The Pennsylvania State University

The Graduate School

CONSEQUENCES OF TRADE OPENNESS ON FIRM-LEVEL DECISIONS AND IMPLICATIONS FOR VOLATILITY AND WAGE INEQUALITY

A Dissertation in

Economics

by

Alejandro Riaño

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

August 2009

The dissertation of Alejandro Riaño was reviewed and approved* by the following:

James R. Tybout
Professor of Economics
Dissertation Advisor, Chair of Committee

Andrés Rodríguez-Clare
Professor of Economics

Ruilin Zhou
Associate Professor of Economics

Mark Anner
Assistant Professor of Labor Studies and Employment Relations

Vijay Krishna
Distinguished Professor of Economics
Director of Graduate Studies, Department of Economics

*Signatures are on file in the Graduate School.

Abstract

This dissertation develops dynamic stochastic models of heterogeneous firms in small open economies and uses them to analyze how firms' decisions are shaped by their participation in export markets and to understand the implications that these decisions have for firm-level volatility and the behavior of wage inequality in developing countries.

Chapter 1 presents a brief description of the issues discussed in the following two chapters. Chapter 2 seeks to find whether exporting helps to reduce a firm's sales volatility by means of diversifying aggregate shocks in its domestic market in an economy with no capital markets and in which exporting is costly. This is a partial equilibrium model with monopolistically-competitive, risk-averse firms that are heterogeneous with respect to their productivity, capital stock and exporting status and that face idiosyncratic as well as aggregate uncertainty. Firms become exporters primarily because of the positive impact to mean profits, even if it means experiencing higher volatility of sales. However, firms take advantage of the possibilities to diversify their revenues, as firms are more likely to become exporters when the correlation between domestic and external aggregate shocks is low and when risk aversion is high.

Chapter 3 builds a dynamic stochastic general equilibrium model of industry evolution for a small open economy in order to understand the link between trade liberalization, technology adoption and wage inequality. Monopolistically-competitive firms use skilled and unskilled labor, decide whether to export or not, and choose what technology to operate. The technology that a firm employs determines the stochastic process for skilled labor productivity, so that larger, more productive firms tend to be more skill-intensive, as observed in the data. The model is estimated using a Simulated Method of Moments estimator, and fitted to plant-level data from the Mexican manufacturing sector after the trade liberalization of 1985. The estimates of the structural model suggest that the skill-biased technology adoption spurred by a unilateral trade liberalization of the magnitude observed in Mexico would result in an increase in the skill premium of about 4.2 percentage points in steady state.

Table of Contents

List of Figures **vii**

List of Tables **viii**

Acknowledgments **ix**

Chapter 1
Motivation **1**
1.1 Trade Openness and Firm-Level Volatility 4
1.2 Trade Openness and Wage Inequality 6

Bibliography **12**

Chapter 2
The Decision to Export and the Volatility of Sales **21**
2.1 Introduction 21
2.2 Model 25
2.2.1 Technology 25
2.2.2 Market Structure 28
2.2.3 Timing 29
2.2.4 Firm's Problem 30
2.2.5 Export Decision 32
2.3 Parametrization 33
2.4 Simulation Results 35
2.5 Concluding Remarks 39

Bibliography **53**

Chapter 3
Trade, Technology Adoption and the Rise of the Skill Premium in Mexico **56**
3.1 Introduction 56
3.2 Mexico in the 1980s 62
3.2.1 Mexico's Trade Policy 63
3.2.2 The Evolution of Wage Inequality in Mexico 65
3.3 Model 67
3.3.1 Preferences and Demand 67
3.3.2 Production 68
3.3.3 Stationary Equilibrium Definition 73
3.4 Data 75
3.5 Estimation 78
3.6 Trade Liberalization 85
3.7 Concluding Remarks 88

Bibliography **102**

Appendix A
Computational Algorithm: "Exports and the Volatility of Sales" **107**

Appendix B
Computational Algorithm: "Trade, Technology Adoption and the Rise of the Skill Premium in Mexico" **111**

Appendix C
Encuesta Industrial Anual: Cleaning Procedure **114**

List of Figures

1.1 Trade Openness Across the World 15
1.2 Fraction of Countries That Have Engaged in Trade Liberalization Reforms 16
1.3 Volatility of GDP Growth Across the World 17
1.4 Volatility of GDP Growth Around Trade Liberalization Episodes . . 18
1.5 Trade Openness in Latin America – Tariffs 19
1.6 Evolution of Income Inequality in Latin America 20

2.1 Sequence of Actions 44
2.2 The Decision to Export 45
2.3 Export Intensity Decision 46
2.4 Evolution of Capital Stock 47
2.5 Mean Capital Stock around Entry into the Export Market 48
2.6 Distribution of Capital Stocks by Exporting Status 49
2.7 Mean Revenues around Entry into the Export Market 50
2.8 Standard Deviation of Revenues around Entry into the Export Market 50
2.9 Export Decision Policy Rule and Risk Aversion 51
2.10 Foreign Market Participation and Demand Correlation 52

3.1 Trade Volume and the Rise of the Skill Premium in Mexico 94
3.2 Protection Measures for Manufacturing during the 1980s (1-digit Industries) 95
3.3 Real Exchange Rate Mexico 1980-1990 96
3.4 Relative Price of Machinery and Equipment 97
3.5 Skill-Intensity Trajectories Around Entry into Export Market . . . 98
3.6 Sequence of Actions 99
3.7 Skill Premium Across 4-digit Industries 100
3.8 Size Distribution by Exporting Status 101

List of Tables

2.1 Export Intensity in Colombian Manufacturing 41
2.2 Baseline Simulation Parameters 41
2.3 Export Intensity (Simulation) 42
2.4 Summary Statistics (Simulation) 42
2.5 Summary Statistics by Exporting Status 43
2.6 Counterfactual Analysis - Shutting Down the Export Market 43

3.1 Trade Openness at the Plant Level 90
3.2 Employment and Relative Wages 90
3.3 Calibrated Parameters 91
3.4 Moments used for Estimation (Data) 91
3.5 Parameter Estimates 92
3.6 Goodness of Fit 93
3.7 Unilateral Trade Liberalization 93

A.1 Estimated Parameters for the Law of Motion of the Price Index . . 110

Acknowledgments

I would like to thank my advisor, Jim Tybout, for all his help, encouragement and patience over this very long process. I am also indebted to my committee members, Mark Anner, Andrés Rodríguez-Clare and Ruilin Zhou, for their valuable feedback. I would also like to thank Kerem Coşar, Ed Green, Nezih Güner, Neil Wallace, Jon Willis and seminar participants at the Fall 2008 Cornell-Penn State Macro Workshop, Federal Reserve Bank of Kansas City, University of Illinois at Urbana-Champaign and Universidad de Los Andes. I especially would like to thank Eugenia González for all the useful comments that have vastly improved the presentation of this work. Financial support from Colfuturo is gratefully acknowledged. This research was supported in part by the National Science Foundation (Grant No.SES-0617888). Any opinions, findings, and conclusions or recommendations expressed in this dissertation are those of the author and do not necessarily reflect the views of the National Science Foundation.

Dedication

I would like to dedicate this dissertation to my parents, Luz and Luis Alejandro, and my sister Juanita, who have helped me in every step of this journey. This work would not have been possible without their unfaltering support and endless encouragement.

Last but not least, I would like to dedicate this dissertation to Eugenia. She has been at my side from my first day of classes to my dissertation defense, always supporting me with an unbounded amount of love, enthusiasm and objectivity. All this effort is worth it because I can share its fruits with her.

Chapter 1

Motivation

The growth of international trade that has taken place over the last three decades has been nothing less than astonishing. Since the 1980s, world trade has been growing at a faster rate than the world's GDP and all the regions in the world have become more integrated to the global economy, as can be seen in Figure 1.1. This new wave of global integration has been facilitated by continuing improvements in transportation technology as well as by a world-wide policy shift towards lower international trade and investment barriers. Figure 1.2 illustrates this trend by showing the cumulative fraction of countries that have engaged in permanent trade liberalization reforms. At the beginning of the 1980s, about one third of all the countries in the world were open to trade; by the end of the decade, half of the countries were considered open, and at the dawn of the Twenty First century, this share was above 90 percent. This paradigm change in economic policy has been especially important in developing countries, which at the time were beginning to climb the value-added ladder, moving away from exporting commodities towards manufacturing goods and services. This shift has been quantitatively important: manufactures, which accounted for less than a quarter of developing country exports in 1980, rose to more than 80 percent by 1998 (World Bank, 2002).

As noted by Tybout (2000), manufacturing firms are highly regarded in developing countries. They are seen as engines of job creation, vehicles for the adoption of cutting-edge technologies and best-practice management strategies as well as a source of positive externalities. On top of that, the relatively small number of firms that export are considered the *non-plus-ultra* of the manufacturing sector: exporters are bigger in terms of employment and assets, are more skill- and capital-intensive, pay higher wages and are more productive than non-exporting plants[1]. Aware of the stronger traits exhibited by firms that compete in global markets, policy-makers have actively pursued export-led growth strategies in many developing countries. But even though deeper integration with the rest of the world is associated with higher growth rates of GDP per capita and greater allocational efficiency, the benefits and costs of trade openness are still hotly debated.

This dissertation studies two important aspects of this debate. Chapter 2, entitled "The Decision to Export and the Volatility of Sales", asks whether exporting helps firms in developing countries to better cope with the volatile business cycles in their home market or, if on the other hand, the exposure to uncertainty from abroad simply results in exacerbating the volatility of firms' sales. Chapter 3, entitled "Trade, Technology Adoption and the Rise of the Skill Premium in Mexico", analyzes the impact of trade liberalization on the factor remunerations of skilled and unskilled workers. In this chapter I show that lower barriers to trade spur the adoption of skill-biased technology, which together with the reallocation of labor between firms, results in higher relative wages for skilled workers in steady

[1]Every single empirical study regardless of the country, period or industry analyzed has documented these substantial differences between exporting and non-exporting establishments. See Alvarez and López (2005), Bernard and Jensen (1999), Bernard et. al. (2007) and Das et. al. (2007), among many others.

state. By fitting the model to data from the Mexican manufacturing sector and estimating its structural parameters, I quantify the contribution of trade-induced skill-biased technical change to the observed rise of wage inequality.

In order to investigate these issues I develop (and estimate in Chapter 3) dynamic models of firm equilibrium behavior in small open economies. This dissertation contributes to a burgeoning body of literature that aims to understand how changes in trade openness influence firm-level decisions, and how these choices aggregate across the size distribution of firms to determine economy-wide variables. Although the chapters are independent from each other, they share a number of feature from a methodological standpoint. First of all, they build upon the seminal contributions of Roberts and Tybout (1996) and Melitz (2003) which recognize the importance of accounting for the large degree of heterogeneity observed across firms in understanding their decision to adopt new technologies, invest in physical capital or export. Second, both models are full-fledged dynamic models with rational expectations in which agents' beliefs are forward looking. Although dynamic models are more frequently used in macroeconomics than in international trade, their use here recognizes the fact that the decisions to either start exporting or adopt a new production technology are characterized by large sunk costs[2] and thus are inherently dynamic. Third, monopolistic competition is the equilibrium concept in the final goods market. Finally, both models share the assumption that firms face downward-sloping demand curves in their domestic market, yet are sufficiently small so that they do not affect world prices. This small open economy assumption provides a better characterization of the environment faced by firms in developing countries like Mexico in the case of Chapter 3, or countries with un-

[2]See Roberts and Tybout (1997) for evidence on exporting. Cooper and Haltiwanger (2006) identify the presence of significant sunk costs of investment in physical capital.

derdeveloped financial systems where the sales diversification advantages provided by exporting should be more important in Chapter 2.

1.1 Trade Openness and Firm-Level Volatility

Although the volatility of aggregate output has subsided across the world since the mid 1970s[3] (See Figure 1.3), it is also true that developing countries are highly turbulent, experiencing longer and more frequent recessions as well as larger output declines on average than developed countries. A concern faced by countries considering liberalizing their trade regimes is that being more open to the rest of the world could result in a more uncertain economic environment at home. The prospect of events that are taking place thousands of miles away and over which domestic economic authorities have no control whatsoever affecting local production and employment does not seem very appealing[4]. On the other hand, a more outwardly-oriented country could have an advantage in weathering home-grown economic downturns. Figure 1.4 shows the behavior of the volatility of GDP growth around trade liberalization episodes for various country groups. Although the figure suggests that for the majority of country groups aggregate output volatility has diminished after trade liberalization, this does not need to be the case at lower levels of aggregation[5]. Since financial systems are relatively underdeveloped and instruments designed to smooth revenue fluctuations are few and not available for a large share of firms, microeconomic volatility is an important concern for policy-

[3]This phenomenon has been referred to by some economists as the "great moderation".

[4]Haltiwanger et. al. (2004) find that external common shocks to Latin American economies, such as the Debt, Tequila and Russian crises, are quantitatively more important than country and sector-specific shocks in explaining the variance of employment growth. They also document a significant effect of cyclical fluctuations in real exchange rates on net and gross job reallocation.

[5]Comin and Mulani (2006) document an upward trend in firm-level volatility over the last three decades, at the same time as aggregate volatility has been steadily falling.

makers in developing countries. Highlighting episodes in which producers thrive notwithstanding the economic crisis is a recurring theme in theme in the popular press during economic downturns. In developing countries these success-amid-adversity stories often involve producers breaking into foreign markets. A natural question to ask then is, does exporting allow producers in developing countries to cope with the uncertain conditions they face in their home country?

Chapter 2 presents a dynamic stochastic partial-equilibrium model that addresses this question. In the model, monopolistically-competitive firms produce using capital and decide whether to export or not. Firms face idiosyncratic productivity uncertainty as well as aggregate demand shocks. An individual firm's state variables include its productivity, capital stock and exporting status, all of which are firm-specific, together with the aggregate demand shocks in both markets and the domestic price index, which are common to all firms. Since firms' decisions take as given the domestic price index, which depends on the entire distribution of capital across firms (an infinite-dimensional object), the model is solved using the approximation method proposed by Krusell and Smith (1998). To better capture the lack of insurance instruments available for firms to smooth their revenues, it is assumed that firms are risk-averse with no access to capital markets. This assumption intends to put all the emphasis on the hypothesis of exporting as a hedge against domestic aggregate shocks. Moreover, unlike earlier research that studied the problem of either a monopolist or a perfectly-competitive firm with free access to foreign markets, this model examines the problem of monopolistically-competitive firms for which exporting is costly. Here I draw from the empirical literature on the decision to export and incorporate significant sunk costs to start selling abroad as well as fixed per-period costs to participate in foreign markets.

Simulation results show that the higher average profits are the main reason why firms decide to become exporters, even if it makes their sales slightly more volatile, due to the combination of extreme liquidity constraints and foreign market entry costs, which in turn makes investment more volatile. This occurs because when firms enter the foreign market they have an incentive to stay in it, even if they are hit by adverse productivity and aggregate shocks. However, firms do respond to the diversification advantages provided by the export market. Firms are more likely to become exporters when the correlation between domestic and external aggregate shocks is low and when risk aversion is high. Also, a higher degree of risk aversion also makes a firm's export decision more responsive to the degree of correlation between domestic and foreign aggregate shocks.

1.2 Trade Openness and Wage Inequality

The claim that trade liberalization is responsible for widening income disparities within countries is one of the most commonly voiced arguments by critics of globalization. The argument goes that only certain groups of individuals, particularly highly skilled workers benefit from increased openness. Unskilled workers on the other hand (which are usually a large segment of the population in developing countries) become more easily substitutable either by workers outside national borders or cheaper labor-saving imported capital equipment. This outcome can be highly problematic in developing countries, especially in Latin America, where income inequality was already high before the liberalization reforms. Higher income inequality reduces the support for efficiency-enhancing market-oriented reforms and induces polarization and social unrest.

The *skill premium*, defined as the wage of skilled labor relative to that of unskilled labor experienced a significant increase in the United States during the

1980s, even though the relative supply of skilled workers increased by more than a 100 percent from the 1960s until the early 1990s (Krusell et. al. 2000). Two (usually competing) explanations for this phenomenon have been advanced: 1) Skill-biased technical change (SBTC), such as the spread of computer-based technologies that tend to complement the tasks performed by individuals with high levels of human capital (i. e. problem-solving and complex communication activities, or "nonroutine" tasks) or substitute for workers in carrying out a limited and well-defined set of cognitive and manual activities (see Author et. al. 2003) and 2) Increased international trade with countries abundant in unskilled labor. Skill-biased technical change spurred by the significant decrease in the real price of machinery and equipment would shift out the relative demand for skilled labor, by a greater magnitude than the shift of relative supply, resulting in a higher skill premium. On the other hand, a larger volume of trade with developing countries would, according to the Heckscher-Ohlin model of trade, cause a reduction in the relative price of unskilled labor-intensive goods, leading to a reallocation of resources towards skilled-labor intensive industries, ultimately increasing the relative real wage of skilled workers (the Stolper-Samuelson theorem). The earlier work focusing on the U.S. experience concluded that SBTC was more important than changes in international trade flows in explaining the rising skill premium, since a significant share of the increase in skill intensity observed took place *within* rather than between 4-digit industries. However, more recent research has shown that 4-digit industries are rather coarse divisions of production activities and can mask a lot of variation in skill intensity, moreover, it has shown that changes in trade orientation can induce significant changes in the organization of the workforce at the plant level. These findings suggest the possibility that skill-biased technical change and trade openness might reenforce each other, resulting in higher wage inequality.

Chapter 3 looks in great detail at the unilateral trade liberalization pursued by Mexico in the mid 1980s and asks how much did the interaction between trade openness and technology adoption contributed to the dramatic changes in factor remunerations observed in its aftermath. Figures 1.5 and 1.6 show the evolution of average tariff rates and Gini coefficients for the largest Latin American countries over the last 25 years. Starting around the mid 1980s there is a trend towards lower tariffs, (as well as towards simpler tariff structures and scrapping of licensing requirements), motivated in part by the poor performance of import-substitution policies in place since the 1960s and the debt crisis of the early 1980s. Shortly afterwards, wage inequality started to rise dramatically, particularly at the end of the decade, stabilizing during the 1990s[6]. This is a puzzling finding, since traditional international trade theory predicts that these countries, abundant in unskilled labor, should have seen a fall in the skill premium after opening up to trade. Among Latin American countries, Mexico stands out because it experienced the largest and quickest increase in the skill premium at the same time as it dramatically changed its outward orientation.

Various factors suggest that skill-biased technical change triggered by an increased exposure to trade could be an important factor behind the increase in inequality in Mexico. First of all, the increase in the skill premium was stronger in tradable sectors like manufacturing than in non-tradables like construction and services (Feliciano, 2001). Second, there was a dramatic fall in the relative price of machinery and equipment[7] starting in December of 1987, product of a secular

[6]This pattern of wage inequality evolution has been documented in several Latin American countries Attanasio et. al. (2004) for Colombia, Bustos (2005) for Argentina, Pavcnik (2003) and Fuentes and Gilchrist (2007) for Chile and Robertson (2004) for Mexico.

[7]Relative to the price of consumption goods.

fall in the price of capital equipment in developed countries (Krusell et. al., 2000 and Eaton and Kortum, 2001) and a large reduction in tariffs at home[8]. The reduction in the price of machinery together with a 30 percent depreciation in the real exchange rate after 1985 resulted in a marked increase both in the share of plants exporting and purchasing imported machinery and equipment. In fact, a significant share of plants decided to undertake both activities at the same time[9]. Finally, there is evidence that new-exporting plants are the ones that increased their skill-intensity the most (Bustos, 2005, finds the same for Argentinean plants) thus indicating that changes in exporting status prompt changes in the production technology of plants.

While this body of evidence is very suggestive, a structural empirical model of trade and technology adoption at the firm-level is needed to assess the quantitative importance of this channel as a determinant of changes in wage inequality. Thus, Chapter 3 develops and estimates a dynamic stochastic general equilibrium model of a small open economy with heterogeneous firms and it uses it to quantify the contribution of skill-biased technology adoption induced by trade liberalization on the rise in the skill premium observed in Mexico after the mid 1980s. In the model, monopolistically-competitive firms produce using skilled and unskilled labor, decide whether to export or not, make entry and exit decisions and choose what technology to operate. The technology that a firm operates determines the stochastic process for skilled labor productivity, so that larger firms tend to be more skill-intensive, as observed in the data. Firms can choose between two technolo-

[8]The production-weighted average tariff for machinery, transportation and equipment fell from 35.6 percent in 1980 to 15.9 percent in June of 1990.

[9]It is also important to note that imported machinery and equipment also becomes more important among plants experiencing investment spikes (i. e. plants that at a given point in time purchase machinery and equipment of value greater than 20 percent of their current capital stock). In 1986, 67 percent of investment spikes involved the purchase of foreign capital goods, by 1990 this share increases to 82 percent.

gies: a "traditional" low-productivity technology that requires a low per-period fixed cost of operation, and a "modern" technology that yields higher productivity draws at the expense of a higher fixed cost[10]. Furthermore, firms face a sunk cost to adopt the modern technology, which aims to capture the costs of retooling and the low resale value of machinery. The existence of sunk costs to adopt the modern technology together with the serially-correlated skilled labor productivity makes the technology adoption decision faced by the firm forward-looking. The model is estimated using plant-level data from Mexico's Annual Manufacturing Survey from 1984 to 1990, covering the period of unilateral trade liberalization that preceded Mexico's entry to GATT in 1986.

Although recent papers have provided suggestive evidence of complementarities between the decision to export and the use of advanced manufacturing technologies (Bustos, 2005, Lileeva and Trefler, 2007, among others), the work presented here presents important contributions to understand the relationship between trade openness, technology adoption and their distributional consequences. The use of structural estimation techniques allows me to recover the deep parameters of the model and evaluate the general equilibrium effect of trade-induced technology adoption on relative wages after a unilateral trade liberalization episode of a similar magnitude to that implemented by Mexico. Moreover, unlike other studies that study the impact of reductions in the variable cost of trade in a two, identical countries setting where a trade liberalization provides easier access of imports to, and exports from, the home country, I specifically look at the impact of a reduction in *import* tariffs alone. This is an important distinction, since Mexican exporters were already facing low tariffs in Mexico's main export markets and these tariffs

[10]For the purpose of mapping the model to the data, it is assumed that a plant that purchases imported machinery and equipment is using the modern technology in the model.

did not change significantly after the trade liberalization. Examining the effect of a unilateral liberalization allows me to show that even if the potential size of the foreign market size does not increase, an import-competition effect can result in an increase in the adoption of advanced technologies. Heightened import-competition reduces the profit margin of domestic firms and these either contract (and become less skill-intensive) or exit the market. At the same time, firms in the middle of the productivity distribution are induced to start exporting due to a terms-of-trade effect, which provides the incentive for them to adopt the modern technology and become more skill-intensive. These two effects combined result in an aggregate increase of the relative demand for skilled workers that in turn pushes the skill premium up.

Bibliography

[1] Alvarez, Roberto and Ricardo A. López (2005): "Exporting and Performance: Evidence from Chilean Plants" *Canadian Journal of Economics* 38: 1384-1400

[2] Attanasio, Orazio, Pinelopi Goldberg and Nina Pavcnik (2004): "Trade Reforms and Wage Inequality in Colombia" *Journal of Development Economics* 74: 331-366

[3] Author, David H., Frank Levy and Richard H. Murnane (2003): "Skill Content of Recent Technological Change" *The Quarterly Journal of Economics* 118: 1279-1333

[4] Bernard, Andrew B. and J. Bradford Jensen (1999): "Exceptional Exporter Performance: Cause, Effect, or Both?" *Journal of International Economics* 47: 1-25

[5] Bernard, Andrew B., J. Bradford Jensen, Stephen J. Redding and Peter K. Schott (2007): "Firms in International Trade" *Journal of Economic Perspectives* 21: 105-130

[6] Bustos, Paula (2005): "The Impact of Trade on Technology and Skill Upgrading: Evidence from Argentina" *mimeo* CREI Universitat Pompeu Fabra

[7] Comin, Diego and Sunil Mulani (2006): "Diverging Trends in Macro and Micro Volatility" *The Review of Economics and Statistics* 88: 374-383

[8] Coooper, Russell W. and John C. Haltiwanger (2006): "On the Nature of Capital Adjustment Costs" *Review of Economic Studies* 73: 611-633

[9] Das, Sanghamitra, Mark J. Roberts and James R. Tybout (2007): "Market Entry Costs, Producer Heterogeneity and Export Dynamics" *Econometrica* 75: 837-873

[10] Deininger, Klaus and Lyn Squire (1996): “A New Data Set Measuring Income Inequality” *World Bank Economic Review* 10: 565-591

[11] Eaton, Jonathan and Samuel Kortum (2001): “Trade in Capital Goods” *European Economic Review* 45: 1195-1235

[12] Feliciano, Zadia (2001): “Workers and Trade Liberalization: The Impact of Trade Reforms in Mexico on Wages and Employment” *Industrial and Labor Relations Review* 55: 95-115

[13] Fuentes, Olga M. and Simon Gilchrist (2005): “Skill-Biased Technology Adoption: Evidence for the Chilean Manufacturing Sector” *mimeo* Boston University

[14] Goldberg, Pinelopi and Nina Pavcnik (2007): “Distributional Effects of Globalization in Developing Countries” *Journal of Economic Literature* 45: 39-82

[15] Haltiwanger, John, Adriana Kugler, Maurice Kugler, Alejandro Micco, and Carmen Pages (2004): “Effects of Tariffs and Real Exchange Rates on Job Reallocation: Evidence from Latin America” *Journal of Policy Reform*, Special Issue, 7: 191-208

[16] Inter-American Development Bank. *Latin America After a Decade of Reforms.* 1997. Johns Hopkins University Press, Washington, D. C.

[17] Kose, M. Ayhan, Eswar S. Prasad and Marco E. Terrones (2006): “How do Trade and Financial Integration Affect the Relationship between Growth and Volatility?” *Journal of International Economics* 69: 176-202

[18] Krusell, Per and Anthony A. Smith, Jr. (1998): “Income and Wealth Heterogeneity in the Macroeconomy” *Journal of Political Economy* 106: 867-896

[19] Krusell, Per, Lee E. Ohanian, José-Víctor Ríos-Rull and Giovanni L. Violante (2000): “Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis” *Econometrica* 68: 1029-1053

[20] Lileeva, Alla and Daniel Trefler (2007): “Improved Access to Foreign Markets Raises Plant-level Productivity... for Some Plants” *mimeo* University of Toronto

[21] Londoño, Juan Luis and Miguel Székely (1997): “Distributional Surprises After a Decade of Reform: Latin America in the Nineties” OCE Working Paper No. 352, Inter-American Development Bank, Washington, D. C.

[22] Melitz, Mark J. (2003): “The Impact of Trade on Aggregate Industry Productivity and Intra-Industry Reallocations” *Econometrica* 71: 1695-1725

[23] Nicita, Alessandro and Marcelo Olarreaga (2006): "Trade, Production and Protection 1976-2005" *mimeo* World Bank, Washington, D. C.

[24] Pavcnik, Nina (2003): "What Explains Skill Upgrading in Less Developed Countries?" *Journal of Development Economics* 71: 311-328

[25] Roberts, Mark J. and James R. Tybout eds., *Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity, and Market Structure*, 1996, Oxford University Press for The World Bank, New York

[26] Roberts, Mark J. and James R. Tybout (1997): "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs" *American Economic Review* 87: 545-564

[27] Robertson, Raymond (2004): "Relative Prices and Wage Inequality: Evidence from Mexico" *Journal of International Economics* 64: 387-409

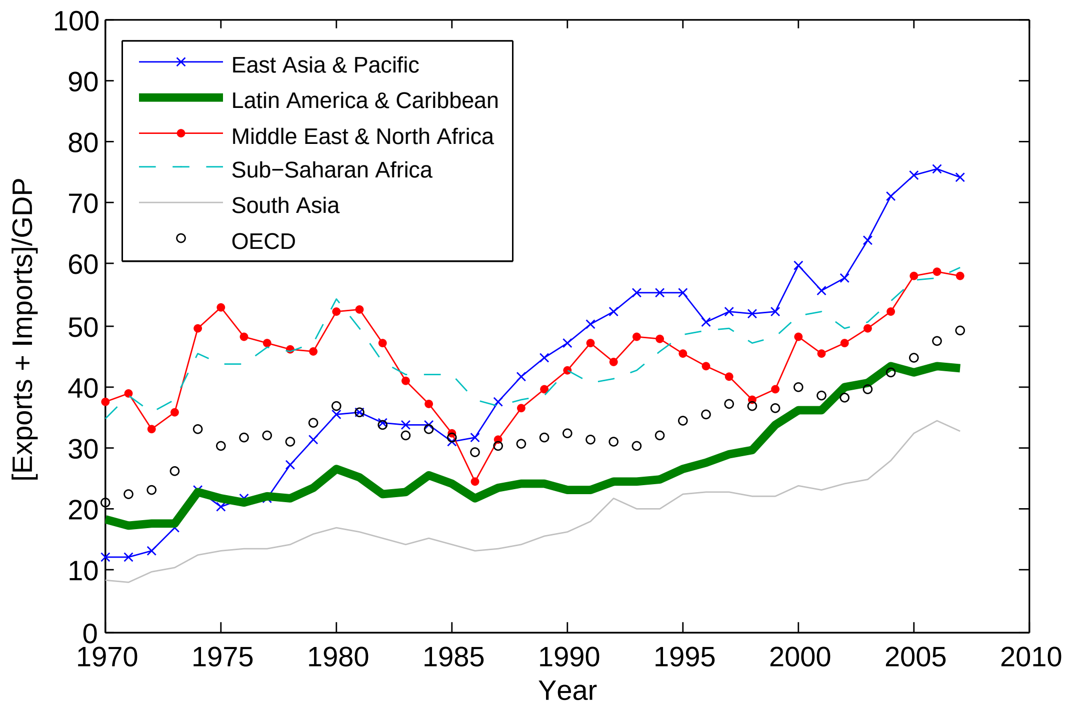
[28] Tybout, James R. (2000): "Manufacturing Firms in Developing Countries: How Well do They do, and Why?" *Journal of Economic Literature* 38: 11-44

[29] Wacziarg, Romain and Karen Horn Welch (2008): "Trade Liberalization and Growth: New Evidence" *World Bank Economic Review* 22: 187-231

[30] Wolf, Martin, *Why Globalization Works?*, 2004, Yale University Press: New Haven and London

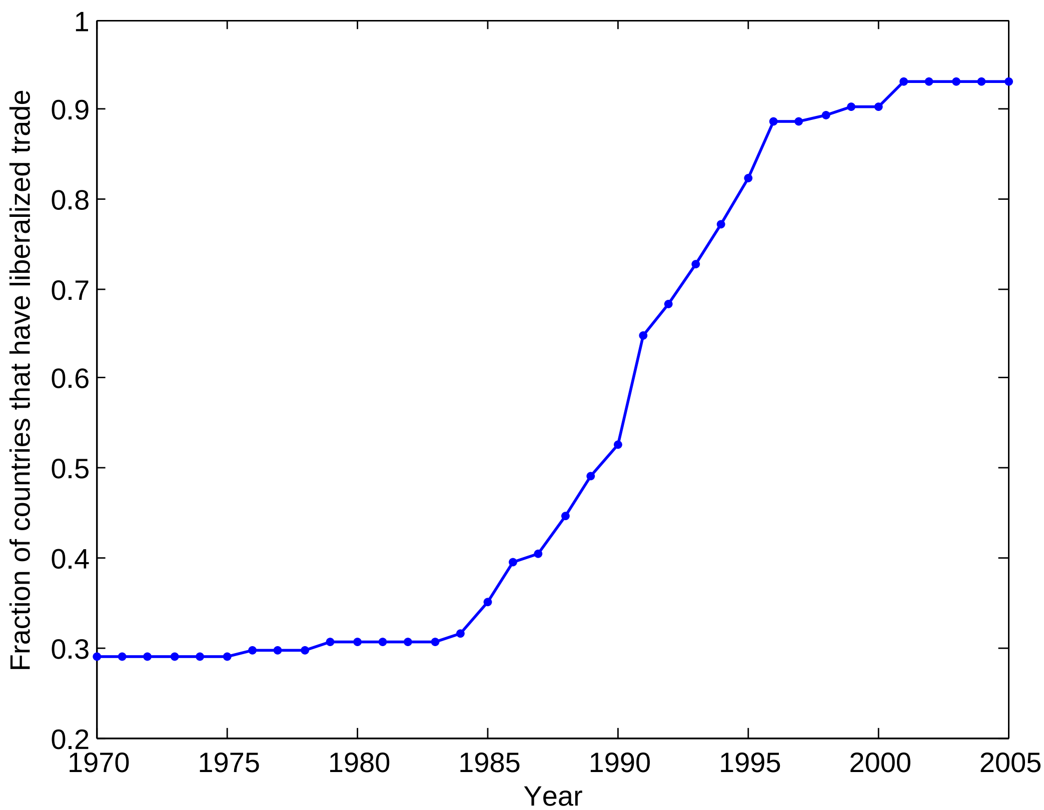
[31] World Bank, *Globalization, Growth and Poverty*, 2002, Washington DC.

Figure 1.1. Trade Openness Across the World



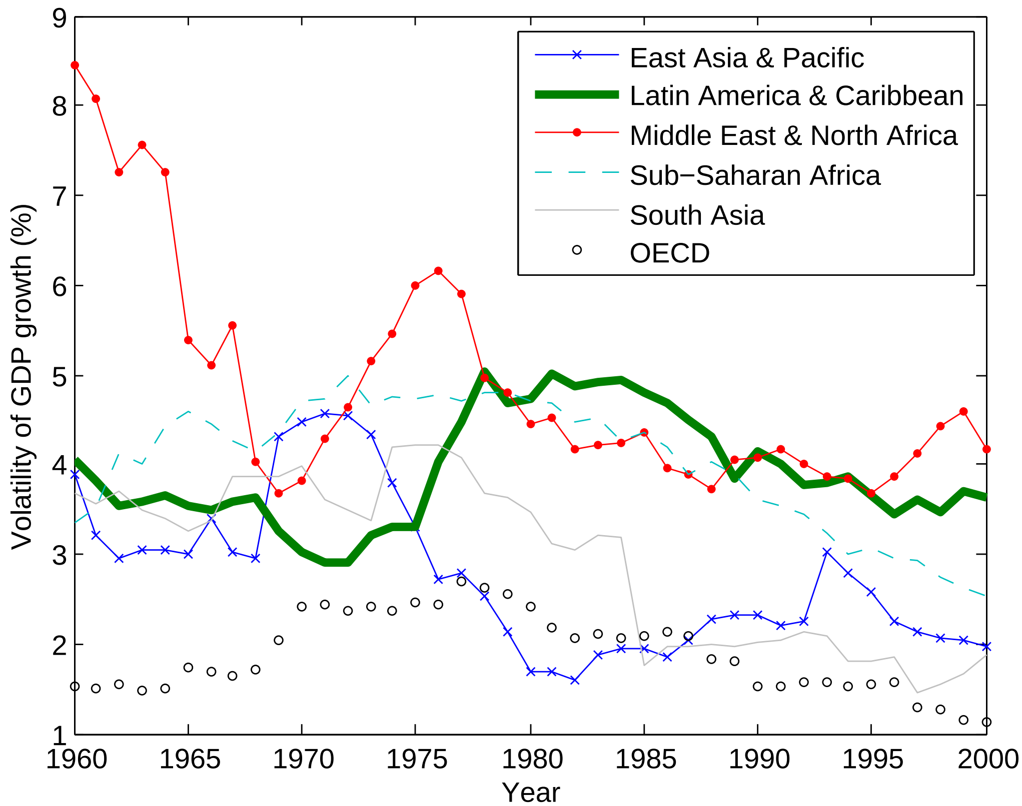
Source: World Bank WDI

Figure 1.2. Fraction of Countries That Have Engaged in Trade Liberalization Reforms



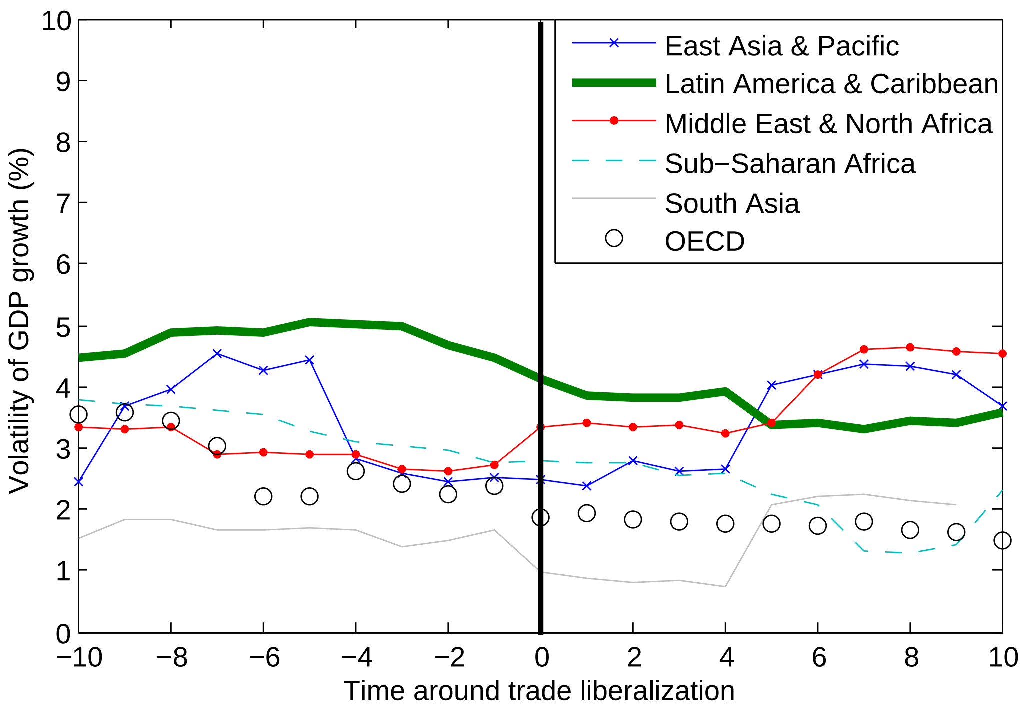
Own calculations. Source: Wacziarg and Horn Welch (2008).

Figure 1.3. Volatility of GDP Growth Across the World



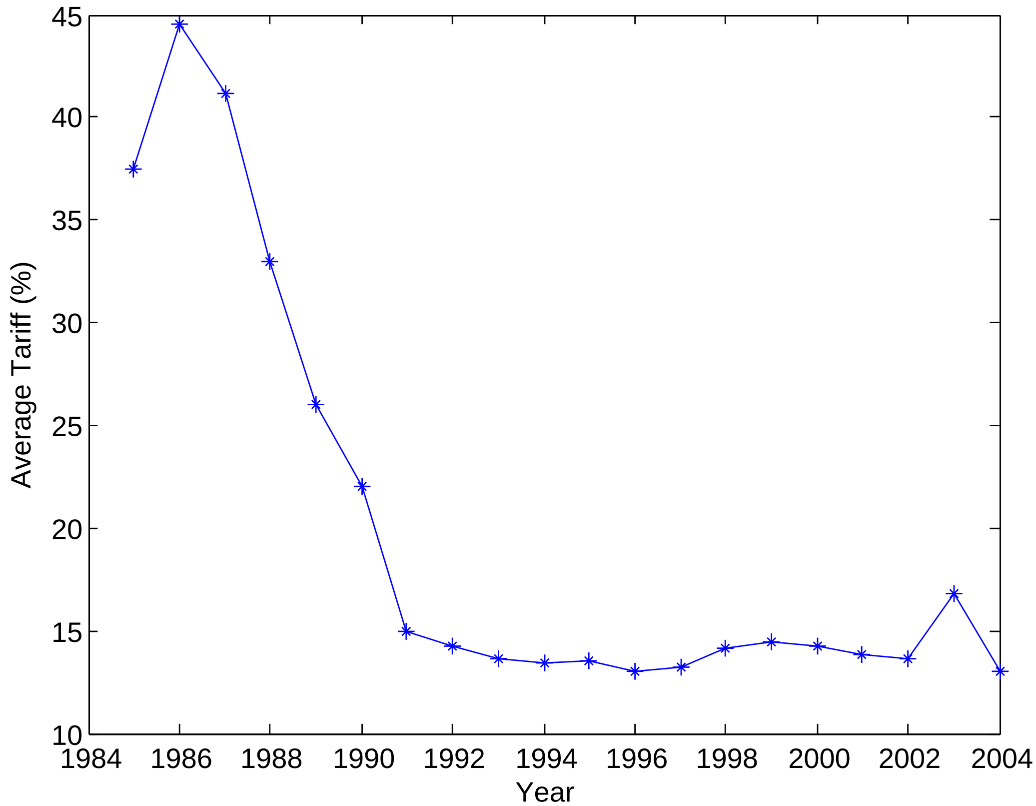
Own calculations. Volatility is measured as the standard deviation of the growth rate of real GDP calculated over 10-year rolling windows. Source: World Bank WDI.

Figure 1.4. Volatility of GDP Growth Around Trade Liberalization Episodes



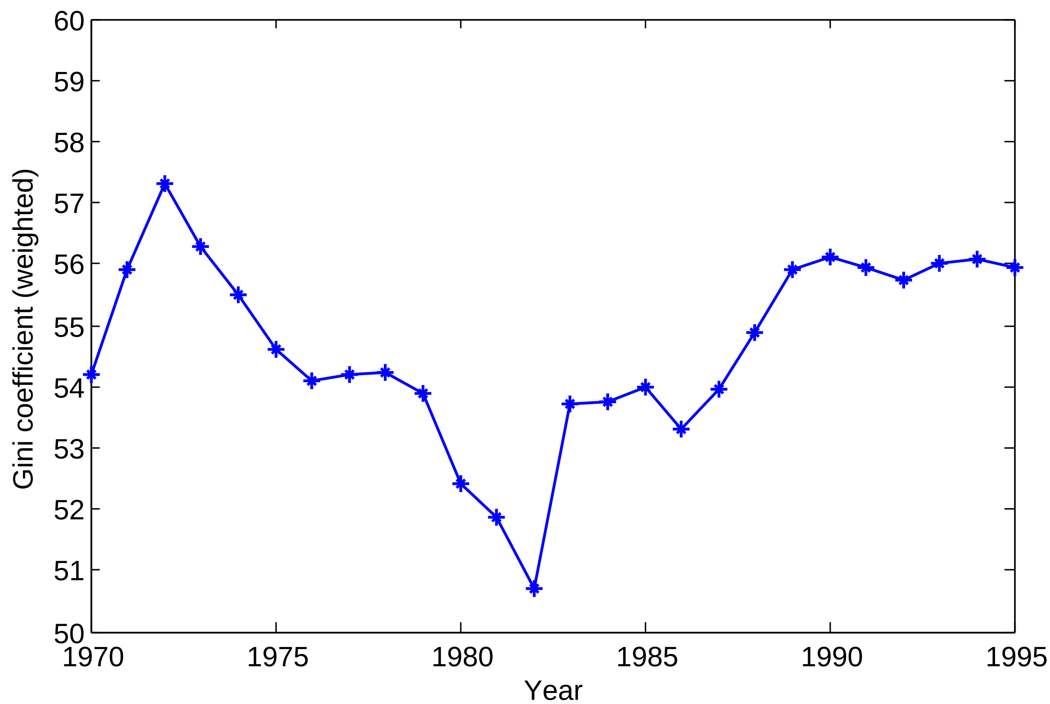
Own calculations. Source: World Bank WDI and Wacziarg and Horn Welch (2008).

Figure 1.5. Trade Openness in Latin America – Tariffs



Weighted-average of average tariffs for the following 11 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela. Source: Inter-American Development Bank (1997) and Nicita and Olarreaga (2006).

Figure 1.6. Evolution of Income Inequality in Latin America



Source: Londoño and Székely (1997). The gini coefficient for income is calculated from household surveys with national coverage for the following 13 countries: Bahamas, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Panama, Peru and Venezuela

Chapter 2

The Decision to Export and the Volatility of Sales

2.1 Introduction

Developing countries have on average more volatile business cycles and rates of output growth than developed countries (Aguiar and Gopinath, 2007, Agenor et. al., 2000), and they also suffer from deeper recessions that occur more frequently than in their developed counterparts (Gavin and Hausmann, 1996). Although there are many factors that make developing countries highly volatile (political instability, fiscal and monetary profligacy, underdeveloped financial systems, etc.) a growing literature has emphasized the role of trade openness as a determinant of volatility both at the aggregate and sectoral levels.

The empirical evidence on the link between trade openness and volatility is mixed. di Giovanni and Levchenko (2005) looking at 3-digit sectoral data for 59 countries between 1963 to 2002, find that although more open sectors tend to be less correlated with the rest of the economy (enjoying a diversification benefit), the exposure to foreign shocks and a tendency toward greater specialization of production tilt the balance toward a positive relationship between trade openness and sales volatility at the sectoral level. Along the same lines, using cross-country data, Easterly et. al. (2001) find that openness increases the volatility of GDP growth. Kose et. al. (2006) on the other hand, find that more openness to trade weakens the negative relationship between volatility and growth. The literature that studies the effects of trade openness on firm-level volatility is much more limited.

There are several ways in which closer global linkages can affect a firm's volatility. International trade can make a firm more vulnerable to external shocks; stiffer competition from abroad can reduce profit margins and make firms more likely to shut down. On the other hand, exporting can help a firm to insure against systemic shocks in its domestic market through diversification of its revenue stream, provided that domestic and external shocks are not perfectly correlated. Firms that participate in foreign markets can cope better with downturns in the domestic business cycle by selling abroad some fraction of the output that was intended to be sold in the domestic market and viceversa. However, even if exporting has a positive effect on sales stabilization, exporting is a hedging mechanism that relatively few firms within an industry can afford if there are significant sunk and fixed costs that exporting firms have to incur to participate in foreign markets (Roberts and Tybout, 1997, Das et. al., 2007). The objective of this paper is to determine whether firms use the export market as mean to diversify market-wide shocks in their domestic market in a dynamic model where exporting is costly. Under the assumption that firms operating in developing countries are risk-averse, more stable sales should have a direct positive impact on firm proprietors' welfare. Furthermore, if these firms operate in an environment where financial markets are highly incomplete and liquidity constraints are pervasive, as it is common in developing countries, a more stable cash flow could result in higher rates of investment in capital goods (Campa and Shaver, 2001).

In this chapter I study the effect of uncertainty and risk-aversion on the export participation decision of firms. I also evaluate how the volatility of sales changes, when counter-factually firms can only sell in the domestic market, thus illustrating the extent to which exports can (or not) help to reduce firm's sales volatility. To do this I construct a dynamic model with heterogeneous, risk-averse firms that accumulate physical capital in a world characterized by extreme liquidity constraints[1], and decide in which markets to sell their output in an environment characterized by macroeconomic and firm-specific uncertainty and entry costs into the export market. I go beyond prior research, discussed below, that has looked at partial correlations between export participation and sales volatility at the firm-level and has ignored the significant entry costs of exporting.

From a methodological perspective, the work in this chapter is closely related to a growing literature using dynamic models of heterogeneous firms in international economics (Alessandria and Choi, 2007, Ghironi and Melitz, 2005 and Ruhl, 2005). Common traits in these models are: firm/plant heterogeneity in idiosyncratic productivity (and sometimes in other dimensions like the cost to start exporting), fixed costs to export and the existence of aggregate uncertainty. The model presented here retains the firm-idiosyncratic productivity and the fixed costs to start and continuing to export, but assumes that aggregate shocks are the product of *demand* fluctuations caused by the business cycle.

Firms choose to enter the export market when the expected present discounted

[1]In this case, the value of diversification provided by exporting should be the greatest, since its payoffs cannot be replicated by a portfolio of securities

utility of profits is sufficiently large to cover the sunk cost to start selling abroad. Exporting increases a firm's size but also makes its investment and sales more volatile. Therefore, even though firms care about the volatility of profits, the increase in mean revenues that they accrue from exporting is sufficiently large for them to decide to sell abroad, even at the expense of more volatile sales. Once firms have begun to export, they have the incentive to remain in the foreign market even when hit by adverse productivity and aggregate demand shocks. When favorable foreign demand conditions return, exporters increase their capital stock significantly more than non-exporters, thus experiencing higher sales volatility. Nonetheless, firms also take advantage of the opportunities to stabilize their earnings: simulation results show that firms are more likely to participate in foreign markets when the correlation between domestic and foreign aggregate shocks is low and when risk aversion is high. Moreover, export participation is more responsive to the correlation of aggregate shocks when risk aversion is higher.

Previous research has found that exporting has a stabilizing effect on sales at the firm level. Hirsch and Lev (1971) using a sample of 288 firms in 5 sectors[2] in Denmark, Israel and The Netherlands find a positive correlation between international diversification and total sales stability, even though domestic sales are more stable than export sales. More recently, Buch et. al. (2006) using plant-level data from the German state of Baden-Wuerttemberg have found that controlling for firm size and productivity, exporters have lower volatility of sales than non-exporters. Campa and Shaver (2001) analyzing a panel of Spanish manufacturing firms find that investment rates for exporters are less sensitive to cash flow that for non-exporters. They argue that this is because liquidity constraints are less binding for exporters and that is in turn a result of more stable cash flows. The

[2]Food, chemicals, textiles, machinery, electronic appliances and electronics

fact that the export status of a firm is easily verifiable can increase the value of the firm because financial intermediaries are more confident about its repayment ability. In a theoretical model with heterogeneous firms, Chaney (2005) shows that the existence of liquidity constraints dampens the response of exports to exchange rate fluctuations. Because even though an exchange rate appreciation reduces the profits for exporters, the intensive margin, it increases the value of a firm's collateral lessening liquidity constraints, thus producing a positive response of the extensive margin of exports. Maloney and Azevedo (1995) study the export decision of price-taking risk-averse firms. They find that export intensity is an increasing (decreasing) function of the expected return (volatility) to export relative to that in the domestic market. However, under their assumption of negative exponential expected utility they find an ambiguous effect of the covariance of domestic and foreign returns on export supply. They test their predictions using firm-level data for Mexico in the 1980s and find that relative returns and volatility are significant determinants of export supply.

This chapter is organized as follows: section 2.2 outlines the theoretical model, sections 2.3 and 2.4 describe the parameters used in the simulations and the results respectively. Section 2.5 concludes.

2.2 Model

2.2.1 Technology

This is a partial equilibrium model of an industry composed of heterogeneous firms that operate in a monopolistic competition environment. There are N risk-averse firms, each producing a differentiated product that maximize the expected lifetime utility of profits,

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t u(\pi_t)\right\}, \quad u(\pi) = \frac{\pi^{1-\gamma}}{1-\gamma}. \tag{2.1}$$

where $\beta \in (0, 1)$ and $\gamma > 0$. The assumption that firms are risk-averse can be rationalized by thinking of firms owned by consumers/entrepreneurs who work in their own firms and whose income comes from the firm's dividends. Maloney and Azevedo (1995) note that in developing countries it is common for managers to own large shares of the firms they run. Even if managers are not the sole owners of a firm, non-managing shareholders with few financial instruments available to share risk would care about the variability of profits, as well as their level. Even in a developed economy like the United States, Moskowitz and Vissing-Jørgensen (2002) find that around 75 percent all private equity is owned by households for which it constitutes at least half of their total net worth.

All firms have access to the same technology:

$$q = e^{\phi}k^{\alpha}, \quad \alpha \in (0, 1). \tag{2.2}$$

where k is the firm's capital stock and ϕ is the firm-specific productivity process that follows a Markov chain $P_{\phi}(\phi'|\phi)$. Capital stock is owned by the firm and is augmented through investment that comes from internal funds. Financial markets are non-existent, so the firm cannot borrow to finance capital investment. A firm's capital stock follows the law of motion,

$$k' = (1 - \delta)k + i, \tag{2.3}$$

where i denotes gross investment and δ is the depreciation rate of capital. At period t the firm chooses the capital stock that will be available at period $t + 1$. Furthermore, I assume that gross investment has to be non-negative, hence, the only way a firm can reduce its capital stock is by not investing and letting the capital stock to depreciate. This assumption operates as a capital-adjustment cost, reducing the responsiveness of investment to shocks. Firms are heterogeneous in the capital stock they own, and also in terms of their export status and idiosyncratic productivity. The last point to notice about the capital accumulation decision of the firm, is that the choice of capital determines the amount of capital input that goes into production. This contrasts with the model of Cooley and Quadrini (2001) where there is a market in which firms can rent capital to/from other firms. In this setting, the amount of output a firm can produce is not constrained by the amount of capital it has accumulated. The idea behind restricting firms' capital accumulation options is to shut down alternatives other than exporting that firms could potentially use to hedge uncertainty.

Firms produce a good that can be potentially sold in two markets: Home (h) and the Rest of the World (f). The difference between the two is that it is costly for a firm to sell its output in the foreign market. A firm that decides to *start* exporting needs to pay a sunk cost F. On top of that, and independently of previous exporting status, a firm that exports in any given period has to pay a fixed cost M. The existence of sunk costs to become an exporter makes the firm's export decision dynamic. The high turnover rates observed in export markets justify the fixed cost M on top of the sunk cost to start exporting, since the Cobb-Douglas production function assumed implies that gross potential export profits are always positive[3]. Let y denote the export status of a firm, with $y = 1$ if the firm decides

[3]On the other hand, the assumption of fixed participation costs of servicing the foreign market implies that exporters have to sell a significant amount of output abroad to cover these fixed costs. Recent evidence by Eaton, Eslava, Kugler and Tybout (2007) documents that new exporters have significantly small exporting revenues.

to export and 0 otherwise. Also, let y_{-1} denote the firm's export status in the previous period. Then the cost of exporting for a given firm are:

$$\text{cost of exporting} = \begin{cases} F + M, & \text{if } y = 1 \text{ and } y_{-1} = 0, \\ M, & \text{if } y = 1 \text{ and } y_{-1} = 1. \end{cases} \tag{2.4}$$

Conditional on exporting, a firm has to decide what fraction of its capital stock, $\theta \in [0, 1]$, wants to use to produce for the foreign market.

2.2.2 Market Structure

In each market $j = h, f$ there is a representative consumer with CES preferences over all available products in country j. I assume that the domestic and foreign market are segmented, so firms can charge different prices in each. A firm located in country h faces the following demand curves for its output:

$$q^h = \frac{(p^h)^{-\sigma_h}}{(P^h)^{1-\sigma_h}} I^h, \quad q^f = \frac{(p^f)^{-\sigma_f}}{(P^f)^{1-\sigma_f}} I^f. \tag{2.5}$$

where I^j is country j's total expenditure on the industry, σ_j is the elasticity of substitution between varieties available in country j and P^j is the price index in country j. Assuming that the number of firms located in country h constitute a very small fraction of all the firms in the rest of the world, the pricing decision of Home firms has a negligible effect on P^f. This is not the case at market h, where the domestic price index is given by:

$$P^h = \left(N^{-1} \sum_{i=1}^{N} (p_i^h)^{1-\sigma_h} \right)^{\frac{1}{1-\sigma_h}}. \tag{2.6}$$

The industry is subject to aggregate demand shocks in each market that are exogenous from the perspective of an individual firm, for instance, business cycle fluctuations. Let z^j denote the demand shock in market j. I will consider the total expenditure in the industry at home, the domestic demand shock, so $z^h = I^h$. In a similar fashion, and making use of the small open economy assumption, the foreign demand shock is $z^f = I^f(P^f)^{1-\sigma_f}$. Furthermore, I assume that aggregate shocks follow a joint Markov process $P_Z(\mathbf{Z}'|\mathbf{Z})$ where $\mathbf{Z} \equiv [z^h \quad z^f]'$, that is independent from the idiosyncratic productivity process.

2.2.3 Timing

The timing of actions is as follows, and is illustrated in Figure 2.1:

1. A firm enters period t with a given capital stock k and last period's export status $y_{-1} \in \{0, 1\}$. Demand shocks z^f and z^h and firm-specific productivity ϕ draws are realized at the beginning of the period.

2. The firm chooses what fraction of its inputs to devote to production for the foreign market, θ, conditional on its previous export status. If the firm did not export last period, it has to pay a sunk cost F to break into the foreign market in period t. A firm needs to pay a fixed cost M in order to export regardless of its previous export status.

3. Finally, the firm chooses its desired capital stock for period $t+1$ and its export status for period t.

Since a firm's capital stock in period t is the result of the firm's decision at $t-1$, the timing assumption implies that output is chosen before the resolution of uncertainty, but the allocation of sales is decided ex-post. This is the same timing assumption used by Eldor and Zilcha (1987) and Donnenfeld and Zilcha (1991). They argue that this assumption better describes the operation of exporting firms as opposed to a setting where firms' output, pricing and export decisions are all made simultaneously, since firms are more flexible to adjust the distribution of sales across different markets than the total scale of their production.

2.2.4 Firm's Problem

From the demand functions in equation 2.5, it can be seen that a firm's pricing decision depends on the price index, which in turn depends on the prices set by all the firms in the industry, and ultimately depending on the distribution of individual firms across capital, productivity and export status, denoted by Γ. Under the presence of aggregate macro shocks (the domestic and foreign demand shocks in the model), the distribution Γ will evolve according to an equilibrium law of motion $\Gamma' = h(\Gamma, \mathbf{Z}, \mathbf{Z}')$.

The firm's state variables can be classified into four categories: 1) *endogenous individual states*, capital stock k and export status y_{-1}; 2) *exogenous individual states*, firm-specific productivity, ϕ; 3) *exogenous aggregate states*, market-wide demand shocks, $\mathbf{Z}$ and 4) *endogenous aggregate state*, domestic price index, P^h. Letting π^h and π^f denote the potential profits from selling in the domestic market and exporting respectively, the firm's problem can be written in recursive form:

$$v(k, y_{-1}, \phi, \mathbf{Z}, \Gamma) = \max_{k', \theta, y} \Big\{ u(\pi^h + y\pi^f) + \beta E\big[v(k', y, \phi', \mathbf{Z}', \Gamma')\big] \Big\} \tag{2.7}$$

s.t:

$$\pi^h + y\pi^f = p^h(q^h; P^h, \mathbf{Z}) q^h(k, \phi, \theta) + \big[p^f(q^f; \mathbf{Z}) q^f(k, \phi, \theta) - M - (1 - y_{-1})F\big] y - i$$

$$q^h = (1 - \theta) e^{\phi} k^{\alpha}, \quad \text{and} \quad q^f = \theta e^{\phi} k^{\alpha},$$

$$p^h = [z^h (P^h)^{\sigma_h - 1}]^{\frac{1}{\sigma_h}} (q^h)^{-\frac{1}{\sigma_h}}, \quad \text{and} \quad p^f = [(z^f)^{\sigma_f - 1}]^{\frac{1}{\sigma_f}} (q^f)^{-\frac{1}{\sigma_f}},$$

$$i = k' - (1 - \delta)k \geq 0,$$

$$\Gamma' = h(\Gamma, \mathbf{Z}, \mathbf{Z}').$$

In order to compute the solution to this problem I follow the approach suggested by Krusell and Smith (1998)[4]. Their methodology assumes that firms' perceptions of how Γ (and therefore P^h) evolves are boundedly-rational. Individual firms assume that the domestic price index evolves according to a relatively simple law of motion. In particular,

$$\log P_{t+1}^h = a_{0,Z} + a_{1,Z} \log P_t^h, \quad Z = 1, \ldots, N_Z, \tag{2.8}$$

where N_Z denotes the total number of macro states used in the computation of the model. Conditional on this perception, decision rules for capital accumulation, pricing and the decision to export can be computed, solving the problem in equation (2.7), replacing the unknown law of motion for the domestic price index by equation (2.8). Using the policy rules, I use simulations to compute firms' optimal prices and the domestic price index $\{P^h\}$ in order to estimate (using an ordinary-least-squares regression) the parameters $\{a_{0,Z}, a_{1,Z}\}$ that determine the law of motion for the domestic price index. Using these estimates, the law of motion is updated until both a fixed point is reached and the R^2's of the regression is sufficiently high (above 0.99). The computational algorithm used to compute the solution to the model is described in more detail in appendix A.

[4]Other recent papers that use this approach in international economics are Ruhl (2005) and Utar (2006)

2.2.5 Export Decision

The export decision of firms consists of two parts: the dynamic decision of entry into the foreign market, and the static decision of how much output to sell abroad. As noted by Baldwin and Krugman (1988), under the existence of a sunk entry cost to access the export market, a firm needs to take into consideration that in latter periods it can continue exporting without incurring in this cost again. This will affect the expected present discounted value of profits, $E[v(\cdot)]$, generating hysteresis. So for instance, if after a positive foreign demand shock a firm decides to pay the sunk cost of entry and start exporting, after the foreign demand goes back to its pre-shock level the firm will continue to export. In other words, there are two cutoff levels of capital, $\underline{k} < \overline{k}$, such that (conditional on the value of idiosyncratic productivity and demand shocks) a firm with a capital stock above $\overline{k}$ starts exporting, and an exporting firm whose capital stock falls below $\underline{k}$ exits the foreign market. This can be seen in Figure 2.2 where the expected present discounted value of the firm is plotted as a function of its capital stock and exporting status.

Roberts and Tybout (1997) find evidence of non-zero entry costs into foreign markets for manufacturing plants in Colombia[5]. Letting R^j denote the potential revenue that a firm can accrue if selling in market j, we can write the entry decision into the foreign market as follows:

$$v^x \equiv \max_{k'} \Big\{ u\big(R^h(k, y_{-1}, \phi, \mathbf{Z}, P^h) + R^f(k, y_{-1}, \phi, \mathbf{Z}, P^h) - M - F(1 - y_{-1}) - i\big) + \beta E\big[v(k', 1, \phi', \mathbf{Z}', (P^h)')\big] \Big\}. \quad (2.9)$$

[5]They also find that plants that have not operated in the export market for two years or more face re-entry costs that are not significantly different from the entry costs faced by plants that have not exported before. This explains the structure of sunk costs used in this paper.

$$v^n \equiv \max_{k'} \Big\{ u\big(R^h(k, y_{-1}, \phi, \mathbf{Z}, P^h) - i\big) + \beta E\big[v(k', 0, \phi', \mathbf{Z}', (P^h)')\big] \Big\}. \tag{2.10}$$

where v^x denotes the value of a firm that decides to export, and v^n the value of a firm that only produces for the domestic market. The decision to start exporting can be expressed compactly as

$$v(k, y_{-1}, \phi, \mathbf{Z}, P^h) = \max\{v^x, v^n\}. \tag{2.11}$$

The static problem of how much output to export, for given values of the capital stock, k and demand and productivity shocks $\{z^h, z^f, \phi\}$ is given by,

$$\max_{\theta \in [0,1]} \Big\{ [z^h (P^h)^{\sigma_h - 1}]^{1/\sigma_h} \big[(1-\theta) e^{\phi} k^{\alpha}\big]^{1-1/\sigma_h} + (z^f)^{1/\sigma_f} \big[\theta e^{\phi} k^{\alpha}\big]^{1-1/\sigma_f} \Big\}. \tag{2.12}$$

The key variables that determine the fraction θ of capital used in the production for the foreign market are the relative magnitudes of domestic and foreign demand and the relative elasticities of demand in these two markets. When the size of the foreign market increases relative to the domestic market, θ increases. A higher elasticity of foreign demand also increases θ since the optimal quantity to be sold in the foreign market increases. This is the same reason why θ is an increasing and concave function of k as seen in Figure 2.3. For a given elasticity of domestic demand (and assuming that $\sigma_h < \sigma_f$), a firm has the incentive to allocate a higher fraction of its capital stock to produce output in the more-elastic foreign market.

2.3 Parametrization

Although I do not calibrate the theoretical model, the choice of parameters used in the simulation tries to be consistent with observed patterns of export participation and mean exports/sales ratios observed in manufacturing industries with high export participation in Colombia for the period 1980-1991, shown in Table 2.1. Table 2.2 presents the parameters used in the baseline simulation. The coefficient of relative risk aversion, discount factor, depreciation rate and the curvature parameter of the production function are standard in the macro literature[6]. The demand elasticities are consistent with the fact that markups in the domestic market tend to be higher than in foreign markets. The sunk cost of entry into the export market is about 1.5 times bigger than the fixed per-period cost to participate in foreign markets. These two parameters are chosen to try to match the patterns of export participation shown in Table 2.1.

Demand shocks are parameterized as a highly-persistent VAR(1) process,

$$\log \mathbf{Z_t} = \begin{pmatrix} c_h \\ c_f \end{pmatrix} + \begin{pmatrix} 0.9 & \rho \\ 0 & 0.9 \end{pmatrix} \log \mathbf{Z_{t-1}} + \varepsilon_t. \tag{2.13}$$

with

$$\varepsilon_t \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0.001 & \Sigma_{12} \\ \Sigma_{12} & 0.005 \end{pmatrix} \right],$$

where the parameter ρ determines the correlation between domestic and foreign demand[7]. In the benchmark simulation the correlation between domestic and foreign demand is set to zero. The intercepts c^h and c^f determine the size of the domestic and foreign markets respectively. Furthermore, I assume that foreign

[6]If anything α, the output elasticity of capital is higher than usual. I chose it to avoid imposing too much curvature into the production function which is also affected by the degree of risk aversion

[7]The covariance matrix of Z_t is given by $\Sigma_Z = A\Sigma_Z A' + \Sigma_\varepsilon$ where A is the matrix of coefficients of the VAR(1) and Σ_ε is the covariance matrix of errors. The correlation matrix between z^h and z^f is given by $corr = D^{-1}\Sigma_Z D^{-1}$, where $D^{-1} = \begin{pmatrix} 1/\sqrt{\Sigma_{Z1,1}} & 0 \\ 0 & 1/\sqrt{\Sigma_{Z2,2}} \end{pmatrix}$

demand may have an effect on the level of domestic demand, but not the other way around. The VAR(1) process is approximated by a 4-state Markov chain using Tauchen's (1986) method, therefore, $z^h \in \{\underline{z}^h, \overline{z}^h\}$ and $z^f \in \{\underline{z}^f, \overline{z}^f\}$.

Idiosyncratic productivity is assumed to follow an AR(1) process,

$$\log \phi_t = 0.75 \log \phi_{t-1} + \mu_t, \quad \mu_t \sim N(0, 0.1). \tag{2.14}$$

which is also discretized using Tauchen's method with $N_\phi = 15$ grid points.

2.4 Simulation Results

To show how the model works, Figure 2.4 presents the evolution of capital stock for two representative firms. Firm 1 starts exporting at $t = 358$ and continues to do so in all periods after. Firm 2, on the other hand, never exports. In the model firms accumulate capital when their idiosyncratic productivity increases and also during periods of high aggregate demand. Entry into the export market is also associated with high firm-specific productivity and high foreign demand[8], which in turn result in positive rates of investment as can be seen in Figure 2.5. New exporters sell a significant share of their output abroad to cover the fixed participation costs. Thus, the decision to export is primarily motivated by a large increase in mean profits rather than as a mean to smooth revenues. Firms accumulate capital prior to entering the export market, and once they break in, they maintain a capital stock that is almost twice as large on average than that of non-exporting firms. When firms go through rough patches of low domestic and foreign demand, investment drops to zero and their capital stock falls dramatically, as can be seen around $t =$

[8] In fact, all episodes of entry into the foreign market occur when foreign demand is high.

420 when the exporting firm experiences twelve consecutive years of low domestic demand (as well as low foreign demand for nine of the those twelve periods).

It is important to notice that even after a long period of low foreign demand when the capital stock of the exporting firm falls below than that of its domestic counterpart, the exporter still finds optimal to serve the foreign market. This is the hysteresis effect caused by the sunk cost to enter the foreign market. As soon as high foreign demand conditions return, the investment rate of the exporting firm picks up and the differences between exporting and non-exporting firms accentuate again, since the target capital stock for domestic firms is significantly lower than that for exporters. The larger scale allowed by the export market makes the level of a firm's capital investment more volatile than if it only operates in the domestic market. Since capital investment is directly related to the amount of output produced, sales tend to be more volatile as well. Exporters are 1.6 times larger and their sales are 21 percent more volatile than those of domestic firms. The significant differences in the dispersion of capital stock can be seen in Figure 2.6 that plots the distribution of capital across firms according to their exporting status. The distribution of capital for non-exporting firms is more concentrated that that for exporting firms. Tables 2.3, 2.4 and 2.5 present summary statistics for the benchmark simulation. As mentioned above, exporters are bigger, have higher investment rates and more volatile total revenues than non-exporters.

Figures 2.7 and 2.8 show the behavior of domestic and total revenues around entry into the export market. Upon entry, mean total revenues increase on impact and although they tend to fall afterwards still remain higher than prior to exporting. Domestic revenues fall as firms channel resources into the foreign market in order to recoup the fixed costs of selling abroad. Regarding the impact of exporting on the volatility of revenues, it can be seen that the volatility of total revenues increases immediately after starting exporting and remains above the one observed prior to start exporting. On the other hand, the volatility of domestic revenues presents a large fall in the first two periods after becoming an exporter.

Although comparing the volatility of sales between exporting and domestic firms is informative, I perform a counterfactual analysis in which firms can only sell in the Home market. Since the random draws for idiosyncratic productivity and demand shocks remain fixed, I can compare the performance of the exporters in the benchmark simulation when they are forced to not sell abroad. Table 2.6 presents the results. Exporting has a positive effect on the scale of firms (capital stock and total revenues) but does not reduce their volatility, exporting firms show a 16 percent reduction in the volatility of their sales when they are constrained to sell in the domestic market alone. Only domestic revenues present a very small reduction in volatility when firms are allowed to export.

In order to examine more closely if the decision to export affects the volatility of revenues I perform two more exercises: 1) study the effect of risk aversion on the export decision, and 2) examine how does export participation respond to changes in the correlation between domestic and foreign demand. As can be seen in Figure 2.9, an increase in the firm's risk aversion parameter reduces both the capital stock cutoff to start exporting and the cutoff to exit the foreign market.

Increasing γ in the benchmark simulation from 1 to 2 leads to an increase in export participation from 21.8% to 61.07%. However, in the case of higher risk aversion, there is a second force kicking in: the optimal scale of a firm decreases as the curvature of the utility function increases (the mean capital stock for non-exporting firms falls from 1.132 to 1.025). Therefore, although more firms would prefer to export, a large number of them do not earn sufficient revenues to cover the fixed costs associated with entry and participation in the foreign market.

Finally, I look at the response of export participation to changes in the correlation of demand shocks. When the parameter Σ_{12} in the aggregate demand process covariance matrix is changed, two elements of the model change: the grid points $\{\underline{z}^h, \overline{z}^h, \underline{z}^f, \overline{z}^f\}$ and the transition matrix P_Z. In order to asses the effect of the correlation of demand shocks on export participation (controlling for the size of both markets) I keep the same grid points as in the benchmark simulation and only allow the transition matrix between aggregate states to change. Figure 2.10 depicts the results. There is a non-monotonic relationship between the degree of correlation between domestic and foreign aggregate demand and export participation. When the correlation is highly negative, it can be observed a significant increase in export market participation (when the correlation moves from 0 to -0.6, export participation goes from 14% to 36.3% of firms). However, when the correlation is high and positive, there is also an increase in the number of firms exporting, relative to the case of zero correlation[9]. Consistent with the comparative statics of risk aversion shown in Figure 2.9 we observe lower export participation when the degree of risk aversion is lower (when γ is set to 0.5 instead of 1). More importantly, the export participation decision becomes less sensitive to the level of correlation between aggregate shocks. That is, the number of exporting firms is less responsive to changes in the correlation structure of demand shocks. This implies that even though the main motivation behind becoming an exporter is the significant increase in average profits, risk-averse firms do take advantage of the diversification possibilities offered by the imperfect correlation between domestic and foreign aggregate shocks. Moreover, these advantages become more valuable to a firm when the degree of risk aversion is higher.

[9] This is probably due to the increase in domestic demand's variance caused by the positive correlation. Maloney and Azevedo (1995) also find an ambiguous effect of covariance on the export supply decision.

2.5 Concluding Remarks

I set up a model where firms accumulate capital and also choose when to start selling in a foreign market. In order to highlight the possible benefits of revenue stabilization associated with exporting, the model assumes that there are no capital markets available for firms. Hence, the only mechanism that a firm has to hedge domestic shocks is by selling some fraction of its output abroad. I find that the significant increase in revenues causes firms to enter the export market, even at the expense of higher sales volatility. The higher volatility of exporters' revenues is a result of their higher volatility of investment, which in turn is caused by the extreme liquidity constraints and significant costs to start exporting in the model. Firms that enter the foreign market have an incentive to remain exporting, even when hit by adverse productivity and macro shocks, increasing the volatility of their sales. Thus, I find that accounting for the significant costs to start exporting, a factor ignored by previous research on this topic, play a very significant role in understanding how trade affects firm-level volatility. However, I also find that firms take advantage of the diversification possibilities allowed by the imperfect correlation of aggregate shocks. More firms decide to enter the export market when the correlation between aggregate shocks is negative, and they also respond more to changes in the correlation when risk aversion is higher.

As it was mentioned in the introduction, there are several other linkages between trade openness and firm-level volatility. For instance, variation of capital adjustment costs across industries could interact with macroeconomic volatility in shaping the decision to export at the firm-level as well. Since firms operating in industries characterized by large adjustment costs find it harder to adjust output levels in the short-run, they would find the option of being able to sell some of their output in other markets more valuable. Moreover, these firms would have a stronger incentive to become exporters when the volatility of the domestic market increases. It would also be interesting to explore how the higher degree of capital market openness has affected firm-level volatility in developing countries. These ideas will be explored in future work.

Table 2.1. Export Intensity in Colombian Manufacturing

Sector	**% Exporters**	**Mean Exports/Sales Exporters (%)**
Textiles	22.4	13.0
Clothing & Apparel	13.1	29.4
Leather	58.2	33.9
Paper	18.5	12.4
Industrial Chemicals	43.9	14.3
Metal Products	21.5	10.1

Own calculations. Source: *Encuesta Anual Manufacturera* (Annual Manufacturing Survey), Colombia, 1980-1991, DANE.

Table 2.2. Baseline Simulation Parameters

Parameter	**Description**	**Value**
γ	Relative risk aversion coefficient	1.0
α	Curvature of production function	0.6
N	Number of firms	100
M	Per-period fixed cost of exporting	0.63
F	Sunk cost to start exporting	0.95
β	Discount factor	0.9
δ	Depreciation rate for capital	0.06
σ_h	Demand elasticity for the domestic market	2.0
σ_f	Demand elasticity for the foreign market	8.0
c_h	Intercept domestic demand shock	0.5
c_f	Intercept foreign demand shock	0.0

Table 2.3. Export Intensity (Simulation)

% Exporters	21.8
Mean Exports/Sales, exporters	45.5

Table 2.4. Summary Statistics (Simulation)

Variable	**Mean**	**St. Dev.**	**Min.**	**Max.**
Capital Stock	1.578	0.724	0.852	4.733
Domestic Revenues	1.425	0.466	0.897	2.512
Foreign Revenues	1.086	0.380	0.459	1.975
Total Revenues	1.663	0.620	1.112	3.995
Investment Rate	0.064	0.101	0.000	0.622

Table 2.5. Summary Statistics by Exporting Status

Variable	**Non-exporters** Mean	St. Dev.	**Exporters** Mean	St. Dev
Domestic Revenues	1.458	0.462	1.307	0.461
Foreign Revenues	n/a	n/a	1.086	0.380
Total Revenues	1.458	0.462	2.393	0.560
Capital Stock	1.309	0.367	2.541	0.859
Investment Rate	0.085	0.133	0.131	0.220

Table 2.6. Counterfactual Analysis - Shutting Down the Export Market

Variable	**Simulated** Mean	St. Dev.	**Counterfactual** Mean	St. Dev
Capital Stock	2.541	0.855	1.585	0.385
Domestic Revenues	1.307	0.461	1.523	0.479
Foreign Revenues	1.086	0.380	n/a	n/a
Total Revenues	2.393	0.560	1.523	0.479

Figure 2.1. Sequence of Actions

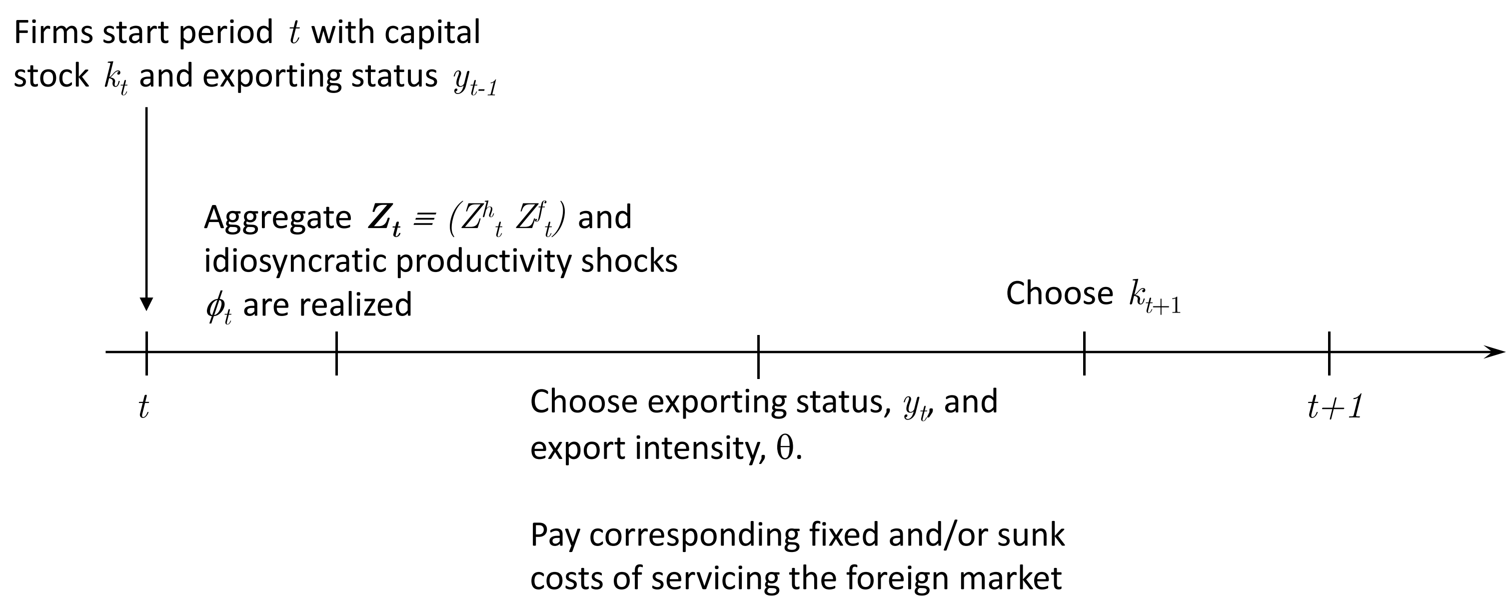
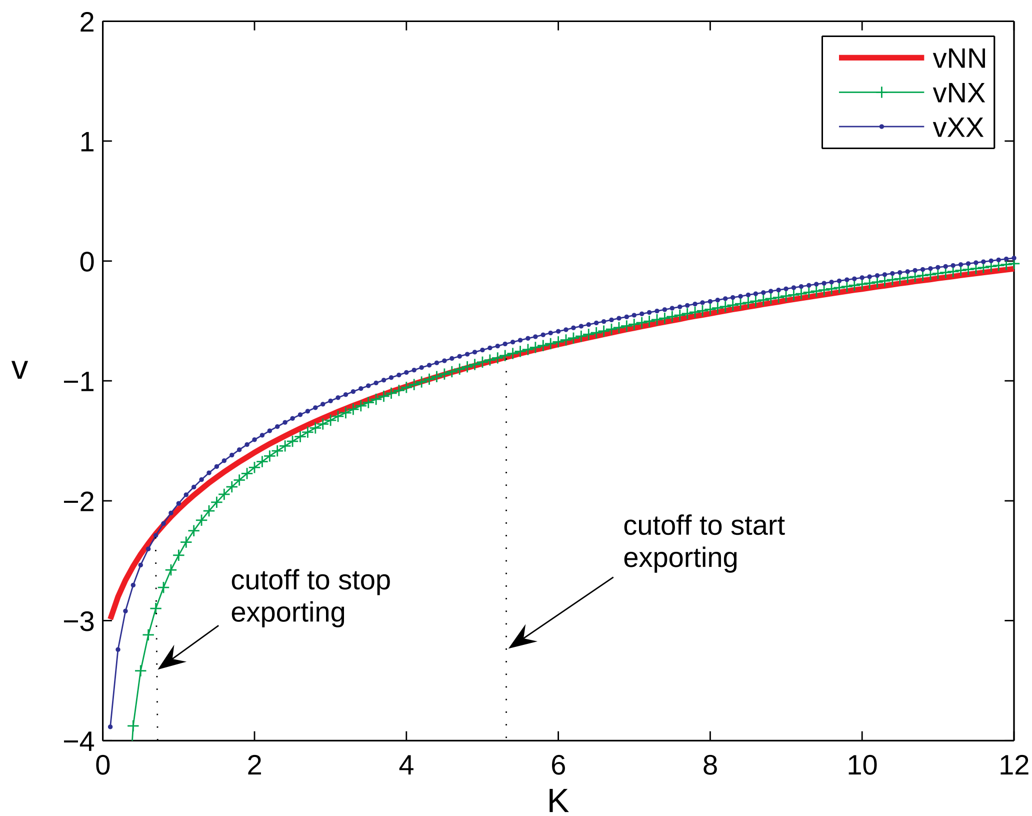


Figure 2.2. The Decision to Export



v_{NN} denotes the expected present discounted value (PDV) of a firm that does not export (either at $t-1$ or t); v_{NX} is the expected PDV for a firm that did not export at $t-1$ but exports at t; v_{XX} is the value for a firm that exports in both periods.

Figure 2.3. Export Intensity Decision

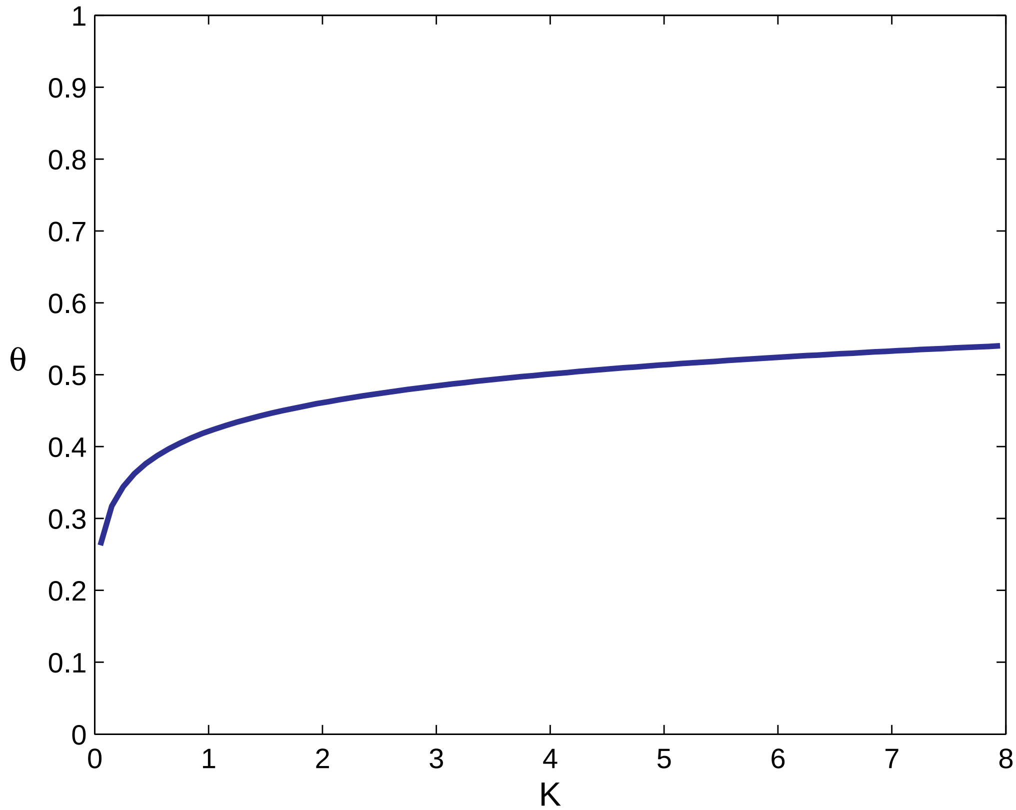


Figure 2.4. Evolution of Capital Stock

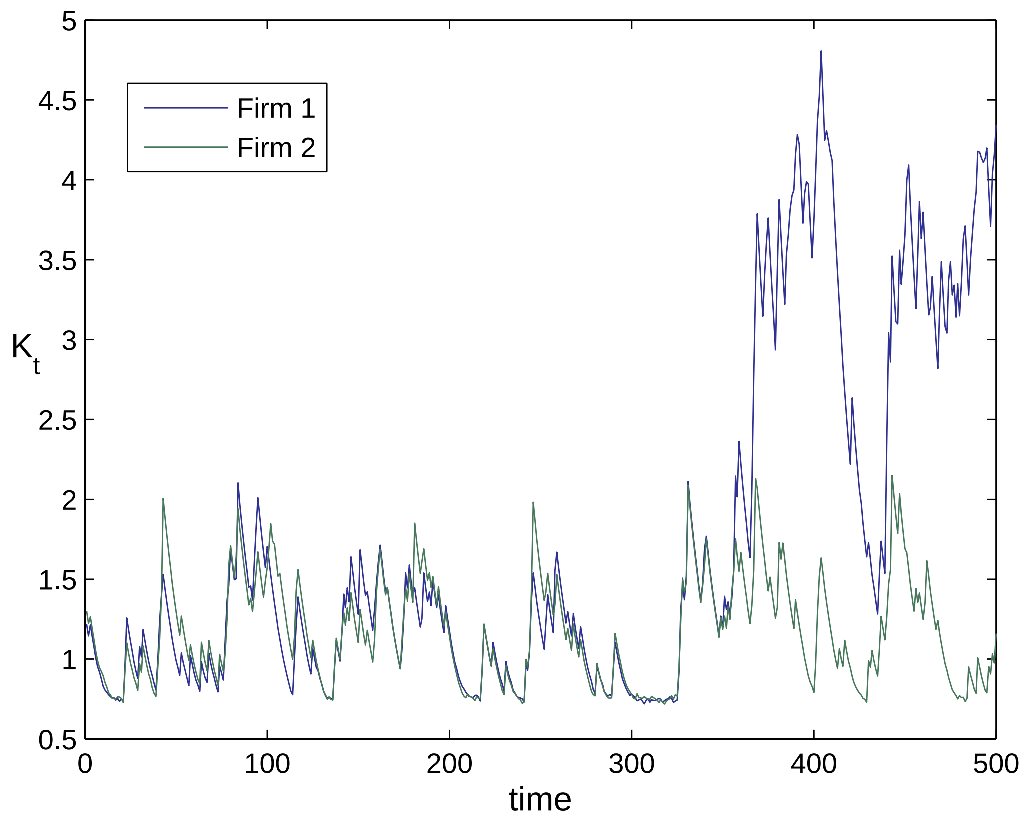


Figure 2.5. Mean Capital Stock around Entry into the Export Market

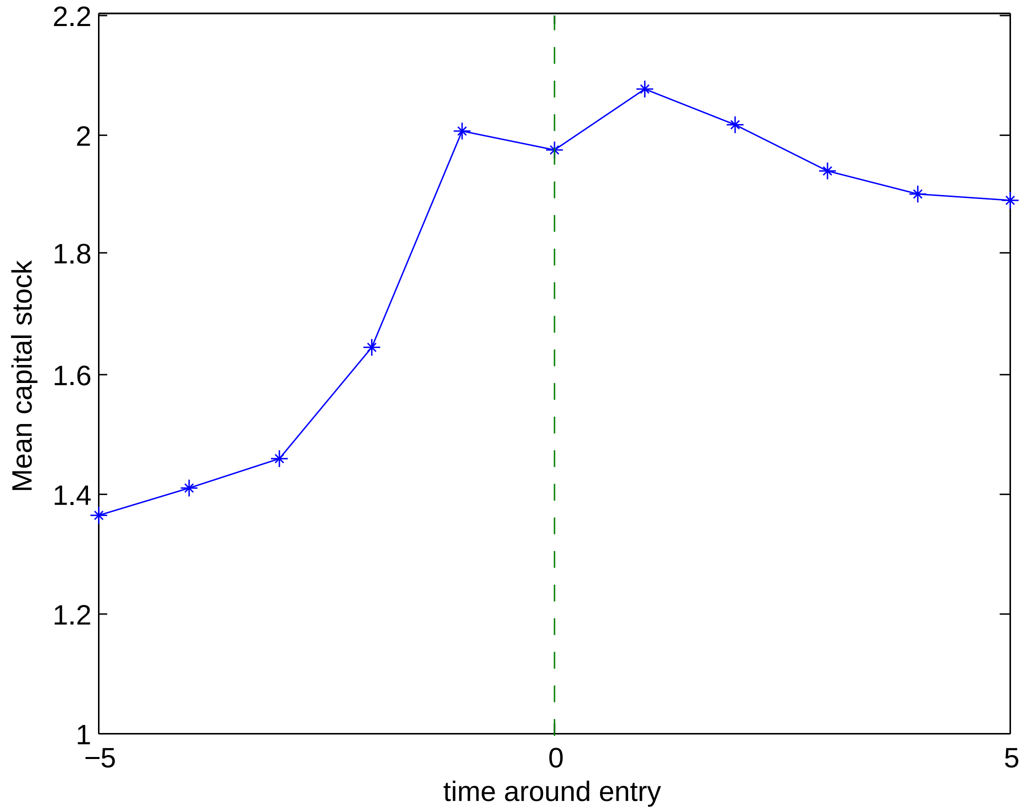


Figure 2.6. Distribution of Capital Stocks by Exporting Status

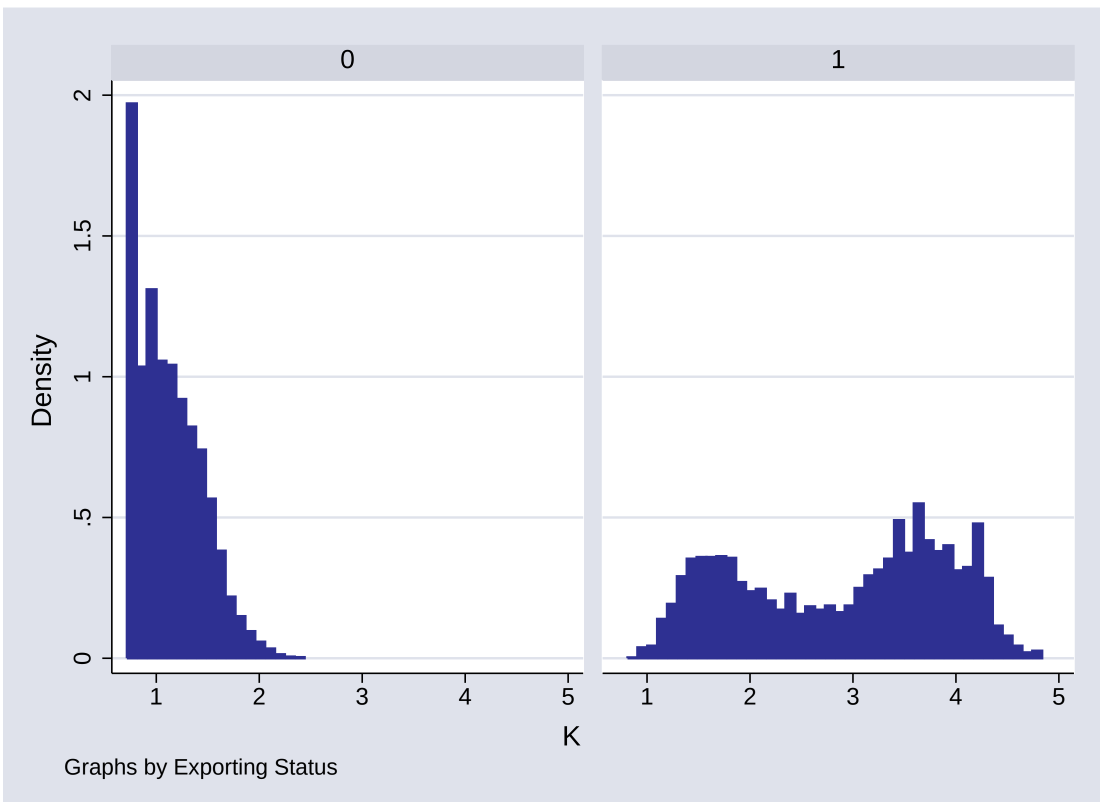


Figure 2.7. Mean Revenues around Entry into the Export Market

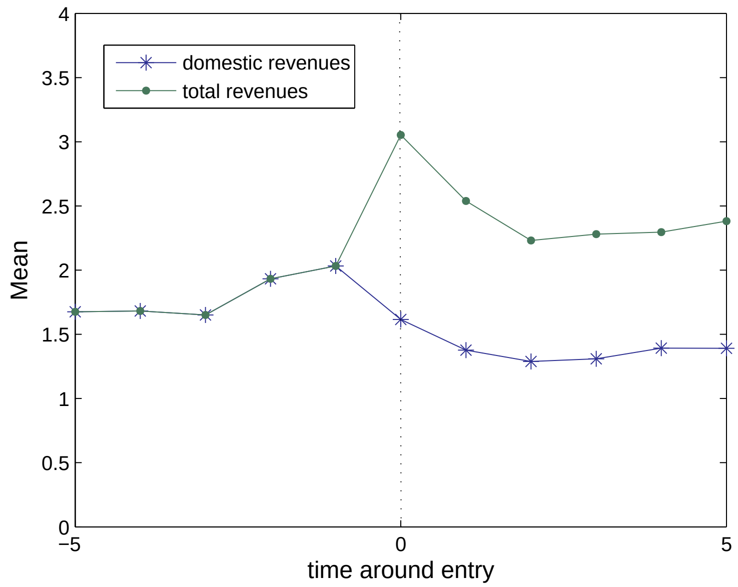


Figure 2.8. Standard Deviation of Revenues around Entry into the Export Market

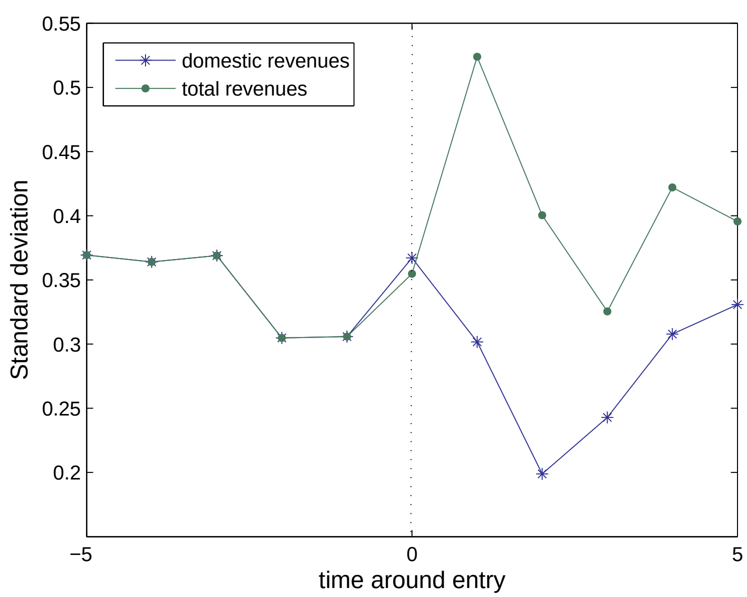


Figure 2.9. Export Decision Policy Rule and Risk Aversion

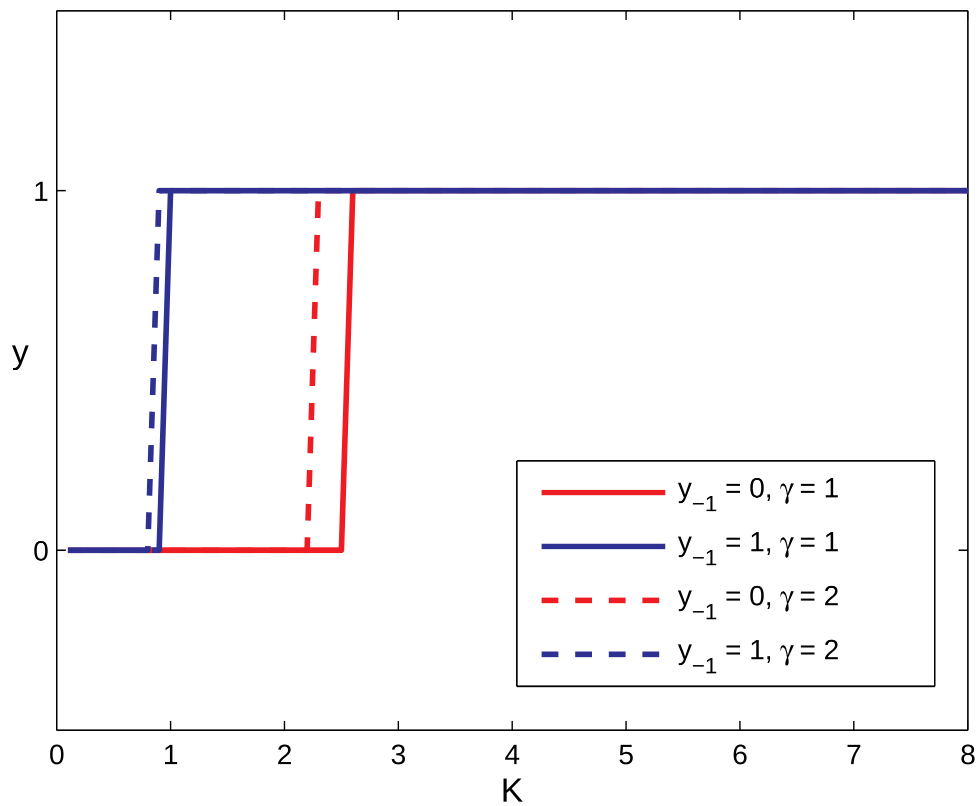
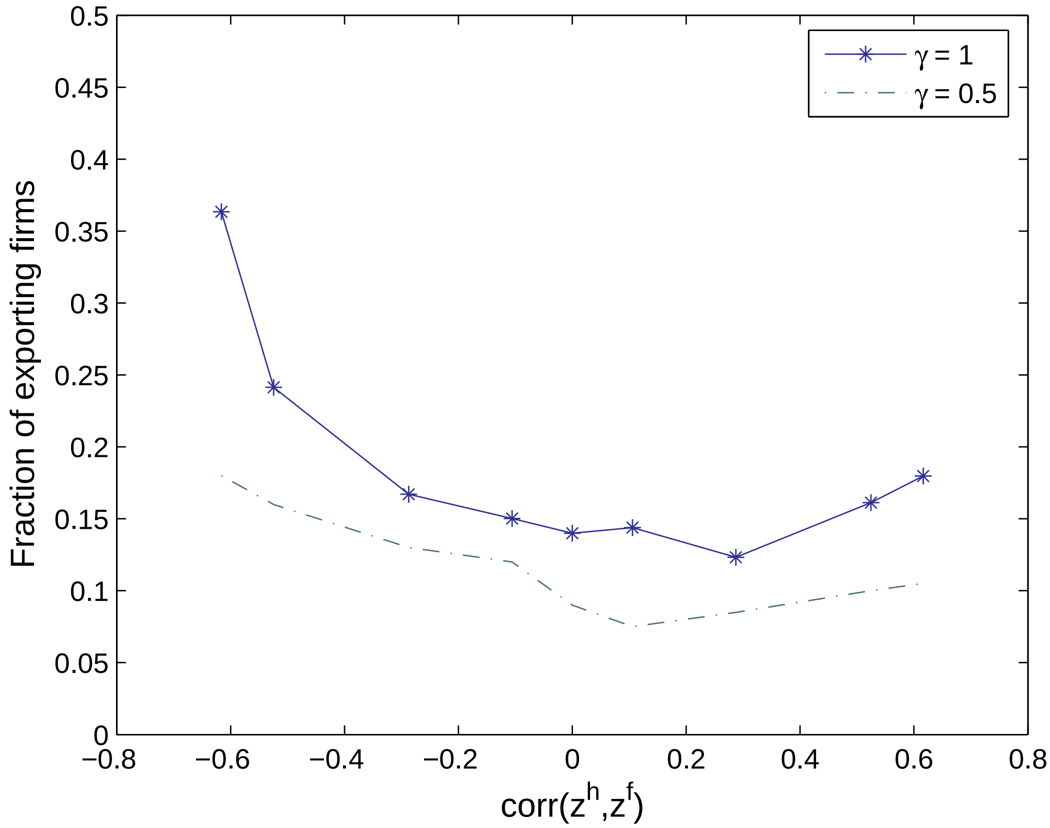


Figure 2.10. Foreign Market Participation and Demand Correlation



Bibliography

[1] Agenor, Pierre-Richard, C. John McDermott and Eswar S. Prasad (2000): "Macroeconomic Fluctuations in Developing Countries: Some Stylized Facts" *World Bank Economic Review* 14: 251-285

[2] Aguiar, Mark and Gita Gopinath (2007): "Emerging Market Business Cycles: The Cycle is the Trend" *Journal of Political Economy* 115: 69-102

[3] Alessandria, George and Horag Choi (2007): "Do Sunk Costs of Exporting Matter for Net Export Dynamics?" *Quarterly Journal of Economics* 122: 289-336

[4] Baldwin, Richard and Paul Krugman (1989): "Persistent Trade Effects of Large Exchange Rate Shocks" *Quarterly Journal of Economics* CIV: 635-654

[5] Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen and Samuel Kortum (2003): "Plants and Productivity in International Trade" *American Economic Review* 93: 1268-1290

[6] Buch, Claudia, Jorg Döepke and Harald Strotmann (2006): "Does Export Openness Increase Firm-Level Volatility?" *mimeo* University of Tubingen

[7] Campa, Jose M. and J. Myles Shaver (2001): "Exporting and Capital Investment: On the Strategic Behavior of Exporters" *mimeo* IESE Business School

[8] Chaney, Thomas (2005): "Liquidity Constrained Exporters" *mimeo* University of Chicago

[9] Cooley, Thomas and Vincenzo Quadrini (2001): "Financial Markets and Firm Dynamics" *American Economic Review* 91: 1286-1310

[10] Das, Sanghamitra, Mark J. Roberts and James R. Tybout (2007): "Market Entry Costs, Producer Heterogeneity and Export Dynamics" *Econometrica* 75: 837-873

[11] di Giovanni, Julian and Andrei A. Levchenko (2005): "Openness, Volatility and the Risk Content of Exports" *mimeo* International Monetary Fund

[12] Donnenfeld, Shabtai and Itzhak Zilcha (1991): "Pricing of Exports and Exchange Rate Uncertainty" *International Economic Review* 32: 1009-1022

[13] Easterly, William, Roumeen Islam and Joseph E. Stiglitz (2001): "Shaken and Stirred: Explaining Growth Volatility" in B. Pleskovic and N. Stern, eds., *Annual World Bank Conference on Development Economics 2001*

[14] Eaton, Jonathan, Marcela Eslava, Maurice Kugler and James R. Tybout (2008): "The Margins of Entry into Export Markets: Evidence from Colombia" in Elhanan Helpman, Dalia Marin, and Thiery Verdier, eds., *The Organization of Firms in a Global Economy*, Cambridge, MA: Harvard University Press.

[15] Eldor, Rafael and Itzhak Zilcha (1987): "Discriminating Monopoly, Forward Markets and International Trade" *International Economic Review* 28: 459-468

[16] Gavin, Michael and Ricardo Hausmann (1996): "Securing Stability and Growth in a Shock-prone Region: The Policy Challenge for Latin America" Working Paper 315, Office of the Chief Economist, Inter-American Development Bank

[17] Ghironi, Fabio and Marc J. Melitz (2005): "International Trade and Macroeconomic Dynamics with Heterogenous Firms" *Quarterly Journal of Economics* CXX: 865-915

[18] Gomes, Joao and Dmitry Livdan (2004): "Optimal Diversification: Reconciling Theory and Evidence" *Journal of Finance* LIX: 507-535

[19] Hirsch, Seev and Baruch Lev (1971): "Sales Stabilization Through Export Diversification" *Review of Economics and Statistics* 53: 270-277

[20] Kose, M. Ayhan, Eswar S. Prasad and Marco E. Terrones (2006): "How do Trade and Financial Integration Affect the Relationship between Growth and Volatility?" *Journal of International Economics* 69: 176-202

[21] Krusell, Per and Anthony A. Smith, Jr. (1998): "Income and Wealth Heterogeneity in the Macroeconomy" *Journal of Political Economy* 106: 867-896

[22] Maloney, William F. and Rodrigo R. Azevedo (1995): "Trade Reform, Uncertainty and Export Promotion: Mexico 1982-1988" *Journal of Development Economics* 48: 67-89

[23] Melitz, Marc (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity" *Econometrica* 71: 1695-1725

[24] Moskowitz, Tobias and Annette Vissing-Jørgensen (2002): "The Returns to Entrepreneurial Investment: A Private Equity Premium Puzzle?" *American Economic Review* 92: 745-778

[25] Roberts, Mark J. and James R. Tybout (1997): "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs" *American Economic Review* 87: 545-564

[26] Ruhl, Kim, J. (2005): "The Elasticity Puzzle in International Economics" *mimeo* University of Texas at Austin

[27] Tauchen, George (1986): "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions" *Economics Letters* 20: 177-181

[28] Utar, Hale (2006): "Import Competition and Employment Dynamics" *mimeo* Pennsylvania State University

Chapter 3

Trade, Technology Adoption and the Rise of the Skill Premium in Mexico

3.1 Introduction

In the last two decades, middle-income developing countries have become more integrated with the world economy by slashing tariffs and scrapping quotas and other non-tariff barriers to trade. At the same time wage inequality has increased dramatically (Goldberg and Pavcnik, 2007, and Hanson and Harrison, 1999a document this relationship focusing mostly on the experience of Latin American countries). This fact is at variance with the prediction of the Stolper-Samuelson theorem which states that the real remuneration of unskilled workers should increase in countries relatively abundant in unskilled labor after opening up trade.

An alternative hypothesis suggested by Acemoglu (2002, 2003) is based on the stylized fact that firms in developing countries import a significant share of their machinery and equipment from skill-abundant developed countries (Eaton and Kortum, 2001). As the relative supply of skilled workers in developed countries (in particular in the US) has risen continuously since the 1970s, machinery and equipment (M&E) goods produced there have become more skill-complementary. When a developing country reduces its barriers to trade, it induces the adoption of skill-biased technology embodied in capital equipment. In this way, trade liberalization in an unskilled-labor abundant country can cause an increase in wage inequality. This paper explores the interplay between trade openness, technology adoption and the skill premium, estimating a structural dynamic model of an open economy with heterogeneous firms that make decisions about exporting, technology adoption and the skill intensity of their workforce. Using micro panel data from Mexico's manufacturing sector I estimate the structural parameters that govern the technology adoption, skill intensity and export decisions for manufacturing firms. I then use my estimated model to quantify the impact of a unilateral trade liberalization on the skill premium. The work in this chapter is the first attempt to structurally estimate the impact that trade-induced technology adoption has on wage inequality.[1]

Using my econometric model I estimate the response of technology adoption and the skill premium to a unilateral trade liberalization of a similar magnitude to the one that took place in Mexico after 1985 (a 38% reduction in the price of the imported good in the model). I find that only a small fraction of plants in the middle of the productivity distribution find it profitable to adopt the more skill-intensive technology (its properties will be defined below). When imports increase, the balanced trade condition implies that the value of exports increases in the same magnitude. This increases the number of high-tech exporting firms in the economy (they increase from 29 to 32 percent of all the firms), while firms in

[1]Krusell et. al. (2000) study the role of falling prices of capital equipment in explaining the increase of wage inequality in the US using a structural estimation framework.

the lower tail of the productivity distribution contract, since they just serve the domestic market and their sales have fallen, and become less skill-intensive or exit. Finally, firms that were using the modern technology before will see their total revenues fall, as the fall in domestic profits is smaller than the rise in exporting profits. Overall, the relative demand for skill increases producing an increase in the skill premium of around 2.4 percent, although the impact of trade liberalization becomes stronger when the cost of technology adoption is also affected by the change in import tariffs.

My model builds on work by Hopenhayn (1992), Melitz (2003) and Yeaple (2005). The model is a dynamic model of industry evolution, where firms produce using skilled and unskilled labor, and are heterogeneous in their relative productivity of skilled labor. Productivity evolves according to an exogenous stochastic process, but unlike Hopenhayn (1992) or Melitz (2003) the mean of this process depends on the technology that a firm chooses to operate. Following Yeaple (2005) firms can choose between two technologies: a "traditional" technology characterized by high marginal costs, but low fixed costs (e.g. a traditional textile loom) and a "modern technology" that has low marginal costs but requires a high fixed cost of operation (e.g. a large-scale automatized sewing machine).[2] Higher productivity draws increase the relative marginal product of skilled labor, so firms substitute towards skilled labor[3], becoming more skill-intensive. Only high-productivity firms (firms with sufficiently large sales) will find optimal to incur the higher per-period fixed cost of operating the modern technology. Hence, modern firms will be larger

[2]My model is similar to Bustos (2005). In her model firms produce using two types of labor, and choose between two technologies characterized by the same trade-off between marginal and fixed cost as in my model. However, her model is static, and assumes that skilled and unskilled workers are perfect complements in production.

[3]This is the case if skilled and unskilled labor are gross substitutes, that is when the elasticity of substitution between the two types of labor is greater than one

and more skill-intensive than firms using the traditional technology[4].

Drawing from the literature on investment in physical capital, I assume that technology adoption is subject to sunk costs, which make firms adjust their technology infrequently. Thus the persistence of technology choice will be reflected in the skill mix that firms employ. Empirically, I identify plants that purchase imported machinery and equipment (M&E) as using the modern technology described above. Alvarez and Robertson (2004) using data from the 1995 National Survey of Employment, Salaries, Technology, and Training (ENESTYC) document that Mexican firms tend to adopt new advanced production technologies through imports rather than through R&D on-site.

Following Melitz (2003) I assume that exporting is costly. Firms selling abroad incur both a per-period fixed cost and an iceberg transport cost per unit of output. Hence, only high-productivity firms export. Trade liberalization will affect firms in different ways depending on the firm's technology and productivity. A reduction on the variable cost of trade will increase profits for existing and new exporters. Among the firms that were using the traditional technology previously, the higher volume of sales provides an incentive to incur the higher fixed cost of operation of

[4]Doms et. al. (1997) observe a set of 17 advanced automation technologies used by manufacturing plants (i.e. numerically controlled machines, robots, programmable controllers, etc.) in a small set of industries (SICs 34-38) in the US. They find a monotonically increasing relationship between the number of technologies used in a plant and the education level of its workforce. They also find that in more technologically advanced plants, non-production workers' share of employment and wage-bill are higher (controlling for size and capital-output ratio). Abowd et. al. (2007) find similar results for a broader sample of firms (including manufacturing, services, wholesale and retail trade) in the US. Fernandez (2001) studies in detail the retooling of a food processing plant in the Midwest. He finds that using a modern automated technology increased the complexity of tasks faced by production workers, and changed the composition of the production workforce in favor of high-skill occupations such as maintenance mechanics and electricians, which in turn commanded the largest increase in real wages, above those observed in the local labor market. For developing countries, Bustos (2005), Hanson and Harrison (1999a) and Pavcnik (2003) also find a positive correlation between the use of advanced technology (i.e. use of patents and licensing agreements, spending on computers and software) and skill intensity at the firm level.

the modern technology. As more productive firms expand, firms on the lower tail of the productivity distribution contract or exit the market altogether, reallocating workers across firms. These firms suffer a double hit as import-competition shifts the demand from domestic to imported goods, and also because the increase in the relative demand for skilled workers pushes up the relative wage of skilled workers increasing costs for all firms.

Mexico is one the best case studies to understand the distributional effects of increased trade openness. Mexico went from being a very closed economy to become one of the most open countries in the world (trade as a fraction of GDP has increased from 20 percent in 1980 to 55 percent in 1995 and it has kept growing, up to 60 percent in 2006). At the same time, the skill premium, defined as the mean wage of skilled workers relative to the mean wage of unskilled workers increased by almost 30 percent between 1985 and 1994, remaining stable afterwards. These two trends are clearly depicted in Figure 3.1. To put it in perspective, it took more than twenty five years for a change of similar magnitude in the skill premium to take place in the United States.

A large body of literature has studied the relationship between wage inequality and trade openness from the perspective of the Hecksher-Ohlin-Samuelson (HOS) model and one of its main corollaries, the Stolper-Samuelson theorem[5]. However, this approach has not been very successful, as these studies find that the correlation between changes in output prices and relative wages at the industry level is extremely low[6]. Moreover, when 'mandated wage' equations (zero-profit conditions

[5]Esquível and Rodríguez-López, 2003, Feliciano, 2001, Hanson and Harrison 1999b and Robertson, 2004 for the case of Mexico.

[6]The Stolper-Samuelson theorem predicts that changes in the relative price of final goods that take place after opening up to trade will shift production toward goods that use the country's abundant factor more intensively. This in turn increases the relative demand for the abundant factor and raising its real reward

derived from HOS) are fitted to the data, their estimates are very imprecise, grossly over-predict wage changes and have very low explanatory power[7]. Other studies that have considered alternative hypotheses for the increase in wage inequality in Mexico include Feenstra and Hanson (1997) that examine the role of foreign direct investment, and Verhoogen (2008) which provides evidence that improved exporting opportunities increase within-industry wage dispersion due to quality-upgrading at the plant level. These two studies are similar to the work presented here in the sense that trade liberalization (or a exchange rate depreciation in the case of Verhoogen's model) produces an outward shift of the relative demand for skilled labor. However, their implications for the patterns of wage inequality in Mexico are limited. Feenstra and Hanson (1997) only analyze the changes in skill-intensity across Mexican states for *Maquiladora* plants which are concentrated in relatively skill-scarce industries in relatively skill-scarce regions and, by law, had to locate in the U.S. border region prior to the North American Free Trade Agreement (NAFTA)[8]. Verhoogen (2008) uses the Tequila crisis as an exogenous shock that provides an incentive to export, to identify the differential effects of relative wages and employment when firms choose to upgrade the quality of their product. Since his is a partial equilibrium model, it is silent about the response of the skill premium to changes in trade policy or the exchange rate. Moreover, the 1990s is a period in which wage inequality in Mexico was remarkably stable, as can be seen in Figure 3.1.

My model is related to a growing literature that studies the complementarities between investment and the decision to export at the firm level. These

[7]Attanasio et. al. (2004) and Hanson and Harrison (1999a, 1999b), argue that the increase in the skill premium can be explained using a HOS framework, since the industries that experienced the largest reductions in protection (and which should have experienced the largest changes in relative prices) were predominantly intensive in unskilled labor

[8]See Bernard et. al. (2005)

papers present evidence for several countries that suggests that exporting and productivity-enhancing investment are complementary actions for a firm.[9] If trade openness does provide a strong incentive for firms to invest and absorb new technologies, then this channel might also be relevant to explain the rise of the skill premium observed in Mexico and other developing countries.

The chapter is organized as follows: section 3.2 presents a brief account of Mexico's trade liberalization process, and a summary of previous research studying the evolution of wage inequality in Mexico. Section 3.3 presents the model and discusses its main implications. Section 3.4 describes the data used for the estimation, looks at the patterns of exporting and defines the proxy for technology adoption used in the estimation. Section 3.5 presents the estimation method, and discusses the resulting structural parameters. Section 3.6 presents the results of a counter-factual trade liberalization. Section 3.7 concludes and suggests avenues for future research. Appendix B provides a brief description of the computational algorithm used to compute the stationary equilibrium of the model in section 3.3, and Appendix C describes the data cleaning procedures.

3.2 Mexico in the 1980s

This section describes the main characteristics of the trade liberalization reform pursued by the Mexican government between 1985 and 1987. It also presents a brief account of the evolution of wage inequality in Mexico.

[9] Aw et. al. (2007) find a positive and significant correlation between shocks that lead a firm to start exporting and shocks inducing investment in R&D/worker training in the Taiwanese electronics industry. Bustos (2005) finds that new exporters outspend existing exporters and domestic firms in technology-related investment in Argentina. Iacovone and Javorcik (2007) document a higher frequency of investment (in physical capital) spikes for Mexican manufacturing firms that will start exporting within the next two years, and Lileeva and Trefler (2007) find that Canadian plants that were induced to become exporters after the CUSFTA agreement increased their labor productivity and adoption of advanced manufacturing technologies.

3.2.1 Mexico's Trade Policy

Mexico, like many Latin American countries, pursued an import-substitution development strategy until the early 1980s. The level and scope of protection of domestic producers against foreign competition were very high even compared to other developing economies. Before the 1985 reform, 92 percent of domestic production was subject to import licenses, the maximum tariff was 100 percent ad-valorem and the production-weighted average tariff was 23.5 percent. At the beginning of the ninety eighties, Mexico's commercial regime was based on three main instruments: i) an ad-valorem tariff scheme, ii) official minimum prices for custom valuation, and iii) quantitative restrictions that included quotas and import licenses. There is a consensus that import licenses contributed the most to restrict trade flows (Kehoe, 1995, Ten Kate, 1992).

Following a spending spree in the late 1970s fueled by high oil prices and unrestricted bank lending, Mexico found itself in a dire situation as world interest rates began to increase, oil prices to tumble and credit to dry up. The balance-of-payments crisis that ensued led to a collapse of the peso, bank runs and a deep recession (Bergoing et. al., 2002, Lustig, 1998). Trade liberalization (*apertura*) marked the beginning of a series of structural reforms carried by President Miguel de la Madrid intended to restore the growth of the Mexican economy. In July 1985, licenses for almost 3,600 tariff items were eliminated. The license coverage ratio fell from 92 to 47 percent between June and December of 1985. Initially, as import licenses were phased out, the government provided some compensation by increasing tariffs, so the average tariff went up from 23.5 to 28 percent during 1985. Furthermore, the government devalued the nominal exchange rate 20 percent, so the effective rate of protection was still relatively high during the early phase of the reform. In 1986 the maximum tariff rate was reduced to 50 percent, and a four-step calendar was announced that would result in a 0-30 percent tariff scale by October 1988. Moreover, in 1986 Mexico joined the General Agreement on Trade and Tariffs (GATT) deepening its commitment to market-oriented economic environment.

The trade liberalization reforms of the ninety eighties were concluded in 1987 with the enactment of the Economic Solidarity Pact (*Pacto*). The government, business organizations and labor unions agreed to speed up trade reform with the hope that stiffer competition from abroad would help to tame inflation. At the end of the year, the tariff structure was simplified from 16 tariff levels to 5, and a maximum tariff of 20 percent ad-valorem. At this point, the fraction of domestic output covered by import licenses was 23 percent, concentrated in a few key industries (such as petroleum refining, transport equipment and some agricultural commodities) and the production-weighted average tariff was 11 percent. The time path of reductions in tariffs and license coverage is illustrated in Figure 3.2. The process of trade liberalization was further deepened when Mexico jointly with the United States and Canada signed the North American Free Trade Agreement (NAFTA) in December of 1992 and coming into effect on January 1st of 1994.

The trade liberalization reforms had a huge impact on the patterns of trade of Mexico. First, the volume of trade has grown by leaps and bounds since 1985 and continues to do so, as is clear in Figure 3.1. Second, the composition of exports changed radically as petroleum's share of total exports fell from 75 percent in 1981 to 35 percent in 1990 as its relative price fell and manufactures increased their importance in total exports. Second, non-oil exports rose threefold from 5.5 to 16 billions of dollars between 1981 and 1990. Imports grew even more, as the real exchange rate depreciation of 1985-1986 was reversed after 1987 (Ten Kate, 1992). Finally, the importance of the United States as a trading partner became more pronounced as Mexico's share of trade with the US rose from 56 percent in 1982 to 70 percent in 1992. This trend has continued after the implementation of NAFTA in 1994. As of 2006, exports to the US (including *maquiladoras*) account for 85 percent of all Mexican exports, while imports from the US constitute 51 percent of total imports (Banco de Mexico, 2007).

3.2.2 The Evolution of Wage Inequality in Mexico

Mexico is one of the least egalitarian countries in the world. Although its Gini coefficient fell consistently since the 1960s until the early eighties (Szekely, 1998), this pattern suddenly reversed after the debt crisis and the ensuing economic reforms. The Gini coefficient of wages increased from 0.43 in 1984 to 0.49 in 1992, a 13.9 percent increase in just eight years (Cortez, 2001). Other measures of dispersion show a similar pattern. Cragg and Eppelbaum (1996) report that the average real wage for individuals with some post-secondary schooling increased by almost 70 percent between 1987 and 1993, while for workers with some primary and some secondary schooling increased by 8 and 15 percent respectively. The ratio of non-production to production wages in manufacturing, another measure of skill premium, increased from 2.25 in 1988 to 2.75 in 1994 and 2.9 in 1996, remaining roughly constant afterwards[10] Thus by all accounts, a large and abrupt increase in wage inequality occurred in Mexico in the latter half on the eighties.

The fact that the large increase in the skill premium coincided with the trade liberalization reforms has resulted in a large body of research that addresses possible linkages between increased trade openness and wage inequality in Mexico. At first glance, there is evidence suggesting trade has increased the skill premium.

[10]This pattern is observed all across the board. Esquível and Rodríguez-López (2003) find that the skill premium increases for 46 out of 49 2-digit industries between 1988 and 1994. I observe the same pattern when comparing 1984 to 1990.

Feliciano (2001) finds that wage dispersion increased more in tradable (manufacturing) than non-tradable sectors (construction, services and government services) and also that changes in wages were more pronounced in industries that suffered the largest reductions in protection. However, trade liberalization was not the only major change taking place in this period. One of the most important components of the *Pacto* was a de-facto freeze of the minimum wage. This combined with an extensive privatization program and a substantial decline in unionization rates (Cortez, 2001) put downward pressure on real wages for workers in the lower end of the wage distribution, increasing wage inequality.

Employment appears to be much more stable than wages during this period. The employment share of manufacturing changed little during the period (on average 31%), and average hours for workers with different levels of education remained fairly constant as well (Feliciano, 2001), thus ruling out important shifts of employment out of the manufacturing sector as a determinant of the evolution of the skill premium. Sánchez-Paramo and Schady (2002) document a 34 percent increase in the relative supply of workers between 1987 and 1999, implying that the relative demand for skilled workers had to increase more than the relative supply to explain the increase in the skill premium[11]. Cragg and Eppelbaum (1996) show that skill upgrading took place in both traded and non-traded sectors between 1987 and 1993 and that the returns to skill-intensive occupations such as professionals and administrators experienced the largest increases over the same period, while the wage premia for less educated occupations such as salespersons and transport workers experienced slower growth.

[11]This argument has been made before by Katz and Murphy, 1992 and Berman et. al., 1998 in support of skill-biased technical change explaining the increased wage inequality in the US during the 1980s.

3.3 Model

In this section I develop a dynamic stochastic general equilibrium (DSGE) model of a small open economy in which firms make decisions regarding the adoption of new production technology and participation in international trade. I will use the model to identify the impact of these decisions on the equilibrium level of the skill premium (defined as the wage of skilled workers relative to unskilled workers) after a trade liberalization reform.

3.3.1 Preferences and Demand

Time is discrete and labeled $t = 0, 1, 2, \ldots$. The economy populated has a mass of L individuals, a fraction λ of which are skilled[12]. Each individual is endowed with one unit of time that is supplied inelastically. Individuals are risk-neutral and maximize the expected present discounted value of a consumption aggregate C_t,

$$E_0 \sum_{t=0}^{\infty} \beta^t C_t, \quad \beta \in (0,1). \tag{3.1}$$

Individual income consists of labor income plus distributed profits of domestic firms. The consumption good is a CES aggregate of a continuum of domestically-produced varieties, $q_d(\omega)$ and a single imported variety, q_f,

$$C = \left(\int_{\omega \in \Omega} q_d(\omega)^\rho d\omega + q_f^\rho \right)^{\frac{1}{\rho}}, \quad \rho \in (0,1), \quad \sigma_c \equiv 1/(1-\rho). \tag{3.2}$$

where Ω denotes the set of domestically-produced goods. It is assumed that the elasticity of substitution among domestic varieties is the same as the elasticity

[12]There are no productivity differences between skilled and unskilled workers. They simply are different factors of production (imperfect substitutes) from the perspective of firms

of substitution between the foreign good and domestic goods. These preferences result in demand functions for variety ω, and for the imported good of the form

$$q_d(\omega) = \left(\frac{Y}{P}\right)\left(\frac{p_d(\omega)}{P}\right)^{-\sigma_c}, \tag{3.3}$$
$$q_f = \left(\frac{Y}{P}\right)\left(\frac{p_f \tau_f}{P}\right)^{-\sigma_c}.$$

where Y is aggregate income, and P is the ideal price index defined as,

$$P = \left[\int_{\omega \in \Omega} p_d(\omega)^{1-\sigma_c} d\omega + (p_f \tau_f)^{1-\sigma_c}\right]^{\frac{1}{(1-\sigma_c)}}. \tag{3.4}$$

I assume that the economy is "small" with respect to the rest of the world in the following sense: consumers can buy the foreign good at a price $p_f \tau_f$, where p_f is the world price of the good (which is set to be the numeraire) and $\tau_f > 1$ is an import tariff. Domestic producers in turn, face a foreign demand schedule $q_x(\omega) = A_x(p_x(\omega))^{-\sigma_c}$ for their variety, where A_x is a parameter. Hence, this economy takes as given the price of imports and the demand schedules for its exports as in Demidova and Rodríguez-Clare (2009).

3.3.2 Production

Firms operate either a traditional or a modern technology. Let $k \in \{1, 2\}$ index the technology used by a firm, with $k = 1$ denoting the traditional technology and $k = 2$ the modern one. A technology k requires a per-period fixed cost of operation f_k denominated in terms of output. I assume that the fixed cost of operating the modern technology is higher than that of the traditional technology, so $f_1 < f_2$. This might reflect higher maintenance costs as the complexity of tasks that workers need to perform increases when using advanced technologies as noted by Fernandez (2001). The only input in production is labor, skilled and unskilled. Firms produce according to the following production function:

$$q = \left[l^{\alpha} + (zh)^{\alpha} \right]^{\frac{1}{\alpha}}, \quad \sigma_p \equiv \frac{1}{1-\alpha} > 0. \tag{3.5}$$

where l and h denote unskilled and skilled labor employed by the firm, σ_p is the elasticity of substitution between skilled and unskilled labor, and z is a firm-specific, skill-biased productivity index. Firm's productivity follows an AR(1) processes with mean $\overline{z}_k/(1-\phi)$ that depends upon a firm's technology choice:

$$\log(z_{t+1}) = \overline{z}_k + \phi \log(z_t) + \varepsilon_{t+1}, \quad \varepsilon_{t+1} \sim \mathcal{N}(0, \sigma_{\varepsilon}^2), \tag{3.6}$$
$$|\phi| \in (0,1), \quad \overline{z}_1 < \overline{z}_2.$$

Technology 2 results in higher productivity realizations on average[13], but requires a higher per-period fixed cost of use relative to technology 1. If a firm wants to start using a different technology, it needs to incur a sunk cost that reflects the costs of retooling and adopting the new productive process[14].

This characterization of technology results in a trade-off for firms between marginal cost (which depends inversely on productivity) and the fixed cost of operating a given technology. The higher productivity realizations that come from using technology 2 will make a firm larger (in terms of employment) and also more skill-intensive, provided that skilled and unskilled labor are gross substitutes[15].

[13]Note that I assume that the persistence and variance of innovations are the same for both technologies.

[14]This representation of the innovation decision is similar in spirit to the one used by Costantini and Melitz (2007) where firms face a one-time opportunity to obtain a high productivity draw which has long-lasting effects on productivity. On the other hand, in Atkenson and Burnstein (2007) firms repeatedly invest in *R&D* controlling the drift of a geometric Brownian motion process that governs productivity.

[15]Doms et. al. (1997), Hanson and Harrison (1999a) and Pavcnik (2003), among others, find

How responsive will skill intensity be to productivity shocks crucially depends on how substitutable skilled and unskilled workers are in production. If the elasticity of substitution between the two types of labor is very high, even small productivity shocks will result in large changes in the relative demand for skilled workers at the firm level. At an aggregate level this will also imply that the skill premium will be highly responsive to aggregate shifts of the relative labor demand for skilled labor.

Firms are monopolistic competitors with market power in the good they sell but are price-takers in the labor market. Hence, the unit cost function for a firm is,

$$mc = \left[w_l^{1-\sigma_p} + \left(\frac{w_h}{z} \right)^{1-\sigma_p} \right]^{\frac{1}{1-\sigma_p}}. \tag{3.7}$$

which is decreasing in firm-specific productivity, z. The firm's decision problem can be partitioned in a static profit maximization, in which a firm chooses optimal price(s) to charge, its labor input and whether or not to export. and a dynamic decision regarding technology adoption. I describe the static problem first. Figure 3.6 describes the sequence of actions that take place in the model.

Static Problem

Incumbent firms can sell their output at home as well as export it, although exporting is costly. A firm that in a given period decides to sell abroad faces two costs: 1) A (per-period) fixed cost f_x of participating in the export market (denominated in terms of output as in Yeaple (2005)) and 2) variable costs that take the form of iceberg transportation costs, so that for one unit of a good to arrive at its final destination, $\tau_x > 1$ units must be shipped. Since production exhibits constant-returns-to-scale, firms independently maximize the profits from domestic

a positive correlation between size and the employment share of non-production workers.

and foreign sales. Therefore, firms set their prices at the usual constant markup over marginal cost,

$$p_d = \left(\frac{\sigma_c}{\sigma_c - 1}\right) mc, \tag{3.8}$$

$$p_x = \tau_x p_d.$$

Every period a firm compares the potential profits from exporting with the participation cost in order to decide whether to export or not. Let $\gamma \in \{0, 1\}$ denote the firm's export decision, with $\gamma = 1$ meaning that the firm is exporting in the current period. The solution to this problem is a cutoff rule for productivity, z_x. Firms with current productivity z_t above the cutoff will export. As soon as their productivity falls below z_x, they stop. Hence, only the most productive firms will export. Given γ, static profits net of exporting costs for Home firms are:

$$\pi_d(k, z) = Y P^{\sigma_c - 1} \left[\left(\frac{\sigma_c}{\sigma_c - 1}\right) mc(k, z) \right]^{1-\sigma_c}, \tag{3.9}$$

$$\pi_x(k, z) = A_x \left[\left(\frac{\sigma_c}{\sigma_c - 1}\right) \tau_x mc(k, z) \right]^{1-\sigma_c},$$

$$\pi(k, z) = \pi_d(k, z) + \max\bigl\{\pi_x(k, z) - f_x mc(k, z), 0\bigr\}.$$

Finally, the firm's input demand is obtained by solving the following program, taking the vector of wages (w_l, w_h) as given:

$$\min_{l,h} w_l l(k, z) + w_h h(k, z) \tag{3.10}$$

s.t.:

$$\left[l^\alpha + (zh)^\alpha\right]^{\frac{1}{\alpha}} = q_d(k, z) + \gamma(k, z) q_x(k, z).$$

Dynamic Problem

A firm starts period t with a given technology k_t, and a productivity level z_{t-1}, these are its state variables. At the beginning of the period the firm draws z_t and decides whether to continue producing or not (we normalize the scrap value to zero). Let $\chi(k,z) \in \{0,1\}$ denote the exit policy rule, where $\chi(k,z) = 1$ denotes exit. An incumbent firm that stays in the market produces, decides whether to export or not, and finally chooses the technology that it will use in period $t+1$. The dynamic programming problem of the firm is given by:

$$V(k,z) = \max\{0, V^C(k,z)\}. \tag{3.11}$$

$$\begin{aligned} V^C(k,z) = \max\Big\{ & \pi(k,z) - f_k mc(k,z) + \beta \int_{z'} Q_k(z,z')V(k,z')dz' \quad , \\ & \pi(k,z) - [f_k + S_{\tilde{k}}]mc(k,z) + \beta \int_{z'} Q_{\tilde{k}}(z,z')V(\tilde{k},z')dz' \Big\}. \end{aligned} \tag{3.12}$$

where $S_{\tilde{k}}$ is the sunk cost that a firm has to pay when switching from technology k to $\tilde{k}$[16] and $Q_k(z,z')$ is the transition density for productivity when using technology k. As I mentioned before, it is assumed that technology 2 requires a higher per-period fixed cost of operation than technology 1, that is $f_1 < f_2$. The solution to this problem produces two policy rules: for technology, $\mathcal{K}(k,z) \in \{1,2\}$, characterized by two productivity cutoffs, $z_{\text{out}} < z_{\text{in}}$ and exit, $\chi(k,z) \in \{0,1\}$, which is also characterized by a productivity cutoff $z_{\text{exit}}(k)$, below which firms decide to exit the market. A firm currently using technology 1 will start using technology 2 if its current productivity draw exceeds z_{in}. However, a firm that already operates

[16] In the estimation I assume that firms do not need to pay any adoption cost when switching from technology 2 to 1, that is, $S_1 = 0$

technology 2 will continue to use it even if its productivity falls below z_{in}, since it takes into account the option value of receiving higher productivity draws in the future without having to pay the adoption cost S_2.

Every period there is a continuum of ex-ante identical potential entrants. The only barrier to entry is a sunk entry cost S_E (denominated in terms of output). When potential entrants pay the sunk entry cost, they draw their initial value of z from a common distribution $G_E(z)$, which is assumed to be log-normal with mean $\mu_E + \sigma_\varepsilon^2/[2(1-\phi^2)]$ and variance $\sigma_\varepsilon^2/(1-\phi^2)$. The value of entry, net of entry costs is:

$$V^E = \int_z V(1,z)dG_E(z) - mc(1,z)S_E. \tag{3.13}$$

I assume that all entrants start using technology 1, so they will be on average smaller than incumbent firms as empirical evidence suggests.

3.3.3 Stationary Equilibrium Definition

A recursive competitive equilibrium for the model consists of a value function for firms $V^C(k,z)$, list of decision rules for pricing $\{p_d(k,z), p_x(k,z)\}$, exporting $\gamma(k,z)$, labor demand $\{l(k,z), h(k,z)\}$, exit $\chi(k,z)$ and technology adoption $\mathcal{K}(k,z)$; a post entry/exit distribution of firms across technologies and productivity $\mu(k,z)$ and a set of aggregate variables: aggregate income Y, ideal price index P, mass of incumbents M and entrants M_E and a vector of wages $\{w_l, w_h\}$ such that:

1. $V^C(k,z)$ solves the dynamic problem of the firm. Decision rules are optimal.
2. Labor demand equals labor supply for both types of workers
3. The flow of entrants balances the flow of exiting firms
4. Equilibrium good prices are consistent with the aggregate price index P

5. Aggregate income Y equals aggregate profits plus total labor income
6. Free entry
7. Balanced trade

Discussion

Several combinations of technology use and exporting status are possible depending on the relative position of these cutoffs in the productivity distribution (for instance, if the productivity cutoff for exporting is too high, it might be the case that all firms that become exporters have first to adopt technology 2). As firms with high productivity levels tend to export and use the modern technology, simulations of the model show that intermediate states such as exporting using technology 1 or not exporting using technology 2, are not very persistent - firms quickly become high-tech exporters or low-tech domestic producers.

When the variable cost of trade that domestic firms face when selling abroad falls, sales for exporting firms (both existing and new) increase providing an incentive to adopt technology 2 as the higher fixed cost of operation can be spread over a higher volume of sales. In a stationary equilibrium with lower trade costs, the share of firms using the modern technology increases. Firms using technology 2 become larger and more skill-intensive at the expense of firms that use technology 1 which will contract or exit the market altogether.

If the economy pursues a unilateral trade liberalization, which would reduce the price that consumers pay for the imported good, the demand for the imported good rises at the expense of the demand for domestic goods, reducing domestic profits for all firms. Qualitatively, the response of firms will be similar as when exporting prospects improve: smaller, unskilled worker-intensive firms will contract and exit, while the most productive firms expand, as these firms reshuffle their sales from the domestic to the foreign market, thus maintaining balanced trade. From an empirical perspective its important to notice the differences between the two scenarios. In a large number of cases when developing countries pursue trade liberalization reforms they do so in a unilateral fashion. At the same time their exporters do not experience significant changes in the level of tariffs they face (since most of their exports are directed towards developed countries where tariffs are very low). This is certainly the case for Mexico[17], and for several Latin American countries as well. Quantitatively I find that since the response of exports is smaller after a unilateral liberalization, fewer firms adopt technology 2 and the skill premium rises by a smaller amount than in the first case.

3.4 Data

The data used in the paper comes from the *Encuesta Industrial Anual* (Annual Manufacturing Survey) produced by the *Instituto Nacional de Estadísticas, Geografía, e Información* (INEGI), the Mexican government statistical agency. After cleaning the data (the exact procedure is described in Appendix C), I have a balanced panel of 1,913 plants for the period 1984-1990. For each plant we have information on the total number of *obreros* (blue-collar workers whose main activities include machine operation, production supervision, repair, maintenance and cleaning) and *empleados* (white-collar workers such as managers, administrators, professionals and salesmen), total number of hours worked for each type of worker, total remuneration, production, input use, investment in capital goods, including

[17] The NBER trade database shows that, from 1970 to 1992, Mexico's annual average trade share with countries that were clearly relatively skill abundant was greater than 90 percent throughout the period, including the United States and Canada (69 percent), Europe (16 percent), and Japan, Australia, and New Zealand (5 percent).

machinery and equipment imports, and exporting status (from 1986 onwards).

Exporting and Use of Imported Technology

Table 3.1 shows how export participation and the use of imported machinery and equipment (M&E) and materials experienced a dramatic increase over the second half of the 1980s. The patterns of openness for the manufacturing sector mirror the behavior of the aggregates for the whole economy shown in Figure 3.1. In 1986, 66 percent of the plants served only the domestic market and did not import any machinery and equipment, by the 1990, this group comprised 42 percent of the sample. At the same time, the number of plants that both export and use imported machinery doubled. The number of plants that export but do not import M&E increased by just 8 percent. Although the barriers faced by Mexican exporters were relatively low and did not change much during this period, one of the components of the macroeconomic stabilization program of 1985 was a 46 percent depreciation of the nominal exchange rate, which in turn resulted in depreciation of the real exchange rate of over one hundred percent, see Figure 3.3, providing a tremendous boost for exports[18]. At the same time, by the end of 1987 the price of machinery and equipment relative to consumer prices experienced a 30 percent fall which persisted until the Tequila crisis of 1994. This trend, which is presented in Figure 3.4, is very similar to what has been documented in the United States by Krusell et. al. (2000), but was also reinforced by a 55 percent tariff reduction.

As has been noted by the literature studying plant-level investment patterns (e.g Cooper and Haltiwanger, 2006), there is a great deal of inaction and spikes in investment rates: for 52 percent of the observations, the gross investment rate

[18] In fact, this real exchange rate depreciation, coupled with the very low price of oil prevailing in 1986 caused a sizeable reallocation towards manufacturing exports away from oil products.

falls below 1 percent of the book value of capital stock, while at the same time, for 6 percent of plant-year observations an investment rate above 25 percent of the value of capital stock is observed. More importantly, 78 percent of these investment spikes involve the purchase of imported M&E. Hence, I identify a plant that *starts* importing machinery and equipment as adopting technology $k = 2$ in the model[19]. Similar definitions of technology adoption have also been used by Huggett and Ospina (2001) and Kasahara (2001).

Relative Employment and Wages

Table 3.2 shows the evolution of mean employment and hourly wages over the sample period. Between 1984 and 1990, the hourly remuneration for skilled workers increased by 20 percent, with most of the increase happening after 1988. Wages for unskilled workers fell by 7 percent in the same period. The two trends put together result in an increase in the skill premium (the relative wage of skilled workers) of 31 percent in just six years, or a rate of growth of 4.6 percent per year, a dramatic rise in the skill premium. Importantly, the rise of the skill premium was not concentrated in a handful of industries, it took place across the board. The skill premium (measured as the ratio of the mean non-production worker wage relative to the mean production-worker wage) increased for 115 out 127 4-digit industries between 1984 and 1990, as show in Figure 3.7.

The pattern of employment is surprisingly stable during the period of study. In the sample, total employment increases by 17 percent, and white and blue-collar employment increase both by 13 percent. Mean employment share of non-

[19]Ideally knowing how important is imported M&E in the capital stock would allow me to better identify the plants that are using more advanced technologies, however this information is unavailable. Other indicators of use of advanced technology such as the use of advanced manufacturing technology and automatized processes are included in the ENESTYC survey which is available after 1992

production workers (a measure of skill intensity) remains stable at around 30 percent during the sample period. However, the wage-bill share of non-production workers increased by 15 percent.

Across the size distribution of plants, both exporters and plants importing M&E are about 18 percent more skill-intensive than domestic plants that do not use imported capital, this premium remains stable throughout the sample period for exporters while declining slightly for plants importing machinery. Moreover, similarly to the findings of Bustos (2005) and as predicted by the model in Section 2.2, new exporters show skill-upgrading before entering the export market[20], while the plants that stop exporting shift their employment towards non-skilled workers, as can be seen in Figure 3.5.

3.5 Estimation

The model presented in section 3.3 is estimated on a balanced panel of 1,913 Mexican manufacturing plants for the period 1984-1990, from the manufacturing survey described in section 3.4. I consider the period 1987-1990 as characterized by the post-liberalization stationary equilibrium of the model. The model is set to fit the size distribution of plants in the steady state with low import tariffs, since in the model productivity differences are directly reflected in size (employment) differences. Other features that the model intends to match are the frequency and intensity[21] of exporting, use of imported technology, differences in skill intensity between exporting and non-exporting plants and the entry rates into exporting and use of imported technology[22].

[20]Controlling for time and industry-specific variation and differences in the capital stock.

[21]Measured as the mean fraction of revenues accrued from exporting

[22]One problem that I face in the estimation is the fact that I do not observe entry and exit of plants in my sample. To circumvent this problem I used a dataset constructed by the Inter-

The structural parameters of the model are estimated using a method of simulated moments (MSM) estimator. Given a vector of parameters $\boldsymbol{\theta}$, the stationary equilibrium of the model is solved and policy rules for employment, exporting, exiting and technology adoption $\{l^*, h^*, \gamma^*, \chi^*, \mathcal{K}^*\}$ are obtained. Using these policy rules, I simulate the behavior of a large number of plants, creating S simulated panel datasets $\{D^s_{it}(\boldsymbol{\theta})\}$[23]. Taking averages over these simulations, I construct a vector of simulated moments,

$$\hat{\mathbf{m}}(\boldsymbol{\theta}) = \frac{1}{S}\sum_{s=1}^{S}\mathbf{m}(D^s_{it}(\boldsymbol{\theta})). \tag{3.14}$$

The estimated vector of parameters minimizes the log-differences between a set of simulated and sample moments:

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}\in\Theta} \Psi = (\log(\hat{\mathbf{m}}(\boldsymbol{\theta}))-\log(\mathbf{m}))'[(1+1/S)\hat{\Sigma}]^{-1}(\log(\hat{\mathbf{m}}(\boldsymbol{\theta}))-\log(\mathbf{m})). \tag{3.15}$$

where $\mathbf{m}$ is the vector of moments calculated directly from the data, and $\hat{\Sigma}$ is the estimated optimal weighting matrix[24]. The objective function results from a complicated dynamic programming problem, hence is not smooth and presents multiple local minima. In order to deal with these issues, I use a stochastic pattern search algorithm to solve the problem in equation 3.15.

There is a set of parameters that are determined out of the estimation routine. The discount factor β is set equal to 0.939 to match the average real interest rate[25] for the period 1982-2006, of 6.46 percent. The fraction of skilled workers

American Development Bank from administrative records collected by the *Instituto Mexicano del Seguro Social* (IMSS) for the period 1994-2000. From this dataset, I obtain the relative sizes of entering and exiting plants as well as the mean entry rate used in the estimation.

[23]The estimation procedure uses $S = 50$.

[24]The details on how the optimal weighting matrix is estimated can be found on Appendix B.

[25]Based on *Certificados de la Tesoreria de la Federacion a 28 días*, CETES bonds.

in the economy is set equal to the mean share of non-production employment, 0.311. Given the CES demand system used, the ratio of domestic revenues to total variable cost is constant across firms, and equal to the markup charged by firms. The mean of this ratio for the post-liberalization period is 1.379, which implies a demand elasticity $\sigma_c = 3.634$. The price of the imported good faced by consumers τ_f is set to 1.05. The variable cost of exporting for Mexican firms is set to match the average U.S. tariff on dutiable goods imported from Mexico, 5 percent. Table 3.3 summarizes the parameter values fixed outside the estimation. Finally, the size of the economy L is normalized to 1,000.

This leaves the following 12 parameters to be estimated by MSM:

$$\theta \equiv \{\overline{z}_1, \overline{z}_2, \phi, \sigma_\varepsilon^2, f_1, f_2, S_2, A_x, f_x, \mu_E, S_E, \sigma_p\}. \tag{3.16}$$

Where $(\overline{z}_1, \overline{z}_2, \phi, \sigma_z^2)$ determine the stochastic process for firm-specific productivity, (f_1, f_2, S_2) are the fixed cost of operating and adopting each technology, A_x is the size of the foreign market, f_x is the fixed cost of participating in the export market in each period, and σ_p is the elasticity of substitution between skilled and unskilled labor.

Table 3.4 reports the moments used in the estimation. The first set of moments is based on the size distribution of plants in the post-liberalization steady state. In the model, all productivity differences will be reflected in size (employment) differences. Fixed costs f_k and and the intercepts of the productivity processes, $\overline{z}_k$ will affect the average size of incumbent firms, since higher fixed costs and higher productivity realizations will result in larger firms in equilibrium. The difference between $\overline{z}_1$ and $\overline{z}_2$ and f_1 and f_2 will be determined by the premium in skill-intensity and size between exporting and non-exporting plants (due to selection effects the largest firms become exporters), as well as by the share of firms importing M&E in steady state.

The parameters governing the decision to export (A_x, f_x) are pinned down by the frequency and intensity of exporting: a larger foreign market induces more firms to export, and also leads exporters to sell a larger share of their output abroad. A higher f_x on the other hand reduces the number of firms engaged in exporting activities, but increases the share of exports in total revenues as the fewer firms that find profitable to export will seek to spread the large fixed cost over a larger volume of sales.

The elasticity of substitution between skilled (non-production) and unskilled (production) workers determines the responsiveness of skill-intensity to productivity innovations (given that labor supply is fixed in the model). If σ_p is large, firms that draw good productivity shocks become very large and highly skill-intensive, while firms that suffer bad draws will shrink and employ a large share of unskilled workers. Matching the share of plants in different size bins, and the employment dispersion will help me to identify σ_p. The relative size of entrants and the mean entry rate (which will be identical to the exit rate in the stationary equilibrium) determine μ_E and S_E.

A set of dynamic moments allows me to identify the root of the auto-regressive process governing productivity which in turn will affect the persistence of skill-intensity, which is very high in the data. If productivity is highly persistent, in my model this would result in a highly persistent skill-intensity across firms (for a given elasticity of substitution), with large changes taking place only when firms switch technology. The dispersion of the size distribution helps me to identify the variance of productivity shocks. Finally, the sunk cost of adopting technology 2 will be identified by the share of firms importing technology in the cross-section and the mean rate at which plants start importing M&E.

Point Estimates

Table 3.5 report the point estimates produced by the model. All the parameters with the exception of the elasticity of substitution are statistically significant. The elasticity of substitution between skilled and unskilled workers is estimated to be 1.41, although is not very precisely estimated as the other parameters in the model, it falls in middle of the range of estimates obtained for the US (between 1 and 2.2) estimated from macroeconomic data, and is very close to the preferred estimate found by Katz and Murphy (1992), 1.42.

The difference on average productivity for the two technologies is statistically significant. Plants that become sufficiently productive to start operating the modern technology become significantly bigger and more skill-intensive. On average, plants using technology 2 are 82 times larger than their counterparts using the high-marginal cost technology, and account for most of the dispersion of the size distribution.

The fixed cost of operation accounts on average for 33 percent of total labor cost. Although there are no other studies that estimate these fixed costs to compare the plausibility of the estimates, Costantini and Melitz (2007) calibrate the fixed cost of operation in their model so that plants devote 20 percent of their labor cost to overhead, assuming that all non-production workers are devoted to overhead, based on results from Bustos (2005). Exporters pay on average 5 percent of their foreign revenues as a per-period cost to serve the world market. However, since the fixed cost of exporting is denominated in units of output, the smaller new exporters pay on average 11 percent of their exporting revenues.

Given the estimated size of the foreign market and the fixed cost of exporting and using technology 2, a firm that breaks into world markets adopts the modern technology immediately. Iacovone and Javorcik (2007) present evidence of frequent investment spikes and skill upgrading for plants that will start exporting in the next two years in the Mexican manufacturing sector. The implication in terms of the labor force composition is that for the plants that start importing M&E, their skill-intensity almost doubles on impact.

Firms that decide to start using technology 2 in the next period incur an adoption cost equivalent to twice their current revenues at the time of switching. Since plants that start using the modern technology always start exporting at the same time, they become 6 times bigger in terms of employment with total revenue 60 times larger on impact.[26]

Table 3.6 shows how the model fits the data. The overall difference between the empirical and simulated moments is about 0.09 log-points, and in fact, this difference for several moments is smaller than 5 percent. The model does a good job matching several features of the size distribution of Mexican manufacturing plants. In particular, the overall mean of the size distribution, the share of exporters and their export and skill-intensity close fit the data. The simulated size distribution is also very close to the data, although the model slightly overestimates the share of large plants.

The main shortcoming of the model is its inability to match the dispersion of the size distribution and the size premium of exporters. As pointed out by Armenter and Koren (2009) models with fixed costs to export have a very hard time matching both the share of exporting plants and the relative size of exporters. Since only one

[26]By the construction of the model, all exporting firms sell the same share of output in foreign markets, about 21 percent in the benchmark estimation. Therefore, all new exporters experience a great boost to their total revenues upon entry.

third of the plants in the sample export, the sizeable fixed cost needed to match this moment results in exporters that are too large. In the data, exporters are about twice as big as non-exporters, while in the simulated model they are 82 times larger. Figure 3.8 depicts the enormous export size premium of exporters that the model generates. This mismatch is also manifested in the skill intensity premium for exporters, since in the model there is a monotonic relationship between size and skill intensity. Although the skill intensity for exporters is closely fitted, non-exporting plants are 58 percent less skill-intensive than in the data. In a similar fashion, the combination of high fixed costs of using the modern technology and fixed costs to participate in the export market that are necessary to match the share of these type of plants in the data, result in an extremely high dispersion of size in the simulated model, almost six times larger than in the data. The fact that the only source of uncertainty in the model is idiosyncratic productivity, which at the same time is highly persistent, contributes to this discrepancy.

Looking at the dynamic moments, the high persistence of the stochastic process for productivity allows me to match the high persistence of exporting status and skill-intensity across firms quite closely. The lower predicted persistence and higher entry rate into exporting reflect the fact there are no sunk costs to enter foreign markets. There is no option value of staying a exporter when productivity falls below the level that induced the firm to start exporting.

The high fixed costs of using the modern technology and exporting together with the highly persistent productivity process produce a size distribution with a relatively high mean size (311 workers) and a high share of small plants (about 71 percent of plants have 30 workers or less). Almost all large plants are high-tech exporters and the majority of plants are non-exporters and new entrants (which by assumption enter the market using technology 1) which face a high probability of exiting the market soon[27].

3.6 Trade Liberalization

Using the estimates from the previous section, I perform a counterfactual analysis and ask what would happen to technology adoption and the skill premium in a high import tariff stationary equilibrium. Comparing this situation with the post-liberalization benchmark allows me to gauge at the contribution to the rise of skill premium of trade-induced skill-biased technology adoption.

In order to capture the experience of Mexico in the second half of the 1980s, I consider a pre-liberalization scenario in which import tariffs are 38% higher than in the post-liberalization benchmark, so τ_f increases from 1.05 to 1.55, while the iceberg transportation cost faced by Mexican exporters remains the same. The results of this experiment are presented in Table 3.7. This increase in τ_f is bigger than the change in the production-weighted average tariff for manufacturing imports that took place after liberalization, but intends to take into consideration the broad licensing requirements that were in place at the time, which are considered the most binding barrier to trade.

A unilateral trade liberalization has a direct effect on the aggregate price index, which falls 21 percent. This has a negative effect on domestic profits and aggregate income which falls by 16 percent, resulting in an decrease in the average plant size of about one percent. After a unilateral trade liberalization, the equilibrium mass of firms in the market falls by approximately 2 percent. Exit takes place at the lower end of the productivity distribution and workers employed on these firms

[27]In fact, contrary to the findings of the empirical literature on industry evolution, the model generates exiting plants that are slightly bigger than new entrants. The size difference between the two is not statistically significant.

reallocate to larger and more skill-intensive firms, a pro-competitive effect.

Notwithstanding the reduction in domestic profits, The balanced trade condition implies that as the value of imports increases, so does the value of exports. The productivity cutoff to start exporting falls, thus increasing the share of exporting plants by 12 percent when import competition is more intense. With the entry of these relatively smaller firms, exporters as a group become on average smaller and less skill-intensive, by 12 and 3 percent, respectively. New exporters also start importing M&E, although the increase is smaller than in the number of firms exporting, since a small fraction of firms in the high-tariff equilibrium import M&E but only serve the domestic market. All of these become high-tech exporters after trade liberalization.

The main difference in the size distribution of firms when import tariffs falls occurs in the middle, as the new users of modern technology shift towards the right of the size distribution. This is a similar result to the findings of Lileeva and Trefler (2007), who show that only Canadian firms with moderate pre-CUSFTA value-added per worker experienced significant gains in productivity as a result of productivity-enhancing investment activities.

Overall, a unilateral trade liberalization decreases profits for a large number of firms in the economy, therefore, the use of modern technology increases by just one percentage point. This modest increase in turn, results in a 2.46 percent rise of the skill premium, far from what is observed in the data. Allowing the sunk cost of technology adoption to be affected by the import tariff (i.e purchasing a foreign piece of equipment subject to an import tariff, resulting in a technology adoption cost $\tau_f S_2$) produces similar results qualitatively. From a quantitative standpoint the change in number of exporters and high-tech firms is larger relative to the benchmark experiment, producing a stronger response of the skill premium which now rises by 4.2 percent. This is my preferred specification, since it takes into account the contribution of changes in trade policy in the price of imported machinery and equipment described in section 3.4. In this case, the stronger response of technology adoption to trade liberalization results in an increase in the skill premium of about one-sixth of the total magnitude observed in the data, a significant quantitative contribution for just this one channel. As mentioned in the introduction, this is the first attempt to quantify how important the complementarity between exporting and investing in productivity-enhancing technologies for understanding changes in wage inequality.

As mentioned in Sections 3.2.1 and 3.2.2, Mexican policymakers pursued drastic policy changes additionally to liberalizing the trade regime, that might have had an important impact in shaping factor remunerations and inequality. For instance, changes in labor market institutions have been argued to have depressed the relative demand for unskilled labor. Through the *Pacto* the Mexican government aggressively pursued a de-indexation of the minimum wage aimed at containing inflation. At the same time, the political power of national unions waned, and with it their ability to influence industry wage agreements in detriment of production workers' wages. One would expect these institutional changes to compress the bottom of the wage distribution, however, Cortez (2001) finds that wage inequality remained stable among workers with low educational attaintment, while growing substantially among college-educated workers. This happened primarily due to a large rise in the return to higher education in the midst of a period of significant educational expansion as noted in Section 3.2.2, which gives support to the adoption of skill-biased technology as a quantitatively important channel affecting the patterns of the skill premium. Furthermore, Cortez (2001) shows that the minimum wage is just binding for agriculture, not services or manufacturing. Thus, the de-indexation of minimum wages should not be as important in explaining the changes in wage inequality in the manufacturing sector.

3.7 Concluding Remarks

This chapter presents a structural empirical model of trade and technology adoption with heterogeneous firms aimed at understanding the extraordinary rise of the skill premium in Mexico after the inception of an ambitious trade liberalization process. Several mechanisms have been proposed that link changes in the degree of trade openness to changes in wage inequality but with limited success. This paper studies the hypothesis that trade-induced adoption of skill-intensive technologies could be behind the increase in inequality. Previous research has lent support to this view by finding that new exporters exhibit higher rates of investment than domestic firms and continuing exporters and also that they are the ones that benefit the most in terms of productivity change. My model does a good job matching several key characteristics of the Mexican manufacturing sector, and produces sensible estimates of the parameters that govern technology adoption. The results of my estimation suggest that the import-competition effect result from trade liberalization does not provide a sufficiently large push of the relative demand for skilled labor (by means of a significantly adoption of modern technology) to explain the rise of the skill premium that we observed in Mexico since the mid 1980s.

Future work on the impact of trade openness on wage inequality would benefit greatly from using data from the National Survey of Employment, Salaries, Technology, and Training (ENESTYC) to construct more refined measurements of advanced manufacturing technology utilization. This would enable researchers to better identify how the labor force composition of a firm changes when specific technologies are introduced in the workplace. Another interesting area for future research is the transitional dynamics of wage inequality after trade liberalizations. Work on this area should aim to explain why the skill premium increase so rapidly after Mexico joined the GATT while remaining stable when it joined NAFTA and its volume of trade almost tripled. Understanding the evolution of wage inequality is particulary interesting since similar patterns are observed in other countries such as Argentina, Chile and Colombia. Structural empirical models of these dynamics should help to further our understanding of the factors determining wage inequality.

Table 3.1. Trade Openness at the Plant Level

	1986	**1990**	**% change**
Fraction of exporting plants	22.8	35.9	57.4
Mean exports/sales	24.7	26.8	8.5
Fraction of plants importing M&E	22.6	37.3	64.9
Expenditure in imported M&E[a]	5.3	9.9	85.5
Fraction of plants importing materials	33.5	50.6	51.1
Expenditure in imported materials[b]	8.0	12.9	60.8

[a]As a fraction of total expenditure in Machinery and Equipment
[b]As a fraction of total expenditure in materials

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.

Table 3.2. Employment and Relative Wages

	1984	**1990**	**% change**
Employment			
Production	201.8	228.9	13.4
Non-production	86.7	98.4	13.4
Hourly wages			
Production	28.7	26.7	-6.8
Non-production	56.1	67.5	20.2
Skill premium	2.10	2.76	31.4

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.

Table 3.3. Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.939
σ_c	Elasticity of substitution, consumption	3.634
τ_f	Post-liberalization import tariff	1.05
τ_x	Export tariff	1.05
λ	Share of skilled workers	0.311
L	Size of Labor force	1,000

Table 3.4. Moments used for Estimation (Data)

Post-Liberalization (1987-1990)	Value
Mean fraction of exporting firms	0.317
Mean exports/sales ratio	0.213
Std. skill share of employment	0.175
Mean skill share, exporters	0.347
Mean entry rate	0.110
Mean total employment	311.76
Std total employment	461.70
Mean total employment, entrants	17.85
Mean total employment, exiters	15.564
Mean fraction of firms using foreign technology	0.222
Mean total employment, exporters	504.93
Correlation(export$_t$, export$_{t-1}$)	0.862
Correlation (skill share$_t$, skill share$_{t-1}$)	0.937
Mean adoption rate imported technology	0.053
Mean entry rate into exporting	0.039
Fraction of plants with 0-30 employees	0.713
Fraction of plants with 30-100 employees	0.209
Fraction of plants with 100-500 employees	0.051

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI, and Job Flows in Latin America dataset, Inter-American Development Bank (2004).

Table 3.5. Parameter Estimates

Parameter	**Point Estimate**
Mean productivity tech. 1 ($\overline{z}_1$)	0.050
	(0.003)
Mean productivity tech. 2 ($\overline{z}_2$)	0.109
	(0.005)
Root productivity process (ϕ)	0.952
	(0.012)
Variance productivity innovations (σ_ε^2)	0.278
	(0.073)
Fixed cost of using tech. 1 (f_1)	91.409
	(2.354)
Fixed cost of using tech. 2 (f_2)	568.53
	(30.242)
Sunk cost of adopting tech. 2 (S)	65.093
	(14.881)
Foreign market size (A_x)	910.23
	(0.892)
Fixed cost of exporting (f_x)	48.726
	(0.045)
Mean productivity, entrants (μ_E)	1.226
	(0.0187)
Sunk cost of entry (S_E)	4.234
	(1.555)
Elasticity of substitution (σ_p)	1.410
in production	(0.952)
Value objective function (Ψ)	0.0926

Standard errors in parenthesis.

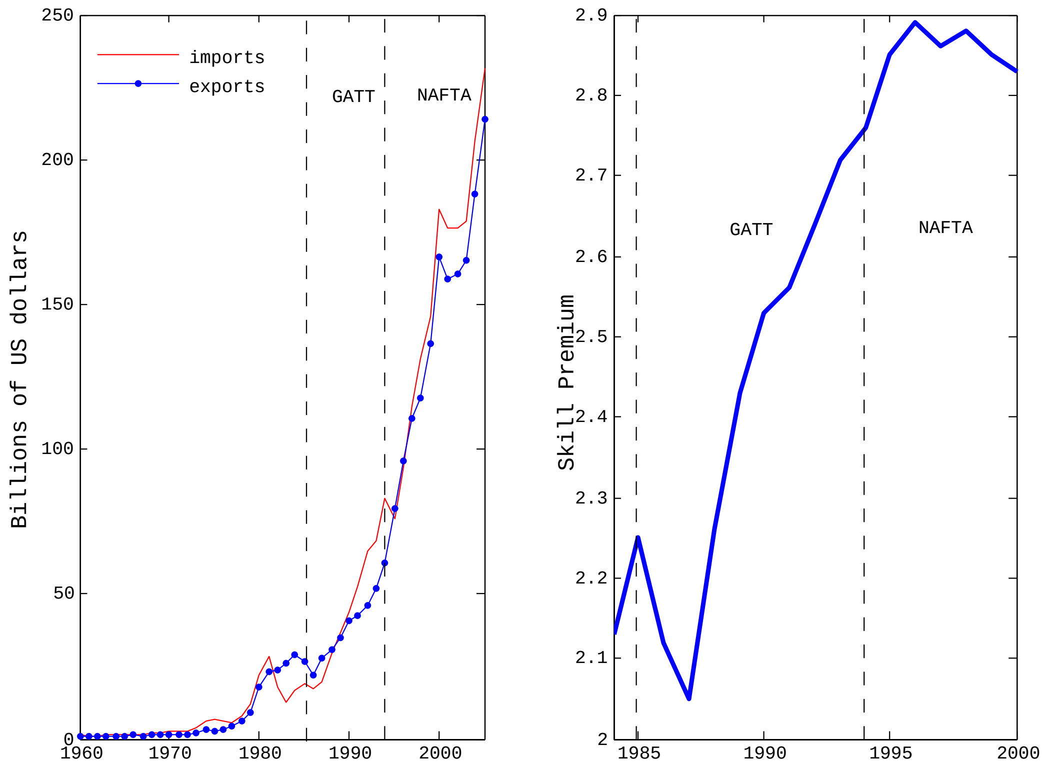
Table 3.6. Goodness of Fit

Post-Liberalization (1987-1990)	**Data**	**Simulated**	**log-difference**
Share of exporting plants	0.317	**0.327**	0.014
Mean exports/sales ratio	0.213	**0.223**	0.018
Std. skill share of employment	0.175	**0.120**	0.164
Skill share, exporters	0.347	**0.345**	0.002
Mean entry rate	0.110	**0.005**	1.280
Mean total employment	311.76	**380.81**	0.087
Std. log(total employment)	461.70	**2,548.45**	0.742
Mean total employment, entrants	17.85	**19.17**	0.030
Mean total employment, exiters	15.564	**21.54**	0.141
Share of plants using imported M&E	0.222	**0.327**	0.169
Mean total employment, exporters	504.93	**1,111.76**	0.343
Corr. (export$_t$, export$_{t-1}$)	0.862	**0.785**	0.046
Corr. (skill share$_t$, skill share$_{t-1}$)	0.937	**0.908**	0.041
Mean adoption rate imported M&E	0.039	**0.043**	0.084
Mean entry rate into exporting	0.033	**0.043**	0.047
Share of plants with 0-30 employees	0.713	**0.708**	0.003
Share of plants with 30-100 employees	0.209	**0.140**	0.172
Share of plants with 100-500 employees	0.051	**0.086**	0.229

Table 3.7. Unilateral Trade Liberalization

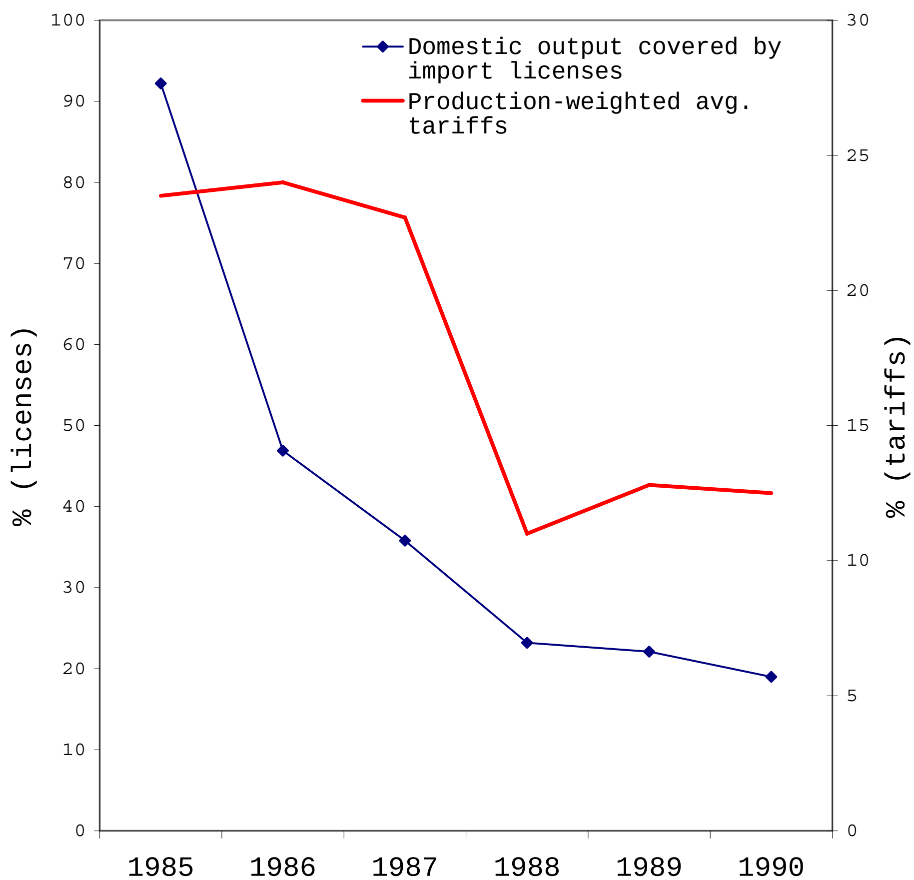
Statistic	**Benchmark** $\tau_f = 1.05$	**High tariff** $\tau_f = 1.55$	**High tariff affecting** S_2
Aggregate income (Y)	100	116.10	118.02
Price index (P)	100	120.91	124.10
Price of foreign consumption good (τ_f)	105	155	155
Mass of incumbent firms (M)	100	101.23	102.50
Skill premium (w_h/w_l)	6.871	6.701	6.584
Share of plants using imported M&E	0.329	0.319	0.274
Share of exporting plants	0.329	0.292	0.262

Figure 3.1. Trade Volume and the Rise of the Skill Premium in Mexico



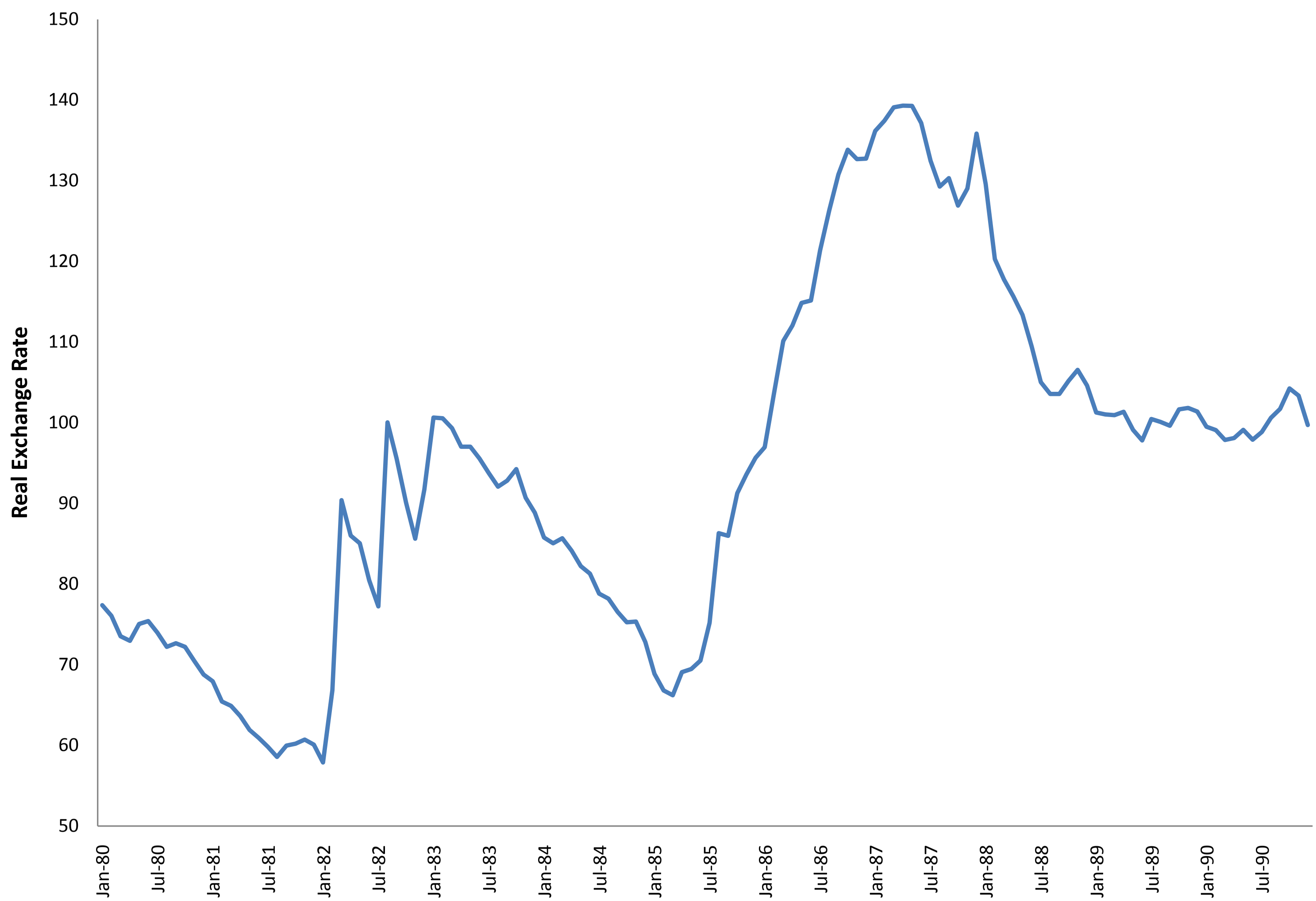
Source: World Bank WDI and INEGI. Exports and imports of manufacturing goods. Skill premium is defined as the mean ratio of non-production to production wages across 2-digit industries.

Figure 3.2. Protection Measures for Manufacturing during the 1980s (1-digit Industries)



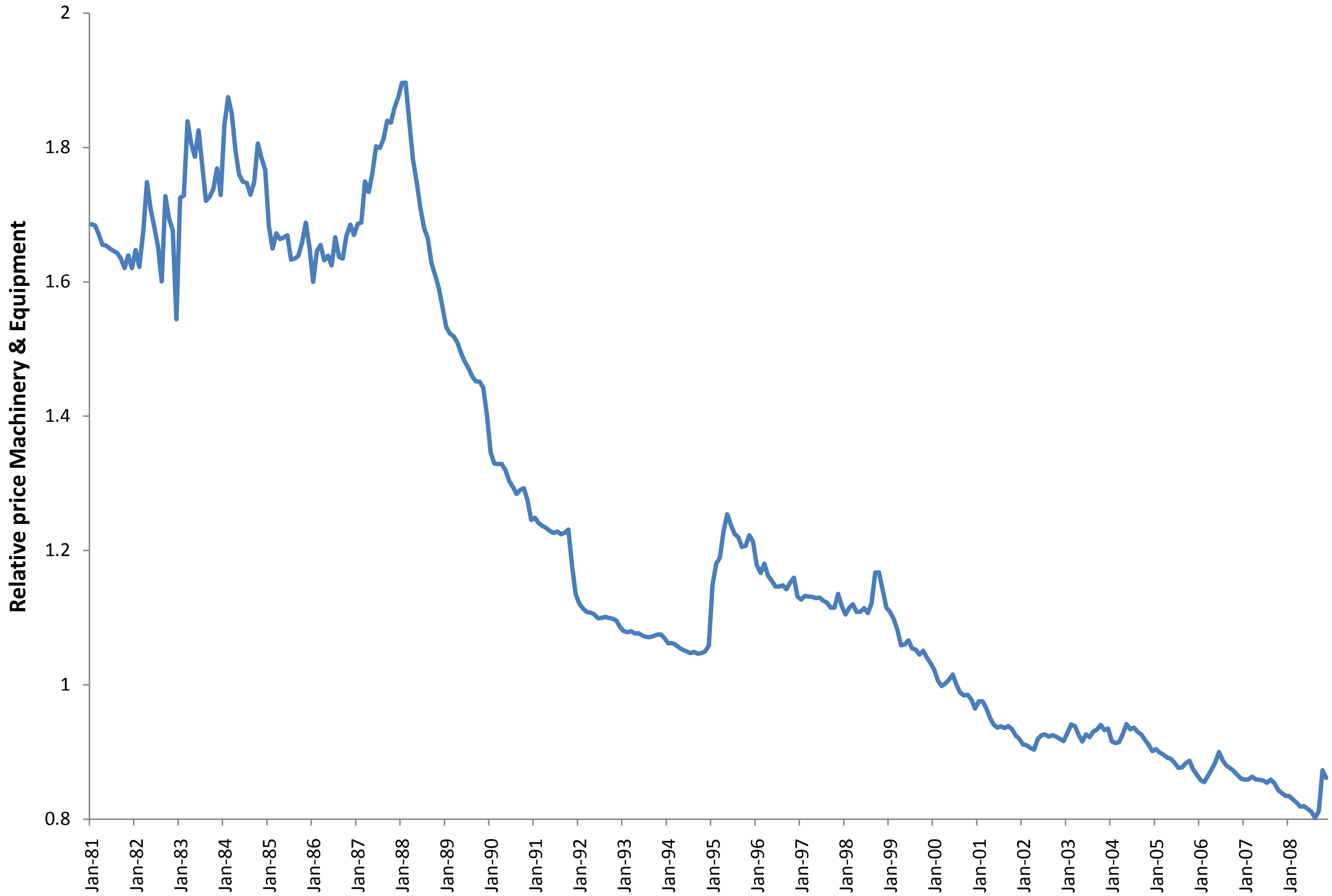
Source: Lustig (1998)

Figure 3.3. Real Exchange Rate Mexico 1980-1990



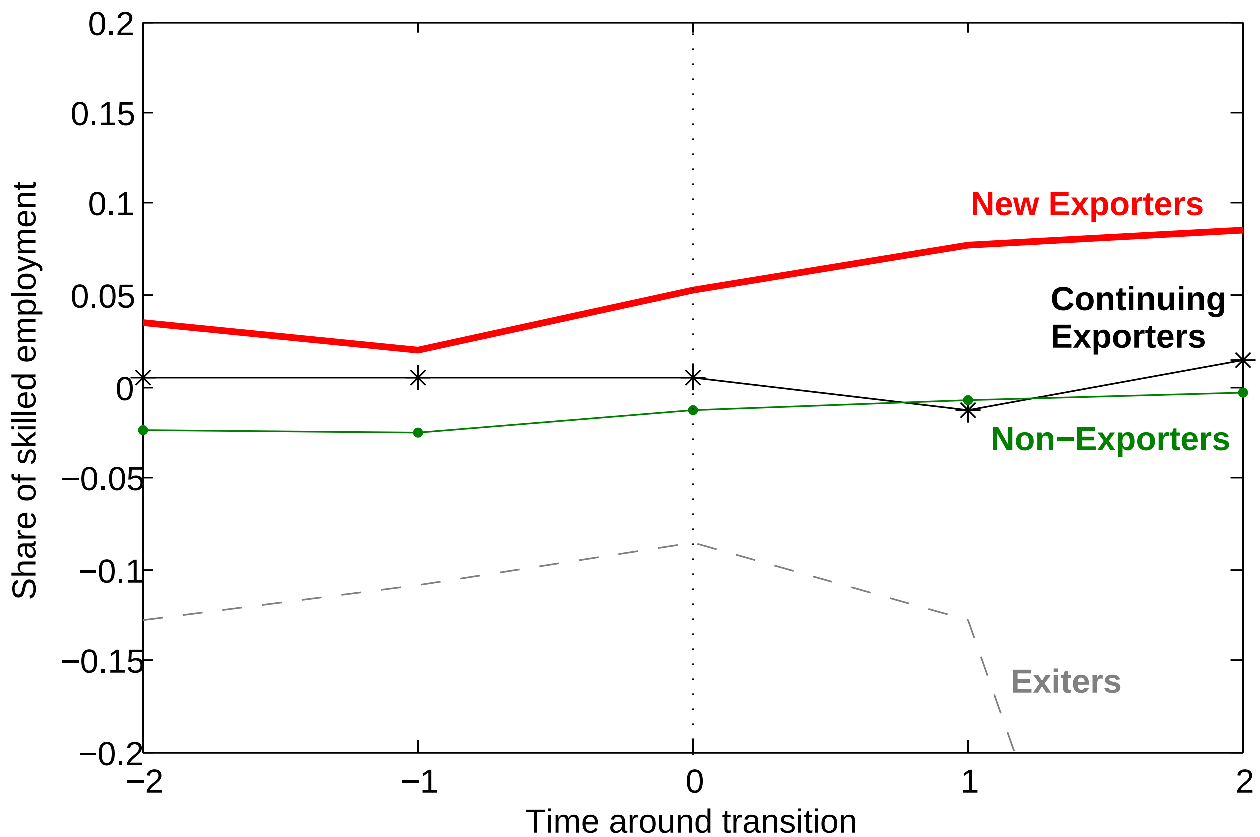
Source: Banco de México.

Figure 3.4. Relative Price of Machinery and Equipment



Source: INEGI.

Figure 3.5. Skill-Intensity Trajectories Around Entry into Export Market



The figure depicts the residual of regressing the share of non-production employment at the plant level on the log of capital stock, time and 4-digit industry-specific dummies around entry into the export market.

Figure 3.6. Sequence of Actions

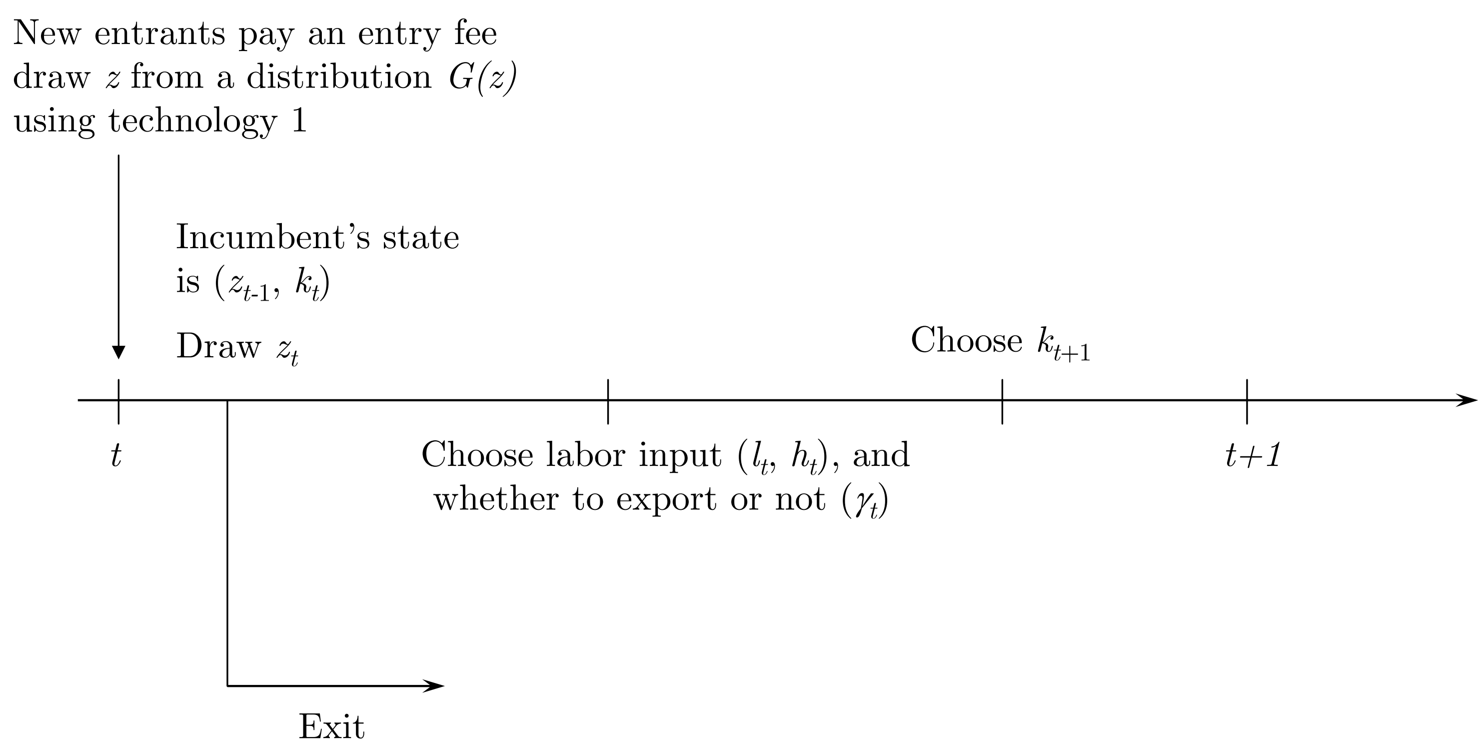
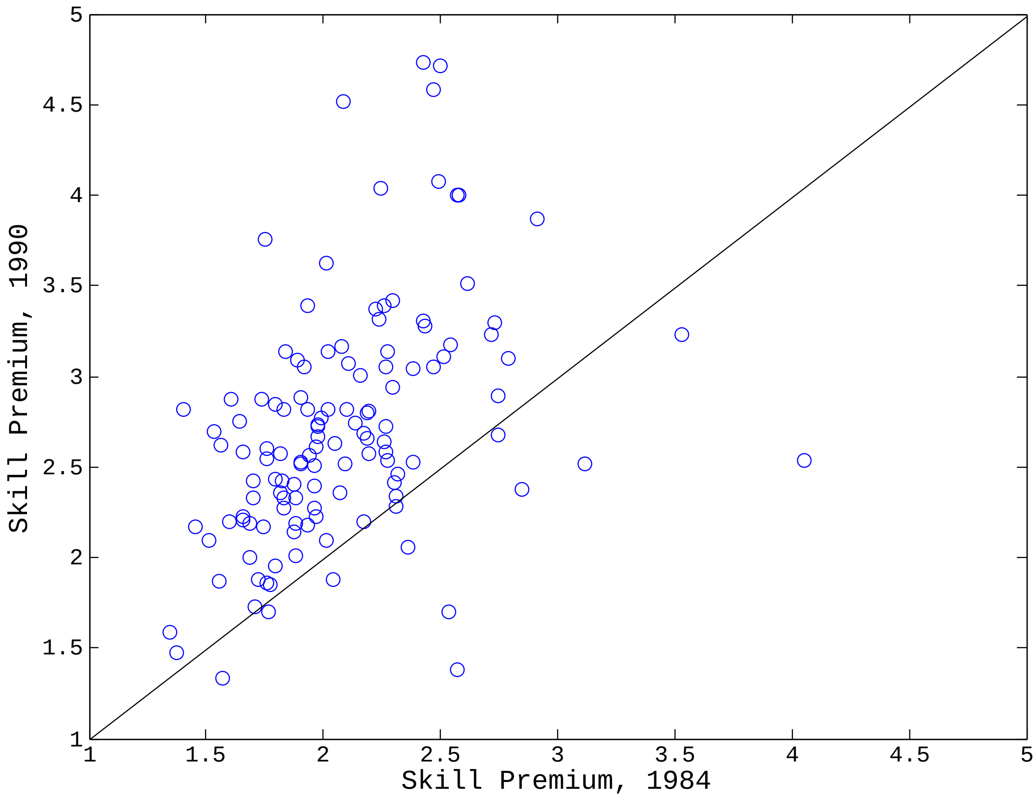
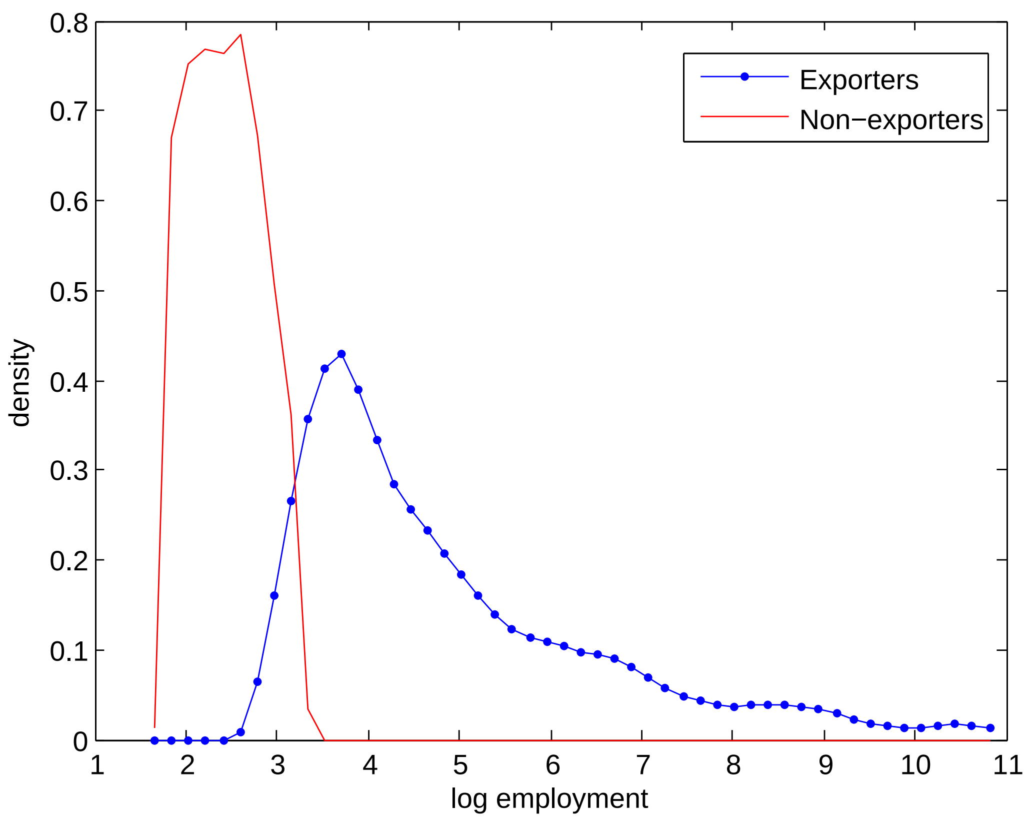


Figure 3.7. Skill Premium Across 4-digit Industries



Own calculations. Mean wage of non-production workers relative to mean wage of production workers by 4-digit industry. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.

Figure 3.8. Size Distribution by Exporting Status



Bibliography

[1] Abowd, John M., John Haltiwanger, Julia Lane, Kevin L. McKinney and Kristin Sandusky (2007): "Technology and the Demand for Skill: An analysis of Within and Between Firm Differences" NBER Working Paper # 13043

[2] Acemoglu, Daron (2002): "Directed Technical Change" *Review of Economic Studies* 69: 781-810

[3] Acemoglu, Daron (2003): "Patterns of Skill Premia" *Review of Economic Studies* 70: 199-230

[4] Alvarez, Roberto and Raymond Robertson (2004): "Exposure to Foreign Markets and Plant-level Innovation: Evidence from Chile and Mexico" *Journal of International Trade and Development* 13: 57-87

[5] Armenter, Roc and Miklós Koren (2009): "Economies of Scale and the Size of Exporters" *mimeo* Federal Reserve Bank of Philadelphia

[6] Atkenson, Andrew and Ariel Burnstein (2007): "Innovation, Firm Dynamics and International Trade" *mimeo* UCLA

[7] Attanasio, Orazio, Pinelopi Goldberg and Nina Pavcnik (2004): "Trade Reforms and Wage Inequality in Colombia" *Journal of Development Economics* 74: 331-366

[8] Aw, Bee Yan, Mark J. Roberts and Tor Winston (2007): "Export Market Participation, Investments in R&D and Worker Training, and the Evolution of Firm Productivity" *The World Economy* 14: 83-104

[9] Banco de México (2007): Estadísticas de Balanza de Pagos.

[10] Bergoing, Raphael, Patrick J. Kehoe, Timothy J. Kehoe and Raimundo Soto (2002): "A Decade Lost and Found: Mexico and Chile in the 1980s" *Review of Economic Dynamics* 5: 166-205

[11] Berman, Eli, John Bound and Zvi Griliches (1994): "Changes in the Demand for Skilled Labor within U. S. Manufacturing Industries" *Quarterly Journal of Economics* 109: 367-398

[12] Bernard, Andrew B., Raymond Robertson and Peter K. Schott (2005) "Is Mexico a Lumpy Country?" *mimeo* Yale University

[13] Bernard, Andrew B. and J. Bradford Jensen (1997): "Exporters, Skill Upgrading, and the Wage Gap" *Journal of International Economics* 42: 3-31

[14] Bustos, Paula (2005): "The Impact of Trade on Technology and Skill Upgrading: Evidence from Argentina" *mimeo* CREI Universitat Pompeu Fabra

[15] Coooper, Russell W. and John C. Haltiwanger (2006): "On the Nature of Capital Adjustment Costs" *Review of Economic Studies* 73: 611-633

[16] Cortez, Willy W. (2001): "What is Behind Wage Inequality in Mexico?" *World Development* 29: 1905-1922

[17] Costantini, James A. and Mark J. Melitz (2007): "The Dynamics of Firm-Level Adjustment to Trade Liberalization" *mimeo* Princeton University

[18] Cragg, Michael Ian and Mario Eppelbaum (1996): "Why has Wage Dispersion Grown in Mexico? Is it the Incidence of Reforms or the Growing Demand for Skills?" *Journal of Development Economics* 51: 99-116

[19] Demidova, Svetlana and Andrés Rodríguez-Clare (2009): "Trade Policy under Firm-Level Heterogeneity in a Small Economy" *Journal of International Economics* 78: 100-112

[20] Doms, Mark, Timothy Dunne and Kenneth R. Troske (1997): "Workers, Wages and Technology" *Quarterly Journal of Economics* 112: 253-290.

[21] Dunne, Timothy, John Haltiwanger and Kenneth R. Troske (1997): "Technology and Jobs: Secular Changes and Cyclical Dynamics" *Carnegie-Rochester Conference Series in Public Policy* 46: 107-178

[22] Eaton, Jonathan and Samuel Kortum (2001): "Trade in Capital Goods" *European Economic Review* 45: 1195-1235

[23] Esquivel, Gerardo and José Antonio Rodríguez-López (2003): "Technology, Trade and Wage Inequality in Mexico Before and After NAFTA" *Journal of Development Economics* 72: 543-565

[24] Feenstra, Robert C. and Gordon H. Hanson (1997): "Foreign Direct Investment and Relative Wages: Evidence from Mexico's Maquiladoras" *Journal of International Economics* 42: 371-393

[25] Feliciano, Zadia (2001): "Workers and Trade Liberalization: The Impact of Trade Reforms in Mexico on Wages and Employment" *Industrial and Labor Relations Review* 55: 95-115

[26] Fernandez, Roberto (2001): "Skill-Biased Technological Change and Wage Inequality: Evidence from a Plant Retooling" *American Journal of Sociology* 107: 273-320

[27] Goldberg, Pinelopi and Nina Pavcnik (2007): "Distributional Effects of Globalization in Developing Countries" *Journal of Economic Literature* 45: 39-82

[28] Grether, Jean-Marie (1996): "Mexico, 1985-1990: Trade Liberalization, Market Structure and Manufacturing Performance" in *Industrial Evolution in Developing Countries*, ed. by Mark J. Roberts, and James R. Tybout, chap. 11. Oxford University Press for the World Bank, New York.

[29] Hanson, Gordon and Ann E. Harrison (1999a): "Who Gains from Trade Reform? Some Remaining Puzzles" *Journal of Development Economics* 59: 125-154

[30] Hanson, Gordon and Anne E. Harrison (1999b): "Trade and Wage Inequality in Mexico" *Industrial and Labor Relations Review* 52: 271-288

[31] Hopenhayn, Hugo (1992): "Entry, Exit and Firm Dynamics in the Long-Run" *Econometrica* 60: 1127-1150

[32] Huggett, Mark and Sandra Ospina (2001): "Does Productivity Growth Fall After the Adoption of New Technology?" *Journal of Monetary Economics* 48: 173-195

[33] Iacovone, Leonardo (2008): "Exploring Mexican Firm-level Data", *mimeo* University of Sussex

[34] Iacovone, Leonardo and Beata S. Javorcik (2007): "Preparation to Export", *mimeo* World Bank

[35] Inter-American Development Bank (2004): Job Flows in Latin America dataset

[36] Kasahara, Hiroyuki (2001): "Temporary Increases in Tariffs and Machine Replacement: The Chilean Experience in 1980-1996" *mimeo* University of Wisconsin-Madison

[37] Katz, Lawrence F. and Kevin M. Murphy (1992): "Changes in Relative Demand, 1963-1987: Supply and Demand Factors" *Quarterly Journal of Economics* 107: 35-78

[38] Kehoe, Timothy J. (1995): "A Review of Mexico's Trade Policy from 1982 to 1994" *World Economy* 18: 135-151

[39] Krusell, Per, Lee E. Ohanian, José-Víctor Ríos-Rull and Giovanni L. Violante (2000): "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis" *Econometrica* 68: 1029-1053

[40] Lileeva, Alla and Daniel Trefler (2007): "Improved Access to Foreign Markets Raises Plant-level Productivity... for Some Plants" *mimeo* University of Toronto

[41] López-Acevedo, Gladys (2002): "Determinants of Technology Adoption in Mexico" World Bank Policy Research Working Paper # 2780

[42] Lustig, Nora, *Mexico: The Remaking of an Economy*, 2nd ed., 1998, Washington DC: Brookings Institution

[43] Melitz, Mark J. (2003): "The Impact of Trade on Aggregate Industry Productivity and Intra-Industry Reallocations" *Econometrica* 71: 1695-1725

[44] Pavcnik, Nina (2003): "What Explains Skill Upgrading in Less Developed Countries?" *Journal of Development Economics* 71: 311-328

[45] Robertson, Raymond (2004): "Relative Prices and Wage Inequality: Evidence from Mexico" *Journal of International Economics* 64: 387-409

[46] Székely, Miguel, *The Economics of Poverty, Inequality and Wealth Accumulation in Mexico*, 1998, Oxford: Macmillan Press

[47] Tauchen, George (1986): "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions" *Economics Letters* 20: 177-181

[48] Ten Kate, Adriaan (1992): "Trade Liberalization and Economic Stabilization in Mexico: Lessons from Experience" *World Development* 20: 659-672

[49] Tybout, James R. and M. Daniel Westbrook (1995): "Trade Liberalization and Dimensions of Efficiency Change in Mexican Manufacturing Industries" *Journal of International Economics* 39: 53-78

[50] Verhoogen, Eric (2008): "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector" *Quarterly Journal of Economics* 123: 489-530

[51] Yeaple, Stephen R. (2005): "A Simple Model of Firm Heterogeneity, International Trade and Wages" *Journal of International Economics* 65: 1-20

Appendix A

Computational Algorithm: "Exports and the Volatility of Sales"

Solving the model involves solving the Bellman equation 2.7 and computing optimal policy rules for next-period's capital, export decision and exports/sales ratio. To solve for the value function v, I use a value function iteration procedure with linear interpolation described below in more detail:

1. Create equally-spaced grids for the *endogenous* state variables of the economy: 1) individual capital stock $k \in \mathcal{K} \equiv \{k_1, \ldots, k_{N_k}\}$ with $N_k = 100$, taking care that k_{N_k} is such that the policy rule for capital is always non-binding, and 2) the price index for the domestic market $P^h \in \mathcal{P} \equiv \{P_1, \ldots, P_{Np}\}$. The price index is defined as $P^h = (N^{-1} \sum_i (p_i^h)^{1-\sigma_h})^{\frac{1}{1-\sigma_h}}$.

2. Create grids for the *exogenous* state variables in the economy: domestic and foreign demand shocks $\{z^h, z^f\}$ and the idiosyncratic productivity shock $\{\phi_i\}_{i=1}^{N_\phi}$ using Tauchen (1986), with $N_\phi = 15$.

3. Assume a law motion for the domestic price index. Specifically:

$$\log P_{t+1}^h = a_{0,Z} + a_{1,Z} \log P_t^h, \quad Z = 1, \ldots, N_Z. \tag{A.1}$$

   and initial values for the parameters $a_{0,Z}$ and a_1, where Z indexes the macro states in the model.

4. Let S denote all the random shocks in the model (i.e. both demand shocks and the idiosyncratic productivity shock), θ the fraction of capital used for

exporting, and Γ the distribution of firms across capital stocks, idiosyncratic productivity and exporting status. The recursive problem for the firm is given by:

$$v(k, y_{-1}, S; \Gamma) = \max_{k', \theta, y} \Big\{ u(\pi^h + y\pi^f) + \beta E\big[v(k', y, S'; \Gamma')\big] \Big\}. \tag{A.2}$$

where

$$\pi^h + y\pi^f = p^h(q^h, P^h, S)q^h(k, \phi, \theta) + \big[p^f(q^f, S)q^f(k, \phi, \theta) \\ - M - (1 - y_{-1})F\big]y + (1 - \delta)k - k'. \tag{A.3}$$

Given the law of motion assumed for the domestic price index, the Bellman equation for the firm can be rewritten as:

$$v(k, y_{-1}, S, P^h) = \max_{k', \theta, y} \Big\{ u(\pi^h + y\pi^f) + \beta E\big[v(k', y, S', (P^h)')\big] \Big\}. \tag{A.4}$$

5. In order to solve the problem in equation (A.4) I use a value function iteration procedure with linear interpolation as follows:

   (i) Solve the first-order condition for θ for all values in the grids of the capital stock, shocks and price index. This is a static problem.

   (ii) Initialize a first guess for the value function, $v(k, y_{-1}, S, P^h)$.

   (iii) given the law of motion for P^h, calculate $(P^h)'$ for all points on the price-index grid. Start iterating over the price index. Call the index of this iteration j.

   (iv) Since $(P^h)'$ does not necessarily belong to $\mathcal{P}$, linearly interpolate v along the P^h dimension. For instance, let $P^h_j < (P^h)' < P^h_{j+1}$, where both $P^h_j, P^h_{j+1} \in \mathcal{P}$. So $v(k', y, S', (P^h)')$ is given by:

$$v(k', y, S', (P^h)') \simeq v(k', y, S', P^h_i) + \\ \left[\frac{v(k', y, S', P^h_{j+1}) - v(k', y, S', P^h_j)}{P^h_{j+1} - P^h_j}\right]((P^h)' - P^h_j). \tag{A.5}$$

   (v) Run over all points in the state space grid $(i_k, y, i_s, j) \in N_k \times 2 \times N_s \times N_p$. And solve:

$$v(k_{i_k}, y_{-1}, S_{i_s}, P^h_j) = \max_{k'_j \in \mathcal{K}} \Big\{ u[\pi(k_{i_k}, k'_j, y_{-1}, S_{i_s}, P^h_j)] +$$

$$\beta E\big[v(k'_j, y, S'_{i_s}, a_{0,Z} + a_1 \log P^h_j)\big]\Big\}. \quad \text{(A.6)}$$

(vi) Once that the optimal k' has been determined for all elements of the grid $\mathcal{K}$, the value of k' is determined off the grid points by approximating the value function $v(\cdot, y_{-1}, S, P^h_j)$ using linear interpolation and maximizing the RHS of equation (26) over k'.

(vii) Repeat this procedure until convergence of the value function has been reached. This result in optimal policy rules for the capital stock, g_k, and the export decision g_y.

6. Using the policy rules g_k and g_y simulate an economy with N firms ($N = 100$) for T periods ($T = 2,500$). In each period calculate the optimal price charged by each firm in the domestic market and calculate $P^h_t = (N^{-1}\sum_i (p^h_{i,t})^{1-\sigma_h})^{\frac{1}{1-\sigma_h}}$. To calculate k' off grid points, use bilinear interpolation. For instance, to calculate $k' = g_k(k, y, S_{i_s}, P^h)$ for $k_{i_k} < k < k_{i_k+1}$ and $P^h_j < P^h < P^h_{j+1}$, define:

$$h_k \equiv (k - k_{i_k})/(k_{i_k+1} - k_{i_k}), \quad h_P \equiv (P^h - P^h_j)/(P^h_{j+1} - P^h_j). \qquad \text{(A.7)}$$

Then, the optimal next-period capital is given by:

$$\begin{aligned} k'(k, y, S_{i_s}, P^h) &= (1 - h_k)(1 - h_P) g_k(k_{i_k}, y, S_{i_s}, P^h_j) + \\ &+ h_k(1 - h_P) g_k(k_{i_k+1}, y, S_{i_s}, P^h_j) + h_k h_P g_k(k_{i_k+1}, y, S_{i_s}, P^h_{j+1}) + \\ &+ (1 - h_k) h_P g_k(k_{i_k}, y, S_{i_s}, P^h_{j+1}). \quad \text{(A.8)} \end{aligned}$$

7. Given a time-series for the domestic price index $\{P^h_t\}^T_{t=500}$, we can estimate the parameters $a_{0,Z}$ and a_1 using ordinary least-squares regression. If the parameters are sufficiently close to the initial guess and the fit of the law of motion is good enough[1] the algorithm stops. Otherwise, the law of motion for the price index is updated and the algorithm returns to step # 3. The estimated parameters for the benchmark simulation appear in Table A.1.

[1] If the R^2 of the regression is above 0.99

Table A.1. Estimated Parameters for the Law of Motion of the Price Index

$\log P^h_{t+1} = a_{0,Z} + a_{1,Z} \log P^h_t$	
$a_{0,1}$	0.1412
	(0.0032)
$a_{0,2}$	0.1413
	(0.0038)
$a_{0,3}$	0.5128
	(0.0053)
$a_{0,4}$	0.5151
	(0.0051)
$a_{1,1}$	0.2534
	(0.0139)
$a_{1,2}$	0.2178
	(0.0183)
$a_{1,3}$	0.2421
	(0.0223)
$a_{1,4}$	0.2027
	(0.0224)
R^2	0.9904
Observations	2,000

Standard errors in parenthesis.

Appendix B

Computational Algorithm: "Trade, Technology Adoption and the Rise of the Skill Premium in Mexico"

This section describes the computational algorithm used to compute the stationary equilibrium of my model.

(i) Let $\boldsymbol{\theta}$ denotes the vector of parameters to be estimated, and $\boldsymbol{\theta_{ne}}$ the vector of parameters calibrated outside the model.

$$\boldsymbol{\theta} = [\overline{z}_1, \overline{z}_2, \phi, \sigma_\varepsilon^2, f_1, f_2, S, A_x, f_x, \mu_E, S_E, \sigma_p]_{12\times 1}, \quad \text{(B.1)}$$
$$\boldsymbol{\theta_{ne}} = [\beta, \lambda, \sigma_c, L, \tau_f, \tau_x]_{6\times 1}.$$

let $\boldsymbol{\theta^0}$ be the initial guess for the estimated parameters.

(ii) The state variables for a firm are: 1) technology $k \in \{1,2\}$ and 2) the idiosyncratic productivity index, z^k. I assume that z^k can take values in a grid $Z^k \equiv \{z_1^k, \ldots, z_N^k\}$. The stochastic process for the idiosyncratic productivity shock is approximated using the method proposed by Tauchen (1986). This produces two sets of grids $Z^1 \equiv \{z_1^1, \ldots, z_N^1\}$ and $Z^2 \equiv \{z_1^2, \ldots, z_N^2\}$ and associated transition matrices $Q_1(z, z')$ and $Q_2(z, z')$, with $N = 100$.

(iii) Given an initial guess for the aggregate macroeconomic variables in the model,

$$X \equiv [P, Y, M, w_l, w_h], \quad \text{(B.2)}$$

firms solve their static problem choosing optimal prices in each market (domestic and foreign), labor demand for each type of worker and whether to export or not, and static profits $\pi(k, z)$ are calculated.

(iv) Running through all points in the state space $i_k = 1, 2$ and $i_z = 1, \dots, N$ solve the firm's dynamic programming problem using value function iteration. Iterate over equation (3.12) until $\|v^\ell - v^{\ell-1}\| < \mathsf{tol}$, where ℓ indexes iterations over the value function, and $\mathsf{tol} = 1e - 4$ is the convergence criterion. This step yields a value function $v(k, z)$, a policy rule for technology adoption $\mathcal{K}(k, z)$, and a policy rule for exiting, $\chi(k, z)$.

(v) Given the policy functions for technology adoption and exiting, and the transition matrix for productivity, construct a transition matrix P of size $(2N \times 2N)$ that gives the conditional probability of visiting state (i'_k, i'_z) next period for incumbent firms with current state is (i_k, i_z). Finally, compute the invariant distribution associated with P, $\tilde{\mu}(k, z)$.

(vi) Define M_E as the mass of potential entrants that can start producing in a given period. In a stationary equilibrium, the flow of successful entrants should exactly balance the flow of exiting firms. Given the distribution of incumbents $\tilde{\mu}(k, z)$, we can solve for M_E:

$$M_E = \frac{M\tilde{\mu}(k, z)'\chi(k, z)}{G_E(z)'(1 - \chi(1, z))}. \tag{B.3}$$

and we can also define the post entry/exit distribution of firms across technologies and productivity, $\mu(k, z)$:

$$\mu(k, z) = \tilde{\mu}(k, z)'(1 - \chi(k, z)) + \left(\frac{M_E}{M}\right) G_E(z)'(1 - \chi(k, z)). \tag{B.4}$$

(vii) Compute the market clearing conditions: 1) labor market clearing, 2) consistency of the aggregate price index, 3) consistency of aggregate income, 4) net value of entry equal to zero, and 5) balanced trade:

$$\frac{h(k, z)}{l(k, z)} - \frac{\lambda}{(1 - \lambda)} = 0, \qquad \text{(Labor Market Clearing)}$$

$$P = \left[M\mu(k, z)' p_d(k, z)^{1-\sigma_c} + \tau_f^{1-\sigma_c} \right]^{\frac{1}{1-\sigma_c}}, \qquad \text{(Aggregate Price Index)}$$

$$Y = M\mu(k, z)'\pi(k, z) \ + L[\lambda w_h + (1 - \lambda) w_l], \qquad \text{(Aggregate Income)}$$

$$G_E(z)' \cdot v(1, z) - mc(k, z) S_E = 0, \qquad \text{(Free Entry)}$$

$$M\mu(k, z)'[\gamma(k, z) r_x(k, z)] - Y \left(\frac{\tau_f}{P}\right)^{1-\sigma_c} = 0. \qquad \text{(Balanced Trade)}$$

a vector $X^* \equiv [P^*, Y^*, M^*, w_l^*, w_h^*]$ that solves the system of equations defined above characterizes the stationary equilibrium of this economy. In the computer code, the function `mktclear` receives as inputs the vector of initial parameters $\boldsymbol{\theta^0}$, and the initial guess for the macroeconomic variables X. The program solves the static and dynamic problems of the firm, finds the stationary distribution of the economy, and produces the vector of market clearing conditions, Φ, such that $X^* = \arg\min \|\Phi(X)\|$.

(viii) Armed with the policy rules for labor demand, exporting, technology choice, entry and exit, generate $S = 50$ simulated panels of firms. Starting with a given number of incumbent firms, $N_{inc} = 200$, with $N_{ent} = (M_E/M)N_{inc}$ potential entrants every period. Using these simulations, compute a vector of simulated moments (averaged across simulations), of size $r > 12$ (the number of parameters to estimate) and minimize the loss function 3.15 with respect to $\boldsymbol{\theta}$.

(ix) The limiting distribution of $\hat{\boldsymbol{\theta}}$ is given by:

$$\sqrt{T}(\hat{\boldsymbol{\theta}} - \boldsymbol{\theta_0}) \to \mathcal{N}(0, V). \tag{B.5}$$

where $V = (\hat{D}\hat{\Sigma}^{-1}\hat{D}')^{-1}$ and $\hat{D}$ is the $(12 \times r)$ Jacobian matrix,

$$\hat{D} = \frac{\partial g(D_{it}, \hat{\boldsymbol{\theta}})}{\partial \boldsymbol{\theta}} \equiv \begin{pmatrix} \frac{\partial g_1(Z,\hat{\theta})}{\partial \theta_1} & \frac{\partial g_2(Z,\hat{\theta})}{\partial \theta_1} & \cdots & \frac{\partial g_r(Z,\hat{\theta})}{\partial \theta_1} \\ \frac{\partial g_1(Z,\hat{\theta})}{\partial \theta_2} & \frac{\partial g_2(Z,\hat{\theta})}{\partial \theta_2} & \cdots & \frac{\partial g_r(Z,\hat{\theta})}{\partial \theta_2} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial g_1(Z,\hat{\theta})}{\partial \theta_{12}} & \frac{\partial g_2(Z,\hat{\theta})}{\partial \theta_{12}} & \cdots & \frac{\partial g_r(Z,\hat{\theta})}{\partial \theta_{12}} \end{pmatrix}. \tag{B.6}$$

where T is the sample size, and $g(D_{it}, \hat{\boldsymbol{\theta}})$ is the difference between the mean vector of simulated moments and the sample moments:

$$g(D_{it}, \hat{\boldsymbol{\theta}}) = \log\left(\frac{1}{S}\sum_{s=1}^{S} m(D_{it}^{s}(\hat{\boldsymbol{\theta}}))\right) - \log\left(\frac{1}{T}\sum_{t=1}^{T} m(D_{it})\right). \tag{B.7}$$

(x) Finally, $\hat{\Sigma}^{-1}$, the optimal weighting matrix, is estimated by bootstrapping the moments directly from the data. The data is re-sampled 1,000 times, and for each sample the vector of moments $\mathbf{m}$ is calculated to produce the estimated variance-covariance matrix.

Appendix C

Encuesta Industrial Anual: Cleaning Procedure

The *Encuesta Industrial Anual* (Annual Manufacturing Survey) is produced by the *Instituto Nacional de Estadísticas, Geografía, e Información* (INEGI), the Mexican government statistical agency. The data contains information on 3,218 manufacturing plants for the period 1984-1990 (for a total of 22,526 plant-year observations) and it is by design a balanced panel that covers roughly 80 percent of cumulative value-added. The sample design is deterministic. Plants with more than 100 employees are included automatically. Plants are ranked according to total value of production and are added to the sample until the set of the selected plants covers approximately 85 percent of the respective classs (4-digit industry) output value. Furthermore, whenever the normal sampling procedure implies that more than 120 plants need to be surveyed to reach the 85 percent threshold, the number of plants surveyed is kept to a maximum of 120; on the other hand if the 85 percent threshold is reached by covering less than 15 plants, then all the plants are included. For more information about the Encuesta Industrial Anual see Iacovone (2008)

The survey contains information on inputs used by manufacturing plants (labor split into production and non-production workers, raw materials, intermediate inputs, energy consumption), and output indicators such as value of production, value of sales, inventory, revenues derived from industrial services like maquila and non-industrial services. The original sample did not have information on the value of imported materials or machinery and equipment and export revenues. However from 1986 onwards this information is available following a World Bank project aimed at collecting exporting information for plants covered by the EIA. The cleaning procedure for the sample follows Grether (1996):

1. An observation is eliminated if one of the following variables is non-positive: total employment, number of non-production workers, number of produc-

tion workers, total wage-bill, value-added[1] and gross value of output. This resulted in the elimination of 1,550 plant-year observations.

2. Elimination of odd observations: observations for which the annual growth rate of total employment was above 300 percent on absolute value; annual growth rate of total remuneration above 1,000 percent in absolute value; annual growth rate of total value of production above 1,000 percent in absolute value; annual growth rate of energy consumption above 2,500 percent in absolute value and annual growth rate of expenditure on materials above 2,500 percent in absolute value. This resulted in the elimination of 5,973 plant-year observations.

3. Elimination of incomplete series: plants that were discarded in at least one year for the reasons mentioned above were discarded for all the other years as well. This resulted in the elimination of 848 plant-year observations.

4. Entry and exit: Some plants are recorded as entrants or exiters even though the sample is supposed to be closed. This resulted in the elimination of 317 plant-year observations.

5. Maquila plants: Plants for which revenues from maquila services were more than 10 percent of total revenues. This resulted in the elimination of 447 plant-year observations.

The final sample contained 13,391 observations (that is, 1,913 per year).

[1] corrected by maquiladora flows, i.e value-added + income from maquila services − expenditure on maquiladora services

Vita

Alejandro Riaño

Alejandro Riaño was born in Ibagué, Colombia on August 14, 1979. In September 2001 he received his B.A. in Economics from the Universidad de Los Andes in Bogotá. In October of the same year he joined the Research Department at the Inter-American Development Bank in Washington D.C. as a Research Fellow working on issues in macroeconomics and international trade. In September of 2003 he started his Ph.D. in Economics at the Pennsylvania State University. His dissertation studies the effects of globalization on firm-level decisions in developing countries. He has also worked as an Instructor and Research Assistant in the Department of Economics at Penn State.