North are more likely to adopt new technology than firms located in the rest of the country? A plausible explanation is that there is a set of factors such as infrastructure, human capital, and number of foreign firms, that facilitates the adoption of new technology by firms located in the North at a lower cost compared to other regions. This is important for firms to subsequently export and compete abroad.

Labor demand. On the question of whether the coefficients in the labor demand estimations could be biased because labor supply might be inelastic in some industries, it was mentioned that the estimations in Technical Paper 2 included industry indicator variables to acknowledge industry effects. An attempt was made to estimate this demand equation for each industry but it was not possible due to data constraints. However, future research will assess how skill-biased technological change varies across industries.

Firm performance and industry. On the issue of whether industry growth was considered in the firm performance estimates, it was mentioned that both fixed and random effects models for firm performance with industry characteristics were estimated. Results and trends were broadly similar, though the fixed effects models tended to yield more robust estimates of the new technology adoption parameter of interest. Technical Paper 1 presented the results from the best models.

Trade liberalization. On the question of whether trade liberalization increased the adoption of new technology, it was explained that with the data used in the analyses (only 3 points in time) it is difficult to disentangle the effects of trade liberalization/NAFTA from business cycle effects. An attempt was made to link the EIA and the ENESTYC panels but there were sample limitations that unable to accomplish this task.

Broader issues. Participants agreed that the report is a very good first step in understanding the interaction between technology adoption and firm performance. Given the results which emerged from this report, future research could address specific questions such as what is the impact of collective bargaining agreements, rules on training, output and technology adoption? what is the impact of minimum wages, or mandatory severance pay on training, output and technology adoption?.

Cleared with and cc: Mr. Marcelo Giugale, Sector Leader and Lead Economist (LCC1C).

Meeting with Mexican Government

Valencia 36, Coordinación General de Políticas, Estudios y Estadísticas del Trabajo, S.T.P.S, Sala de Juntas, Piso 3

October 9, 20001

5:00 – 8:00

Government staff participating in the meeting:

Dr. Jaime Domingo López Buitrón (Coordinador General de Políticas, Estudios y Estadísticas del Trabajo, STPS)
Lic. Roberto Grijalva (Subcoordinador de Documentación y Formación Laboral, STPS)
Arq. Mario González Torres (Subcoordinador de Análisis y Política Laboral, STPS)
Lic. Roberto López Esquinca (Subcoordinador de Estadísticas del Trabajo, STPS)
Mtro. Antonio Amerlinck Assereto (Director de Estudios Económicos Laborales, STPS)
Lic. Víctor Martínez Manrique (Director de Investigación, STPS)
Lic. Ángel Velázquez Juárez (Subdirector de Estudios del Sector Laboral, STPS)
Lic. Ramón Picazo Castelán (Director de Evaluación, STPS)
Lic. Daniel Parra (Director de Análisis e Información Sectorial, STPS)
Lic. Patricia Morales (En representación del Director General de Capacitación, STPS)
Lic. Jaime Botello Triana (Asesor del Director de Operación, STPS)
Lic. David Topete (Director de Asuntos Hacendarios, SHCP)
Lic. Alberto Mejía (Subdirector de Asuntos Hacendarios, SHCP)
Lic. Silvia Rodríguez (Subdirectora de Difusión y Seg. Financiamiento Bilateral, SHCP)
Dr. Enrique Dávila (Asesor Especial del Subsecretario de Egresos, SHCP)
Lic. Héctor Orozco Vázquez (Coordinador de Asesores Subsecretaría de Egresos, SHCP)
Ing. Moisés Ramos (Director de Tecnología y Calidad, SE)
Ing. Ricardo Cancino (Subdirector de Calidad, SE)
Lic. Abigail Durán (Coordinador de Encuestas de Establecimientos, INEGI)
Lic. Jesús Esquivel García (Subdirector de Indicadores de Ciencia y Tecnología, CONACYT)
Dr. Rodolfo de la Torre (Universidad Iberoamericana)
Dr. Ángel Calderón (El Colegio de México)
Dra. Liliana Meza (Universidad Anáhuac)

Bank staff participating in the meeting:

Marcelo Giugale (Sector Leader and Lead Economist, PREM)
Anna Sant'Anna (Social Sectors Specialist, HD)
Gladys López Acevedo (Economist, PREM)
Erica Soler Hampejsek (Research Assistant, PREM)