

ESSAYS IN POLICY ANALYSIS: STRATEGIC TRADE THEORY AND THE
ELIMINATION OF AGRICULTURAL SUBSIDIES

By

JEFFREY ALLEN LUCKSTEAD

A dissertation submitted in partial fulfillment of
the requirements for the degree of the

DOCTOR OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
School of Economic Sciences

MAY 2013

To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation of Jeff Luckstead find it satisfactory and recommend that it be accepted.

Ron C. Mittelhammer, Ph.D., Co-Chair

Stephen Devadoss, Ph.D., Co-Chair

Mark J. Gibson, Ph.D.

ACKNOWLEDGMENT

I am extremely grateful for the support and mentoring I received from my co-major advisors and committee chairs, Dr. Ron C. Mittelhammer and Dr. Stephen Devadoss during my Ph.D. program. Their enthusiasm, dedication, and hard work truly enhanced my education and made me a better researcher and economist. They spent countless hours helping and encouraging me throughout every aspect of the research process, allowing me to achieve goals beyond my expectations. Dr. Stephen Devadoss deserves special acknowledgment for going above and beyond the expectations of a major professor. His dedication to students in every aspect of their education is unparalleled. Since I met him seven years ago, he has done everything in his power to help me achieve my professional goals. I am extremely grateful to have him as a major professor and mentor.

I am very thankful to my committee member, Dr. Mark J. Gibson. The courses he taught inspired several research topics. He was both supportive of my ideas and provided constructive advice, which enhanced the depth and quality of our work.

I would like to acknowledge the Agricultural Food Research Initiative of the National Institute of Food and Agriculture, Grant # 2010-65400-20431, for financial support during the research phase of my dissertation.

I thank the staff, Danielle Engelhardt, Ben Weller, Jaimie Dahl, and others of the School of Economic Sciences for their support and help during my study in the Ph.D. program.

I thank my classmates and friends at the School of Economic Sciences who helped broaden my understanding of economics through discussion and seminars. Jude Bayham and Xiaojiao Jang deserve special recognition for the countless hours spent discussing economics and research problems; these interactions made me a better economist.

ESSAYS IN POLICY ANALYSIS: STRATEGIC TRADE THEORY AND THE
ELIMINATION OF AGRICULTURAL SUBSIDIES

Abstract

by Jeffrey Allen Luckstead, Ph.D.
Washington State University
May 2013

Co-Chairs: Ron C. Mittelhammer and Stephen Devadoss

The purpose of this dissertation is to advance the understanding of the impacts of trade and domestic policies on production, trade, welfare, and productivity. The first chapter summarizes and extends the New Empirical Industrial Organization (NEIO) literature by showing that the cost function specification plays a crucial role in identifying the market power parameter in both autarky and trade models.

The second chapter uses a strategic trade policy framework and the NEIO literature to analyze the oligopolistic competition between U.S. and Chinese apple exporters in the Association of Southeast Asian Nations (ASEAN) and in their domestic apple markets. A theoretical model is defined and quantitative results are derived for changes in ASEAN tariffs on imports of U.S. and Chinese apples and the latter countries' subsidies. A structural econometric model is estimated and simulated to quantify the effects of changes in the tariffs and subsidies on trade flows, price, and welfare.

The third paper develops a strategic trade model based on the new trade theory to analyze competition between Florida and São Paulo processors in the U.S. orange juice market and São Paulo processors in the European orange juice market. Comparative static results are derived to analyze the effect of a reduction in the U.S. and European tariffs on sales and welfare in the United States, São Paulo, and Europe. A structural econometric model is specified, and the

NEIO literature is utilized to identify the market power parameters. The estimated structural model is simulated to quantify a reduction in the U.S. and European tariffs.

The fourth chapter analyzes the short- and long-run effects of various subsidies by developing a dynamic general equilibrium model with firm-level productivity shocks and endogenous entry and exit. Measurement statistics are specified for welfare, real gross domestic product, and total factor productivity to make the analysis resemble the data-based measurements macroeconomist typically implement. The model is calibrated to a general and widely accepted set of functional forms and parameters. The impacts of the elimination of subsidies are quantified by numerically solving the model for both steady state values and equilibrium transition paths for the above measurement statistics.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	iii
ABSTRACT.....	iv
LIST OF TABLES.....	x
LIST OF FIGURES.....	xi
DEDICATION.....	xii
CHAPTER	
1 Introduction.....	1
1.1 Background.....	1
1.2 Strategic Trade Policy.....	2
1.2.1 Chapter 2 Summary.....	4
1.2.2 Chapter 3 Summary.....	4
1.2.3 Chapter 4 Summary.....	6
1.3 Firm-Level Heterogeneity and Endogenous Entry and Exit.....	7
1.3.1 Chapter 5 summary.....	9
2 Econometric Issues Related to Identification of the Market Power Parameter.....	12
2.1 Introduction.....	12
2.2 Autarky Models.....	13
2.2.1 Aggregation.....	14
2.2.2 Constant Marginal Cost.....	14
2.2.3 Linear Marginal Cost.....	16
2.2.4 Marginal Cost with Interactive Quantity.....	18

2.3	Trade Models	20
2.4	Past Studies of Market Power Estimation.....	24
2.5	Conclusions.....	25
3	U.S. and Chinese Strategic Trade Policies and Product Differentiation in the ASEAN	
	Apple Market.....	26
3.1	Introduction.....	26
3.2	Model	30
3.3	Analytical results	32
3.3.1	Welfare Analysis of Subsidies.....	36
3.4	Econometric Specification.....	37
3.5	Quantitative Results	40
3.5.1	Data	40
3.5.2	Estimation	42
3.5.3	Lerner Index.....	46
3.5.4	Simulation Results	50
3.6	Conclusions.....	53
3.7	Appendix.....	54
3.7.1	Comparative Statics	55
3.7.2	Optimal Subsidy.....	59
4	Imperfect Competition between Florida and São Paulo (Brazil) Orange Juice Producers	
	in the U.S. and European Markets.....	60
4.1	Introduction.....	60
4.2	Theoretical Analysis	64

4.2.1	Strategic Trade Model	64
4.2.2	Tariff Analysis.....	65
4.3	Empirical Analysis.....	69
4.3.1	Econometric Model	70
4.3.2	Data	72
4.3.3	Estimation.....	74
4.3.4	Lerner Index	77
4.3.5	Simulation Results.....	79
4.4	Conclusions.....	82
4.5	Appendix.....	83
4.5.1	Comparative Statics.....	83
4.5.2	Welfare Analysis of Tariff Changes.....	87
5	The Dynamics of Subsidy Removal with Heterogeneous Firms	91
5.1	Introduction.....	91
5.2	Model.....	94
5.2.1	Consumers	94
5.2.2	Firms.....	95
5.2.3	Bank.....	96
5.2.4	Government	98
5.2.5	Market-Clearing Conditions.....	98
5.2.6	Equilibrium.....	98
5.3	Measurement.....	99
5.3.1	Social Welfare	99

5.3.2	Gross Domestic Product.....	99
5.3.3	Total Factor Productivity.....	101
5.4	Calibration.....	102
5.5	Policy Experiments	103
5.5.1	Lump-Sum Operating Subsidy.....	105
5.5.2	Output Subsidy.....	106
5.5.3	Intermediate Input Subsidy	107
5.5.4	Interest Rate Subsidy.....	108
5.5.5	Comparison to a Representative Firm Model.....	109
5.5.6	Transition Dynamics and Growth Accounting.....	110
5.6	Conclusions.....	112
5.7	Appendix.....	113
5.7.1	Algorithm for Calculating the Steady State	114
5.7.2	Algorithm to Calculate the Transition Dynamics.....	115
BIBLIOGRAPHY.....		117

LIST OF TABLES

3.1	Variable Definitions.....	44
3.2	U.S. and Chinese Apple Exports to ASEAN.....	45
3.3	Demand Flexibilities and Conjectural Elasticities for ASEAN.....	46
3.4	U.S. and Chinese Domestic Apple Markets.....	47
3.5	U.S. and Chinese Domestic Markets.....	47
3.6	Lerner Indices for the Export Market.....	49
3.7	Simulation Results of Tariff and Transport Cost Changes.....	51
3.8	Simulation Results of Production Subsidies.....	53
4.1	Variable Definitions.....	75
4.2	U.S. and European Demand Functions.....	76
4.3	Supply Relation for Florida Processors.....	76
4.4	Supply Relations for Sao Paulo Processors.....	78
4.5	Impacts of Tariff Reductions, Ave. 2006-09.....	80
5.1	Calibration of the Model.....	102
5.2	Long-Run Effects: Steady State Comparison.....	104
5.3	Measure of Firms, Percent of Total Measure.....	105
5.4	Change in Welfare with Subsidy Removal.....	105
5.5	Comparison of the HF and RF Models, Percentage Changes.....	110
5.6	Welfare Comparison.....	111
5.7	Welfare Comparison for Various Time Lengths Before Reform.....	112

LIST OF FIGURES

2.1 Market Power is Identified for Constant Marginal Cost.....	16
2.2 Identification of Market Power with Non-Constant Marginal Cost	19
2.3 Identification of Market Power in Trade Models	23
3.1 U.S., Chinese, and Southern Hemisphere Market Shares in ASEAN	27
3.2 U.S. and Chinese Lerner Indexes.....	50
5.1 Comparison of TFP.....	110
5.2 Growth Accounting, Output Subsidy Case.....	112

Dedication

I dedicate this dissertation to my wife, Jenny Jo Morrison, and my mother and father, Mary and Steven Luckstead, who provided unwavering encouragement and emotional and financial support throughout the Ph.D. program.

Chapter 1

Introduction

1.1 Background

In recent decades, governments in both developed and developing countries have made strides toward market liberalization by reducing and removing trade and domestic distortions. Examples of this liberalization include the establishment of free trade areas, such as the North American Free Trade Area and the Association of South East Asian Nations, and the restructuring of domestic policies, such as the movement toward decoupled subsidies in U.S. and European agriculture and the removal of agricultural subsidies in New Zealand. The market structure that is used to evaluate these reforms has significant implications for both the direction and magnitude of these policy changes on economic variables (Russo et al., 2011; Sexton et al., 2007).

The goal of this dissertation is to advance the understanding of the impact of trade and domestic policies on supply, demand, trade, welfare, and productivity under two distinct market structures: imperfect competition and firm heterogeneity. First, using a strategic trade policy framework, the degree of imperfect competition in the fresh apple market in the United States, China, and the Association of Southeast Asian Nations and also in the frozen concentrated orange juice market in the United States, Brazil, and Europe are examined theoretically and estimated econometrically. Then, for each of the above markets, based on the estimated market structure, the effects of changes in tariffs and subsidies are analyzed. Second, a dynamic general equilibrium model with firm-level heterogeneity and endogenous entry and exit is developed to understand the short-run (transition dynamics) and long-run (steady state) implications of agricultural policies such as the decoupling and elimination of subsidies on firm entry and exit, value added, industry-level productivity, and welfare.

The following sections elaborate on the theoretical and quantitative methods used for studying the strategic trade policies of Chapters 2, 3, and 4 and firm-level heterogeneity with endogenous entry and exit of Chapter 5.

1.2 Strategic Trade Policy

Until the mid 1970s, international trade policy analyses were performed under the assumption of perfect competition. The implication is that all distortionary policies reduce welfare for both the domestic and foreign countries (Grossman and Rogoff, 1995). However, developments in industrial organization in monopolistic competition and taste for variety in the mid-1970s (Dixit and Stiglitz, 1977) set the stage for seminal advances in international trade theory in the late 1970s and 1980s. These advances led to *new trade theory* which analyzes international trade under imperfectly competitive market structures and shows that countries with similar factor endowments and comparative advantages engage in trade in similar products (Krugman, 1979, 1980; Lancaster, 1980). The assumption of imperfectly competitive markets also had profound implications for international trade policy analyses.

By assuming oligopolistic competition, Brander (1981) extended new trade theory by deriving two-way trade, or cross-hauling, in homogenous products. In this context, firms act strategically by influencing the market through manipulation of their output or price to maximize profits. A groundbreaking result in international trade policy analysis was derived by Brander and Spencer (1985), who showed that under oligopolistic competition in a third market, export subsidies offered by the home country's government can be welfare improving for the home country at the expense of the foreign country. This result is driven by the home country capturing part of the foreign country's market share as output expands, leading to higher profits, which can outweigh the subsidy cost and production inefficiencies. This phenomenon is known as rent shifting in the new trade theory. For the first time, a result contradictory to the perfectly competitive environment in trade policy analysis was derived. From this seminal work, theoretical and empirical research known as *strategic trade policy* flourished (Eaton and Grossman, 1986; Flam and Helpman, 1987;

Dick, 1993; Krugman and Smith, 1994). Strategic trade policy is defined by Spencer and Brander (2008), as "trade policy that affects the outcome of strategic interactions between firms in an actual or potential international oligopoly." A very common example is the wide-bodied aircraft trade dispute, where Boeing and Airbus are duopolists in the world market. Both the U.S. and European governments implicitly subsidize these companies to gain a competitive edge, which helped Boeing and Airbus strategically compete against each other (Baldwin and Krugman, 1988; Klepper, 1990; Spencer and Brander, 2008). While strategic trade policy was a common tool for analyzing industrial sectors throughout the late 1980s and 1990s, it was not commonly used in international agricultural policy analysis, even though strategic interaction is common in food production and marketing chains, such as the Canadian Wheat Board and large U.S. food multinational companies.

Chapters 2-4 extend the theoretical and empirical methods of strategic trade policy to analyze the imperfect competition in two agricultural markets: fresh apples and orange juice. For these analyses, strategic trade policy models are developed and analytical results are derived. From these models, structural econometric models are formulated to estimate and statistically test the degree of oligopolistic competition and market power. The structural econometric model requires simultaneous estimation of a system of supply relations and demand functions. The supply relations equate market price to marginal cost plus a markup term that consists of price elasticities of demand and market power parameters. In the econometric estimation, market power parameters are not necessarily identified and require careful consideration. Empirical methods known as the *new empirical industrial organization* (NEIO), which were developed about the same time as the new trade theory was advanced, are used to identify and estimate the parameters of the econometric models. The estimated econometric model is then simulated to quantify the magnitude of the impacts of trade policies such as tariffs and subsidies on quantities, prices, and welfare.

The following subsections summarize Chapter 2, which covers identification of market power, Chapter 3, which studies the strategic trade policies in the apple market, and Chapter 4, which examines the strategic trade policies in the frozen concentrated orange juice market.

1.2.1 Chapter 2 Summary

The pioneering NEIO work by Appelbaum (1982) estimated market power using output and input demand functions and a supply relation with constant marginal cost and by Bresnahan (1982) showed that to identify the market power parameter for a supply relation with a linear marginal cost function, a rotation of the demand curve is necessary.

Chapter 2 demonstrates the crucial role the specification of the cost function plays in identifying the market power parameter in both autarky and trade models. First, the current identification strategies used for autarky models are discussed. For a constant marginal cost function, the market power parameter is identified for all specifications of the demand curve. However, when the marginal cost is non-constant, the market power parameter is not automatically identified. The current identification strategy is to shift and rotate the demand curve through an exogenous variable interacting with the right-hand-side endogenous variable.

Second, the identification strategies for non-constant marginal cost functions are extended by showing mathematically and graphically that identification is also achieved by interacting quantity and an input price in the marginal cost function regardless of the demand specification.

Finally, it is shown mathematically and graphically that if a commodity is sold in both the domestic and foreign markets, the market power parameters are identified regardless of the specific form of the marginal cost and demand specifications.

1.2.2 Chapter 3 Summary

Oligopolistic competition between U.S. and Chinese exporters in the Association of Southeast Asian Nations (ASEAN) fresh apple market is analyzed using strategic trade theory and the NEIO literature. Competition in the U.S. and Chinese domestic markets is also analyzed. All fresh apples consumed in ASEAN are imported because the tropical climate in Southeast Asia is not conducive to apple production. Over the sample period, 1986 to 2009, U.S. and Chinese apple exporters dominated the ASEAN fresh apple market. Due to differences in sanitary and phytosanitary conditions and grading standards in the United States and China, apples are differentiated by

quality in ASEAN, and U.S. apples are considered to be of higher quality than Chinese apples.

Both trade and domestic policies play an important role in the fresh apple market. During the sample period, both U.S. and Chinese apples were subject to applied tariffs by ASEAN ranging between 5 and 30 percent. However, the Chinese-ASEAN free trade area is set to remove all tariff and nontariff barriers on Chinese apples in 2015. Both U.S. and Chinese apple production have received subsidies. U.S. apple producers received market loss payments totaling \$262 million between 2001 and 2004. Chinese apple producers received a 2 million yuan subsidy to purchase apple seedlings in 1984 and apple bagging subsidies in the late 1990s and early 2000s.

To analyze the degree of market power that U.S. and Chinese apple producers exert in the ASEAN market and their domestic markets, a strategic trade policy model is developed. The analytical results show that higher ASEAN tariffs and transport costs for a country contracts its exports and expands its domestic sales. In contrast, the competitor's exports expand, but its domestic sales fall. An increase in the production subsidy in one country expands exports to ASEAN and domestic sales, which displaces the rival's exports to ASEAN.

The structural econometric model is derived from the strategic trade policy model, and the NEIO literature is implemented to address the issue of identification of the market power parameters. The econometric model is estimated simultaneously, and market structure is calculated through the Lerner Index. The empirical results show that U.S. exporters earned oligopolistic rents in ASEAN through the late 1990s, but these rents decreased beginning in 2000 as the market share of Chinese apples increased significantly. Chinese exporters followed marginal cost pricing through the mid-1990s during a time of low market shares; however, as their market share expanded, their markup increased dramatically and surpassed that of the United States in 2001. In the U.S. and Chinese domestic markets, the Lerner Indexes are zero, implying that apples are competitively priced.

The structural model is simulated to quantify the impact of 1) elimination of the ASEAN tariff on Chinese apples and 2) a 10 percent increase in the U.S. and Chinese subsidies. The simulation results are qualitatively consistent with the analytical predictions. The elimination of

the tariff by ASEAN on Chinese apples augments ASEAN imports from China by 13.81 percent and the price of Chinese apples declines by 11.68 percent. Conversely, U.S. apple exports to ASEAN decline by 19.24 percent and the U.S. apple price increases by 1.46 percent. A country's subsidy expands its production, which increases its exports and welfare at the expense of the other country's export sales and welfare. The results show a 10 percent increase in U.S. (Chinese) apple subsidy increases U.S. (Chinese) welfare by \$13 (\$47) million and decreases Chinese (U.S.) welfare by \$4 (\$5) million.

1.2.3 Chapter 4 Summary

Over 90 percent of the frozen concentrated orange juice (FCOJ) sold in the United States is supplied by a small number of processors located in Florida and São Paulo (Brazil). These two states are the largest orange juice producing states in the world. Florida exports minimal amounts of FCOJ because of the high level of per capita consumption in the United States. São Paulo, in addition to exporting to the United States, also supplies the majority of European FCOJ market. The U.S. and European governments impose tariffs of \$0.2971 per SSE (single strength equivalent) gallon and 15.2 percent, respectively, as of 2000.

Based on the new trade theory, a strategic trade model is developed to analyze the oligopolistic competition between Florida and São Paulo processors in the U.S. FCOJ market and São Paulo processors in the European FCOJ market. Analytical results for reductions in the U.S. and European tariffs are derived for sales and welfare changes for the United States, São Paulo, and Europe. A reduction in the U.S. tariff increases São Paulo's exports to the United States while decreasing its exports to Europe. As a result, Florida's sales in the United States contract. Net U.S. welfare is ambiguous because Florida's processors lose and U.S. consumers gain while tariff revenues are indeterminate. Since São Paulo captures market share from Florida in the United States, its welfare increases, even though its exports to and profits from Europe decline. The loss in European consumer surplus and tariff revenues leads to a net welfare decline.

A decrease in the European tariff expands São Paulo's exports to Europe and reduces its

exports to the United States, which augments Florida's sales in the United States. Net U.S. welfare is analytically indeterminate because this tariff reduction causes Florida's producers to gain, U.S. consumers to lose, and tariff revenues to decrease. A reduction in the European tariff has an ambiguous effect on São Paulo's welfare because São Paulo's profit in Europe increases but its profit in the United States decreases as a result of loss in market share. The rationale for this result is that São Paulo cannot capture the market share from European processors as there is no European FCOJ production. The change in European welfare is also ambiguous because, though the consumers benefit from the tariff reduction, the tariff revenues can increase or decrease.

From the theoretical model, the structural econometric model is derived, and the NEIO literature is utilized to identify the market power parameters. The econometric model is estimated as a system of supply relations and demand functions. The Lerner Index suggests that both Florida and São Paulo processors mark the U.S. price of FCOJ over their marginal costs and earn oligopolistic rents. However, because São Paulo processors are more concentrated and have lower input costs, they have a greater markup over their marginal costs. Furthermore, São Paulo exporters earn oligopolistic rents in the European market.

The structural model is simulated to analyze a reduction in the U.S. and European tariffs. A 25 percent decline in the U.S. tariff results in a 26.58 percent increase in São Paulo's market share and an 8.27 percent decrease in Florida's market share in the U.S. FCOJ market. São Paulo's exports to Europe decline by 10.65 percent. As a result of this trade liberalization, U.S. and São Paulo net welfare increase by \$25.44 million and \$12.76 million, respectively, while European welfare falls by \$41.42 million. A 25 percent reduction in the European tariff causes São Paulo to expand its exports to Europe by 61.16 percent and contract its U.S. market share by 5.90 percent, which augments Florida's U.S. market share by 1.88 percent. European and São Paulo net welfare rise by \$202.33 million and \$19.78 million, while U.S. welfare falls by \$7.03 million.

1.3 Firm-Level Heterogeneity and Endogenous Entry and Exit

Hopenhayn and Rogerson (1993) develop a dynamic general equilibrium model with firm-level

heterogeneity and endogenous entry and exit to analyze long-run firm and industry dynamics.¹ This model accounts for the observed firm-level size data of high turnover of both employees and firms while aggregation to the industry level remains highly tractable. As established firms fall behind the productivity frontier, they contract and exit. Resources are reallocated to new entrants and expanding firms. The model features productivity shocks resulting in firm-specific uncertainty. Firm entry requires a sunk investment cost, and optimal exit decisions are based on the history of the productivity shocks.

Hopenhayn and Rogerson (1993) build on the equilibrium theory of industry evolution, firm-specific uncertainty, and firm-level entry and exit developed in the 1970s and 1980s. Lucas and Prescott (1971) are the first to develop a theory of industry evolution. The model in Lucas (1978) explains the observed size distribution of firms, while Brock (1972) and Smith (1974) are the first to propose dynamic models of firms entry and exit. Jovanovic (1982) develops the first theory with firm-level productivity shocks that evolve according to a stochastic process. Pakes and Ericson (1998) consider a model featuring entry and exit that is driven by an uncertain outcome in firm-specific investment. While these models are seminal in understanding firm-level dynamics, they are too complicated to analyze industry-level dynamics.

Since the early 1990s, studies incorporating firm-level heterogeneity have proliferated. There is a growing literature that focuses on the link between factor misallocation and cross-country differences in productivity and GDP per worker (Guner et al., 2008; Restuccia and Rogerson, 2008; Fattal, 2012; Da Rocha and Pujolas, 2011; Buera et al., 2013). These papers have two commonalities: 1) they feature a dynamic model with heterogenous firms and 2) the government imposes idiosyncratic policies—generally, the high-productivity firms are taxed while the low-productivity firms are subsidized. This policy scheme leads to unique prices for each firm and reallocates resources across establishments. This literature shows that these policies reduce the average size of establishments, output per firm, and productivity.

The model developed in Chapter 5 is also related to work by Chu (2003) and Gourio and

¹The seminal work by Hopenhayn (1992) is a key element of this model.

Miao (2011). Chu (2003) considers a dynamic two-sector (industrial and agricultural) general equilibrium model with firm-level heterogeneity and endogenous entry and exit in the industrial sector to analyze the effect of an import substitution policy on equilibrium transition paths of aggregate GDP, real income, the measure of entrants and firms, capital, and the real wage. A subsidy in the industrial sector supports low-productivity firms and results in economy wide inefficiencies. In the long-run, this policy drives down GDP and has high dynamic welfare costs. Gourio and Miao (2011) develop a dynamic model with heterogeneous firms to analyze the optimal transition path of a cut in a dividend tax and capital gains tax. Two cases for the tax cuts are considered: 1) permanent and unexpected and 2) temporary and unexpected. In the first case, aggregate quantities of output, consumption, labor, investment, and capital increase in the long run. However, in the second case, steady state values remain unchanged, but in the short run, temporary changes to the tax code cause aggregate investment to decrease, dividend payments to increase, and aggregate labor, capital, and output to rise.

The next subsection summarizes Chapter 5, which analyzes the implication of subsidies in a heterogeneous firms model with entry and exit.

1.3.1 Chapter 5 Summary

Recently, some countries have made strides to reform their agricultural policies. For example, both U.S. and European governments have decoupled their agricultural subsidies to minimize market distortions (Femenia et al., 2010). Static models show that this farm policy eliminates market distortions. However, decoupled subsidies influence agricultural producers' entry and shutdown decisions, which lead to both short- and long-run distortions. Another prominent example is New Zealand's restructuring of its economy in 1984 in response to a decade long great depression (Evans et al., 1996). The agricultural sector was at the center of the reforms, which eliminated all subsidies. Prior to these reforms, extensive agricultural subsidies caused inefficient input and output decisions and propped up low-productivity firms that would have otherwise exited, which induced additional market distortions. These policy reforms in the United States, Europe, and

New Zealand have had significant implications for productivity and welfare.

The goal of this chapter is to analyze the short- and long-run effects of income, output, input, and interest rate subsidies on an economy. This is accomplished by 1) developing a dynamic general equilibrium model with firm-level productivity shocks and endogenous entry and exit and 2) specifying measurement statistics for welfare, real GDP, and total factor productivity (TFP) to make the analysis resemble the data-based measurements macroeconomists typically implement. Based on the model specification and measurement statistics, TFP is decomposed into two components: the reallocation of resources from low- to high-productivity firms and the adjustment in the scale of the firms. The model is calibrated to a general and widely accepted set of functional forms and parameters. Then, the impact of the elimination of each of the subsidies is quantified by simulating the model to solve for both the steady-state values and the equilibrium transition dynamics. The transition path of the above model is also compared to the path of same model redefined with a representative firm.

For each of the subsidy cases, the numerical simulation proceeds as follows: First, solve for the initial steady state with the subsidy in place. Second, remove the subsidy and re-solve the steady state. Third, solve for the equilibrium transition path using the pre- and post-reform steady states as initial and terminal conditions, respectively. The first and second steps characterize the long-run dynamics and the third step defines the short-run transition impacts of the policy reform.

The simulation analysis leads to five key conclusions. First, the more directly the subsidy affects profits, and thus the value of the firm, the smaller the subsidy, in terms of percent of real GDP, needs to be for low-productivity firms to operate. Second, if the full transition path is not taken into account, welfare gains are understated or negative. For example, comparison of the pre- and post-reform steady states of a 13.3 percent output subsidy removal suggests that real income declines by 1.0 percent, but the lifetime real income increases by 2.2 percent over the full transition path. Third, for the output subsidy removal, the representative-firm model understates productivity gains by a factor of 2.7 relative to the heterogeneous-firms model. Also, an income subsidy is non-distortionary in the representative-firm model, and thus to fully ascertain the distortionary effect

of this subsidy, a heterogeneous-firms model must be considered. Fourth, the elimination of the subsidies causes TFP to decline in the short-run but to gain substantially in the long-run. The results of the output subsidy removal show that resource reallocation from low- to high-productivity firms accounts for 0.7 percent of the productivity gain, while the adjustment in the scale of the firms augments productivity by 3.2 percent. Fifth, productivity effects are smaller while welfare impacts are more pronounced if the interval between the announcement and implementation of the reform is shorter.

Given our results, income (decoupled) subsidies, as pursued by the United State and European Union, continue to distort the agriculture sector by causing adverse effects on measured TFP and welfare. In fact, because inefficient firms find it optimal to operate at a lower subsidy level, a decoupled subsidy that is equal to the same percent of real GDP as an output or input subsidy will lead to larger distortions in measured TFP and welfare than those caused by an output or input subsidy. Thus, claiming decoupled subsidies are non-distortionary is not valid, and therefore eliminating all agricultural subsidies is the most efficient policy approach as undertaken by New Zealand.

Chapter 2

Econometric Issues Related to Identification of the Market Power Parameter

2.1 Introduction

Pioneering work by Appelbaum (1982) and Bresnahan (1982) in the new empirical industrial organization literature dealt with econometric issues in estimating market power. Appelbaum (1982) estimated output and input demand functions and a supply relation with constant marginal cost which allowed him to estimate the market power parameter in his model. Bresnahan (1982) implemented an output demand function and a supply relation with linear marginal cost and showed that a rotation of the demand curve is necessary to identify the market power parameter. Since these two studies, empirical estimation of market power has proliferated, and most of these studies have focused on estimating market powers in specific industries (Bresnahan, 1989; Sheldon and Sperling, 2003).

In this study we present new insights into how the market power parameter can be identified in econometric models with and without trade. First, we underscore the crucial role that the specification of the marginal cost function plays in identifying market power when an industry operates solely in the domestic market, i.e., under autarky. To lay the foundation for our analysis, we discuss the identification process for a constant marginal cost as in Appelbaum (1982) and a linear marginal cost as in Bresnahan (1982). Second, we offer a new identification strategy using a marginal cost in which quantity interacts with input prices. Third, we demonstrate that identification of the market power parameter can be achieved for general specifications of marginal cost and demand functions if the industry being modeled sells in both foreign and domestic markets. Finally, we cover past studies, which are good applications of market power estimations, but do

not explicitly discuss the identification process as described in our study. Consequently, we relate their empirical estimation to the identification methods delineated in our paper.

2.2 Autarky Models

This section presents identification requirements of the market power parameter for autarky models for three types of marginal cost functions—constant, linear, and interactive marginal costs.

Consider the firm-level profit:

$$\pi^i = P(Q, \mathbf{Y}) q_i - C^i(q_i, \mathbf{w}), \quad i = 1, \dots, m \quad (2.1)$$

where $P(\cdot)$ is the demand function, P is the price, Q is the quantity demand, \mathbf{Y} is a vector of demand shifters, q_i is the firm-level output, $C^i(\cdot)$ is firm-level cost function, and \mathbf{w} is a vector of input prices. The first-order condition for a given firm is to equate the perceived marginal revenues to marginal costs:

$$P(Q, \mathbf{Y}) + q_i P'(Q, \mathbf{Y}) \frac{\partial Q}{\partial q_i} = MC^i(q_i, \mathbf{w}) \quad (2.2)$$

where $P'(Q, \mathbf{Y}) = \frac{\partial P(Q, \mathbf{Y})}{\partial Q}$ and $MC^i(\cdot)$ is the marginal cost function. Multiplying 2.2 by $\frac{Q}{P}$ and $\frac{P}{P}$, the firm-level supply relation is

$$P = MC^i(q_i, \mathbf{w}) - \frac{\partial Q}{\partial q_i} \frac{q_i}{Q} \frac{P'(Q, \mathbf{Y})}{P} Q P. \quad (2.3)$$

Substituting the firm-level conjectural elasticity, $\lambda_i = \frac{\partial Q}{\partial q_i} \frac{q_i}{Q}$, and price flexibility, $\varepsilon = -\frac{P'(Q, \mathbf{Y})}{P} Q$, into (2.3) yields:

$$P = MC^i(q_i, \mathbf{w}) + \lambda_i \varepsilon P. \quad (2.4)$$

As shown by the second term on the right-hand-side of (2.4), a downward sloping demand function is not sufficient for a firm to exercise market power, and we must consider the interaction of the conjectural elasticity and demand flexibility. Under perfect collusion or monopoly, $q_i = Q$ and $\lambda_i = \frac{\partial Q}{\partial Q} \frac{Q}{Q} = 1$ and the firm's ability to price above marginal costs depends solely on the price flexibility. Under Cournot competition, a firm perceives that its output does not influence the

other firm's output decisions, and $\frac{\partial Q}{\partial q_i} = 1$ and $\lambda_i = \frac{q_i}{Q}$. A firm's ability to price above marginal costs depends on the demand flexibility weighted by its market share. Making no market structure assumption, $\lambda_i = \frac{\partial Q}{\partial q_i} \frac{q_i}{Q}$, and a firm's ability to price above marginal costs depends on the demand flexibility weighted by the conjectural elasticity. Under perfect competition $\lambda_i = 0$, and price equals marginal cost.

2.2.1 Aggregation

Since firm-level data is generally not available, most studies use industry-level supply relations, which can be derived by aggregating firm-level decisions. Multiplying (2.4) by firm i 's market share $\left(\frac{q_i}{Q}\right)$ and aggregating, we obtain

$$P \sum_{i=1}^m \frac{q_i}{Q} = \sum_{i=1}^m \frac{q_i}{Q} MC^i(q_i, \mathbf{w}) - \varepsilon P \sum_{i=1}^m \lambda_i \frac{q_i}{Q}. \quad (2.5)$$

Substituting the industry-level average marginal cost, $MC(Q, \mathbf{w}) = \sum_{i=1}^m \frac{q_i}{Q} MC^i(q_i, \mathbf{w})$, and industry-level conjectural elasticity, $\lambda = \sum_{i=1}^m \frac{q_i}{Q} \lambda_i$, into (2.5), the industry supply relation is

$$P = MC(Q, \mathbf{w}) + \varepsilon \lambda P. \quad (2.6)$$

To specify estimable supply relations, the cost and demand functions need to be defined. Three types of cost functions are considered, from which the marginal cost functions are derived, and appropriate demand functions are presented.

2.2.2 Constant Marginal Cost

Appelbaum (1982) estimates market power using a system of equations containing output and input demand functions and a supply relation with a constant marginal cost derived from the Generalized-Leontief cost function. To build the foundation of the analysis, we show both mathematically and graphically the identification process for the constant marginal cost

$$MC(\mathbf{w}) = \sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2}, \quad (2.7)$$

derived from the Generalized-Leontief cost function

$$C(Q, \mathbf{w}) = \sum_{j=1}^n b_j w_j + \left[\sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2} \right] Q.$$

The linear inverted-demand function is

$$P = \gamma_0 + \gamma_1 Q + \gamma_2 Y. \quad (2.8)$$

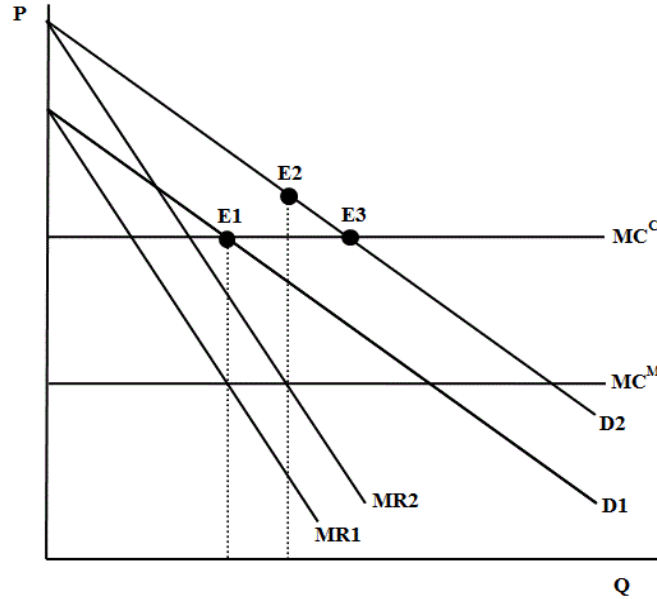
Substitute the marginal cost function (2.7) and the flexibility derived from the demand function (2.8) into (2.6) to obtain the supply relation

$$P = \sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2} - \lambda \gamma_1 Q. \quad (2.9)$$

Econometric analysis requires simultaneous estimation of the demand function (2.8) and supply relation (2.9). The parameters in the demand function are identified because the number of excluded exogenous variables ($\frac{n(n+1)}{2}$ variables of $w_j w_k$ s) is greater than or equal to the number of endogenous variables (P and Q) minus one. The parameters in the supply relations including $\lambda \gamma_1$ are also identified because the number of excluded exogenous variables (Y) is equal to the number of endogenous variables (P and Q) minus one. From the demand function γ_1 is estimated, and from the supply relation $\lambda \gamma_1$ is estimated as a single combined estimate. By dividing the estimate of $\lambda \gamma_1$ by the estimate of γ_1 , the conjectural elasticity λ is identified.

Figure 2.1 illustrates the above identification process. First consider the competitive marginal cost MC^C , monopoly marginal cost MC^M , demand curve D1, and the corresponding marginal revenue curve MR1. For these curves, the initial reference equilibrium for the competitive and monopoly markets are the same at E1. If the demand curve shifts from D1 to D2 due to changes in demand shifters, the corresponding marginal revenue curve changes from MR1 to MR2. The new competitive equilibrium is at E3 and the monopoly equilibrium is at E2. Thus, the supply function for the competitive market traces E1 and E3, whereas the supply relation for the monopoly market traces E1 and E2. This illustration shows that the competition and monopoly equilibriums are observationally different, and that market power is identified under monopoly (also see Sheldon and Spurling (2003) for this graphical analysis).

Figure 2.1: Market Power is Identified for Constant Marginal Cost



2.2.3 Linear Marginal Cost

Bresnahan (1982) shows mathematically and graphically that under autarky with linear marginal cost and demand functions, the market power parameter cannot be identified, and to remedy this problem, he implements a rotation of the demand curve through an exogenous variable interacting with the right-hand-side endogenous variable. We review Bresnahan's analysis to facilitate the identification processes discussed in the subsequent sections.

Consider the quadratic cost function

$$C(Q, \mathbf{w}) = \frac{1}{2}b_0Q^2 + Q \sum_{j=1}^n b_jw_j,$$

which yields a linear marginal cost

$$MC(Q, \mathbf{w}) = b_0Q + \sum_{j=1}^n b_jw_j. \quad (2.10)$$

This marginal cost function is similar to the one utilized by Bresnahan (1982). For this marginal cost function and the demand function (2.8), the supply relation (2.6) becomes

$$P = b_0Q + \sum_{j=1}^n b_jw_j - \lambda\gamma_1Q. \quad (2.11)$$

Combining the coefficients on Q into one term, the supply relation is rewritten

$$P = \sum_{j=1}^n b_j w_j + (b_0 - \lambda \gamma_1) Q. \quad (2.12)$$

The demand function (2.8) and supply relation (2.12) are simultaneously estimated. The demand function is identified because the number of excluded variables (n variables of w_j s) is greater than or equal to the number of endogenous variables (P and Q) minus one. The supply relation is also identified because the number of excluded exogenous variables (Y) is equal to the number of endogenous variables (P and Q) minus one. However, the conjectural elasticity (λ) is not identified. From the demand function, γ_1 is estimated and from the supply relation, $(b_0 - \lambda \gamma_1)$ is estimated as a single estimate. From these two estimates, the conjectural elasticity λ and the marginal cost coefficient b_0 cannot be identified. Bresnahan (1982) provides a graphical analysis of this non-identification. To remedy this problem, he proposes a demand function with an exogenous variable interacting with right-hand-side endogenous variable:

$$P = \gamma_0 + \gamma_1 Q + \gamma_2 Y + \gamma_3 Q Z + \gamma_4 Z, \quad (2.13)$$

where Z is the price of a substitute or complement good. Substitution of the marginal cost function (2.10) and the flexibility from the demand function (2.13) into (2.6) yields the following supply relation

$$P = b_0 Q + \sum_{j=1}^n b_j w_j + \lambda Q^*, \quad (2.14)$$

where $Q^* = -(\gamma_1 + \gamma_3 Z) Q$. The demand function is identified because the number of excluded exogenous variables (n variables of w_j s) is greater than or equal to the number of endogenous variables (P and Q) minus one. The parameters in the supply relations are also identified because the number of excluded exogenous variables (Y and Z) are equal to the number of endogenous variables (P , Q , and Q^*) minus one. With the interaction term Z , estimation of the demand function (2.13) and supply relation (2.14) will yield separate estimates of γ_1 , γ_3 , λ , and b_0 . Thus, the conjectural elasticity and the marginal cost coefficients are uniquely identified because of the rotation of the demand curve as captured by $\gamma_3 Z$. Bresnahan (1982) also illustrates graphically

this identification process. Consequently, if the marginal cost is linear and only the domestic market is considered, where quantity demand is equal to quantity supplied, Bresnahan's approach of rotating the demand curve is essential for identification of the conjectural elasticity.

2.2.4 Marginal Cost with Interactive Quantity

In this subsection, we show mathematically and graphically a new identification strategy for the market power parameter. This strategy exploits a marginal cost function that has quantity entering interactively with input prices. Consider a modified version of the Generalized-Leontief cost function

$$C(Q, \mathbf{w}) = Q \sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2} + \frac{1}{2} Q^2 \sum_{j=1}^n b_j w_j,$$

which yields the following marginal cost

$$MC(Q, \mathbf{w}) = \sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2} + Q \sum_{j=1}^n b_j w_j. \quad (2.15)$$

For this marginal cost function and the following demand function

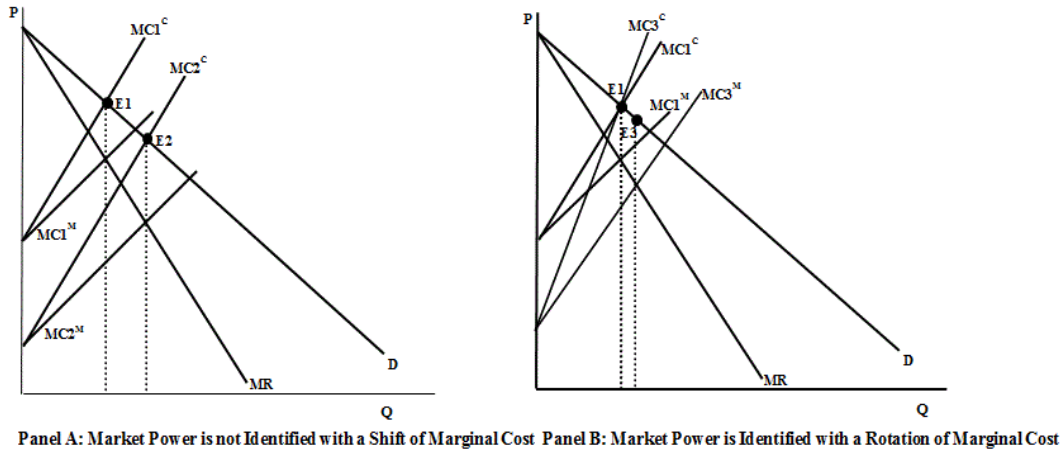
$$P = \gamma_0 + \gamma_1 Q + \sum_{l=1}^{\ell} \delta_l Y_l, \quad (2.16)$$

the supply relation (2.6) becomes

$$P = \sum_{j=1}^n \sum_{k=1}^n b_{jk} w_j^{1/2} w_k^{1/2} + \sum_{j=1}^n b_j Q_j^* - \lambda \gamma_1 Q, \quad (2.17)$$

where $Q_j^* = 2w_j Q$. The econometric analysis requires simultaneous estimation of the demand function (2.16) and supply relation (2.17). The parameters in the demand function are identified because the number of excluded exogenous variables in the demand function ($\frac{n(n+1)}{2}$ variables of $w_j w_k$ s) is greater than or equal to the number of endogenous variables (P and Q) minus one. The parameters in the supply relation, including $\lambda \gamma_1$, are also identified if the number of excluded exogenous variables (ℓ variables of Y_l s) is greater than or equal to the number of endogenous variables (P , n variables of Q_j^* s, and Q) minus one, that is $\ell \geq n + 2 - 1$. Estimation of the demand function (2.16) and the supply relation (2.17) will yield an estimate for γ_1 and one combined estimate for $\lambda \gamma_1$. Using the estimate of γ_1 , the conjectural elasticity λ can be identified

Figure 2.2: Identification of Market Power with Non-Constant Marginal Cost



from the estimate of $\lambda\gamma_1$. For this marginal cost function, even though there is no rotation of the demand curve, the conjectural elasticity is identified because of the rotation of the marginal cost function. In addition, this marginal cost allows for a wider scope of demand specifications.

Figure 2.2 illustrates this identification process. In Figure 2.2, Panel A, $MC1^C$ and $MC1^M$ correspond to the marginal cost of the competitive and monopoly markets, respectively. The demand curve and the marginal revenue curves are denoted by D and MR . The initial reference equilibriums for the competitive and monopoly markets corresponding to these curves are the same at $E1$. Suppose output does not interact with input prices in the marginal cost function, then a downward shift in the competitive and monopoly cost curves due to changes in input prices lead to identical equilibrium, $E2$, for both competitive and monopoly markets. Thus, the competitive and monopoly markets trace the same supply relations, and these two markets are not observationally distinct. From these data points, it is not clear whether the competitive or monopoly supply relation is estimated, and thus the conjectural elasticity is not identified.

In Figure 2.2, Panel B, $MC1^C$, $MC1^M$, D , and MR curves and initial reference equilibrium $E1$ are the same as in Figure 2.2, Panel A. Now, because of the interactive quantity term with input prices, the competitive and the monopoly marginal cost curves shift down and rotate up as illustrated by $MC3^C$ and $MC3^M$, which yield competitive equilibrium $E1$ and monopoly equilibrium $E3$. Thus, the competitive equilibrium remains the same with a rotation of the marginal cost curve.

However, under monopoly competition, the supply relation is traced by the shift in the equilibrium from E1 to E3, which identifies the market power parameter.

2.3 Trade Models

With globalization, many commodities are also traded internationally. This section extends the previous analysis to the case where firms sell in both the domestic and foreign markets. The firm-level profit function is

$$\pi^i = P^d(Q^d, Y^d) q_i^d + P^x(Q^x, Y^x) q_i^x - C^i(q_i^d + q_i^x, \mathbf{w}),$$

where $P^d(\cdot)$ and $P^x(\cdot)$ are the domestic and export demand functions, P^d and P^x are the domestic and export prices, Q^d and Q^x are the industry-level domestic and export sales, Y^d and Y^x are domestic and foreign demand shifters, q_i^d and q_i^x are the firm-level domestic and export sales, and $C^i(\cdot)$ is the cost function. The first-order conditions for the domestic and foreign market are

$$P^d(Q^d, Y^d) + q_i^d P^{d'}(Q^d, Y^d) \frac{\partial Q^d}{\partial q_i^d} = MC^i(q_i^d + q_i^x, \mathbf{w}) \quad (2.18)$$

$$P^x(Q^x, Y^x) + q_i^x P^{x'}(Q^x, Y^x) \frac{\partial Q^x}{\partial q_i^x} = MC^i(q_i^d + q_i^x, \mathbf{w}) \quad (2.19)$$

where $P^{d'}(Q^d, Y^d) = \frac{\partial P^d(Q^d, Y^d)}{\partial Q^d}$, $P^{x'}(Q^x, Y^x) = \frac{\partial P^x(Q^x, Y^x)}{\partial Q^x}$, and $MC^i(\cdot)$ is marginal cost.

After multiplying (2.18) by $\frac{Q^d}{P^d}$ and $\frac{P^d}{P^d}$ and (2.19) by $\frac{Q^x}{P^x}$ and $\frac{P^x}{P^x}$ and rearranging terms, the domestic and foreign supply relations are written as

$$P^d = MC^i(q_i^d + q_i^x, \mathbf{w}) - \frac{P^{d'}(Q^d, Y^d) Q^d}{P^d} \frac{\partial Q^d}{\partial q_i^d} \frac{q_i^d}{Q^d} P^d \quad (2.20)$$

$$P^x = MC^i(q_i^d + q_i^x, \mathbf{w}) - \frac{P^{x'}(Q^x, Y^x) Q^x}{P^x} \frac{\partial Q^x}{\partial q_i^x} \frac{q_i^x}{Q^x} P^x. \quad (2.21)$$

Substituting the domestic firm-level conjectural elasticity, $\lambda_i^d = \frac{\partial Q^d}{\partial q_i^d} \frac{q_i^d}{Q^d}$, and domestic demand flexibility, $\varepsilon^d = -P^{d'}(Q^d, Y^d) \frac{Q^d}{P^d}$, and into (2.20), and the foreign firm-level conjectural elasticity, $\lambda_i^x = \frac{\partial Q^x}{\partial q_i^x} \frac{q_i^x}{Q^x}$, and foreign demand flexibility, $\varepsilon^x = -P^{x'}(Q^x, Y^x) \frac{Q^x}{P^x}$, into (2.21), the

domestic and foreign firm-level supply relations are written as

$$P^d = MC^i(q_i^d + q_i^x, \mathbf{w}) + \varepsilon^d \lambda_i^d P^d \quad (2.22)$$

$$P^x = MC^i(q_i^d + q_i^x, \mathbf{w}) + \varepsilon^x \lambda_i^x P^x. \quad (2.23)$$

To aggregate to the industry level, the firm-level supply relations, (2.20) and (2.21) are weighted by their share of the domestic and foreign market, $\frac{q_i^d}{Q^d}$ and $\frac{q_i^x}{Q^x}$, and summed across all firms to obtain

$$P^d \sum_{i=1}^m \frac{q_i^d}{Q^d} = \sum_{i=1}^m \frac{q_i^d}{Q^d} MC^i(q_i^d + q_i^x, \mathbf{w}) + \varepsilon^d P^d \sum_{i=1}^m \frac{q_i^d}{Q^d} \lambda_i^d \quad (2.24)$$

$$P^x \sum_{i=1}^m \frac{q_i^x}{Q^x} = \sum_{i=1}^m \frac{q_i^x}{Q^x} MC^i(q_i^d + q_i^x, \mathbf{w}) + \varepsilon^x P^x \sum_{i=1}^m \frac{q_i^x}{Q^x} \lambda_i^x. \quad (2.25)$$

Substituting, the industry-level marginal cost function $MC(Q, \mathbf{w}) = \sum_i \frac{q_i^d}{Q^d} MC^i(q_i^d + q_i^x, \mathbf{w})$ where $Q = Q^d + Q^x$, and the industry-level conjectural elasticities, $\lambda^d = \sum_{i=1}^m \frac{q_i^d}{Q^d} \lambda_i^d$ and $\lambda^x = \sum_{i=1}^m \frac{q_i^x}{Q^x} \lambda_i^x$, into (2.24) and (2.25), the aggregate supply relation is

$$P^d = MC(Q, \mathbf{w}) + \varepsilon^d \lambda^d P^d \quad (2.26)$$

$$P^x = MC(Q, \mathbf{w}) + \varepsilon^x \lambda^x P^x. \quad (2.27)$$

Again, to specify estimable supply relations, cost and demand functions need to be defined. For the marginal cost functions, any one of the three marginal cost functions defined above can be used, but the linear marginal cost (2.10) is considered because if identification of the conjectural elasticity parameters for this case is possible, then identification for the other two cases is readily apparent as discussed below. Consider the following domestic and export demand functions:

$$P^d = \gamma_0 + \gamma_1 Q^d + \gamma_2 Y^d \quad (2.28)$$

$$P^x = \alpha_0 + \alpha_1 Q^x + \alpha_2 Y^x. \quad (2.29)$$

With the marginal cost (2.10) and demand functions (2.28) and (2.29) defined, the domestic

and export supply relations are derived as

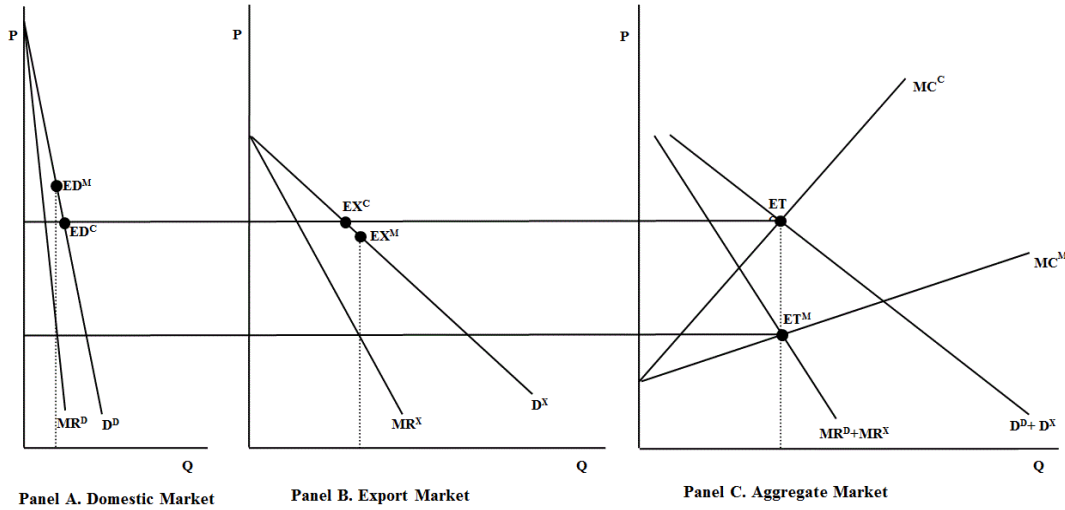
$$P^d = b_0Q + \sum_{j=1}^n b_j w_j - \gamma_1 \lambda^d Q^d$$

$$P^x = b_0Q + \sum_{j=1}^n b_j w_j - \alpha_1 \lambda^x Q^x.$$

The domestic and export demand functions and domestic and export supply relations are simultaneously estimated. The domestic function is identified because the number of excluded exogenous variables (n variables of w_j s) is greater than or equal to the number of endogenous variables (P^d and Q^d) minus one. Similarly the export demand function is also identified. The domestic supply relation is identified because the number of excluded exogenous variables (Y^d and Y^x) is equal to the number of endogenous variables (P^d , Q , and Q^d) minus one. Similarly, the export supply relation is also identified. The conjectural elasticity parameter for the domestic market is identified because with the estimate of γ_1 from the domestic demand equation and from the combined estimate of $\gamma_1 \lambda^d$ from the domestic supply relation, the domestic conjectural elasticity parameter λ^d is determined. Furthermore, the marginal cost coefficient b_0 is identified because $Q (= Q^d + Q^x)$ is different from Q^d . The conjectural elasticity parameter for the export market is also identified because with the estimate of α_1 from the export demand function and from the combined estimate of $\alpha_1 \lambda^x$ from the export supply relation, the export conjectural elasticity parameter λ^x is computed. In addition, the marginal cost parameter b_0 is also identified because $Q (= Q^d + Q^x)$ is different from Q^x .

The above analysis is illustrated in Figure 2.3. Panel A depicts the domestic demand D^D and the corresponding marginal revenue MR^D . Panel B presents the export demand D^X and the corresponding marginal revenue MR^X . Panel C illustrates the aggregate demand $D^D + D^X$ and the marginal cost for the competitive (MC^C) and the monopoly (MC^M) markets. For the competitive market, the equilibrium is at ET^C where the aggregate demand intersects MC^C in panel C. From ET^C , trace across to obtain the competitive equilibriums in the export (EX^C) and domestic (ED^C) markets. For the monopoly case, at the equilibrium, marginal revenue is equal to marginal cost in each market, and the sum of the domestic sales plus the export sales is equal to total supply,

Figure 2.3: Identification of Market Power in Trade Models



which is given at point ET^M in panel C. From ET^M , go across to each market to the intersection of the marginal revenue and marginal cost to obtain the quantity and prices and equilibrium points from the demand curves. The equilibrium points for the export and domestic markets are at EX^M and ED^M , respectively. Even though the total quantity is the same under both the competitive and monopoly markets, as evident from panel C, the equilibrium quantities, and thus prices, are different in the domestic and export markets under competition and monopoly. Consequently, the equilibrium points in the domestic and foreign markets differ under competition and monopoly. Furthermore, it can be readily visualized if the demand curves in both the domestic market and/or export market shift up, then the new equilibrium points in these two markets under competition and monopoly will be distinct. Therefore, the supply relations under competition and monopoly traces different equilibrium points in each of these markets, which allows for identification of the market power parameters.

For the constant marginal cost function, it is straight forward to apply the identification rule to determine that all the parameters, including the conjectural elasticities, are identified. For marginal cost function with interactive quantity term, all the parameters are also identified as long as the domestic and export demand functions have adequate number of exogenous variables.

2.4 Past Studies of Market Power Estimation

This section covers some examples of past NEIO studies that estimated market power in specific industries. Since these studies did not explicitly discuss the identification process embedded in their analysis, we explain how they achieved identification based on one or a combination of the identification methods presented preceding sections.

Bettendorf and Verboven (2000) analyzed the incomplete transmission of input price to consumer prices of coffee beans in the Netherlands. They estimated a demand equation and domestic supply relation with a constant marginal cost as in Appelbaum (1982). Their results show that market power exists in the coffee beans.

Buschena and Perloff (1991) analyzed the world coconut oil export market by assuming a dominant firm (Philippines) and competitive fringe firms (rest of the world). Because the world is considered as a single market and the dominant firm faces the residual demand after accounting for the fringe supply, the quantity supplied is equal to quantity demanded at the equilibrium for the dominant firm and the identification method discussed in the trade section is not applicable. They applied Bresnahan's approach of a linear marginal cost and a rotation of the demand curve to achieve identification, and their results indicate that Philippines exercise market power as a dominant firm.

Arnade et al. (1998) estimated market power for the U.S. domestic and export markets for the poultry processing, rice milling, meat processing, and cigarette industries. Although not necessary for identification because both the domestic and foreign markets are considered, they employ a marginal cost with interactive quantity and input prices. They find market power for the poultry processing, rice milling, and meat processing industries in the domestic market and for the rice milling and cigarettes in the export market.

Yerger (1996) considered U.S. domestic and several export markets for two related products: chemical-based wood pulp and sulphate-based wood pulp. The author employed a methods similar to that in the trade section because total output is sold in both the domestic and export markets. Yerger implemented a constant marginal cost in his estimation and finds market power in the

export markets, but not in the domestic markets, for both pulp types. Even though Yerger did not discuss the identification process in his analysis, as we discussed in the trade section, identification was automatically achieved even with a constant marginal cost.

2.5 Conclusions

This study shows that specification of cost functions play a crucial role in identifying the conjectural elasticities. In particular, if the marginal cost is constant or if output enters interactively with input prices, conjectural elasticities are identified without a rotation of the demand curves. In addition, if output is sold in both the domestic and export markets, even with linear marginal cost function, conjectural elasticities are identified without a rotation of the demand or marginal cost functions.

Chapter 3

U.S. and Chinese Strategic Trade Policies and Product Differentiation in the ASEAN Apple Market

3.1 Introduction

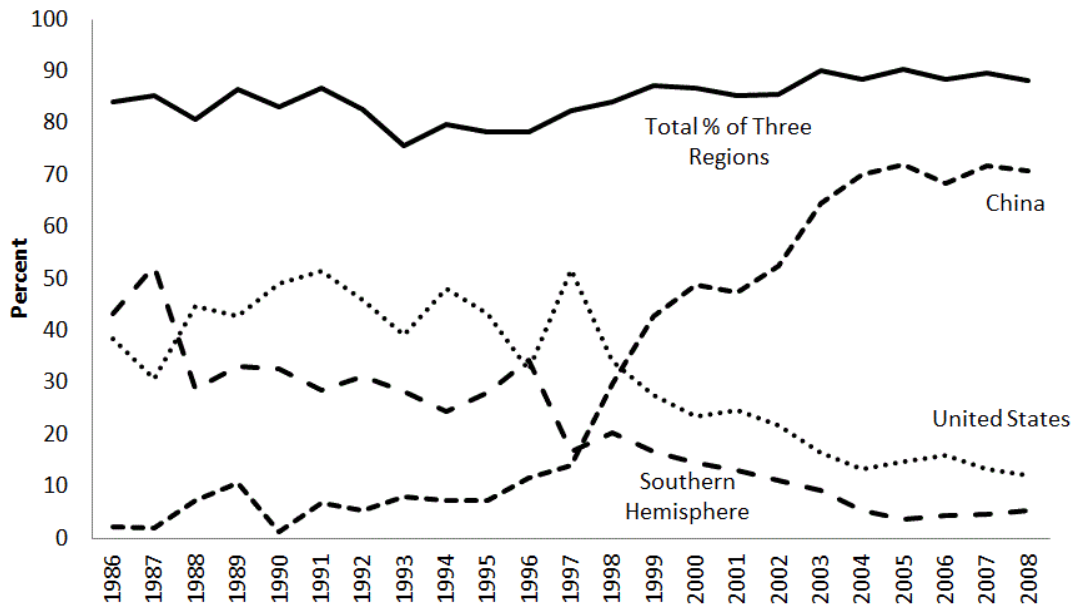
The countries that form the Association of Southeast Nations (ASEAN)—the largest free trade area in terms of population¹—import all of their fresh apples because the tropical climate is not conducive for apple production. Due to economic reforms and steady growth, fresh apple imports by ASEAN countries² have increased by 432 percent between 1990 and 2008, while world apple trade has increased by only 102 percent (Food and Agricultural Organization, 2011). Over the past thirty years, U.S. and Chinese apple exporters have competed directly for this apple market (Huang and Gale, 2006). The United States was a major exporter of apples to ASEAN controlling between 30 - 50 percent of the market until the late 1990s when Chinese exporters became dominant (Food and Agricultural Organization, 2011). By the late 2000s, the U.S. market share of apple exports to ASEAN dropped to 14 percent, whereas the Chinese market share rose to 70 percent (see Figure 3.1).

U.S. apple production peaked in 1998 at 5.28 MMT (million metric tonnes) and has since declined by 14.5 percent. In addition, the domestic apple market in the United States is a mature market with the domestic demand plateauing at 2.26 MMT, and U.S. apple exports have also declined after reaching a maximum of 0.74 MMT in 1994. Thus, increasing apple exports to regions such as ASEAN is important for the U.S. apple industry to remain profitable and viable. With stagnant domestic and export sales, real apple prices have declined from a peak of \$290 per

¹The ten ASEAN countries are Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, which have a combined population of 591 million people and a GDP of \$1.8 trillion (The World Bank, 2011).

²Since apple production is zero, apple consumption is identical to imports.

Figure 3.1: U.S., Chinese, and Southern Hemisphere Market Shares in ASEAN



MT in 1991 to \$208 per MT in 2008. U.S. apple producers received \$261.54 million in subsidies through the market loss program between 2001 and 2004 because of low apple prices during the period 1998 to 2000 (Environmental Working Group, 2011).

Since the overarching reforms in 1979, the Chinese government emphasized increasing agricultural production. However, poor orchard management and the underdevelopment of storage facilities, transportation, and infrastructure substantially hindered the production, quality, and marketability of Chinese apples. In 1984, the Chinese government transformed its apple industry by relinquishing state control of apple orchards to private farmers and providing a 2 million Yuan subsidy to purchase apple seedlings (Zhan et al., 2009)—which set the stage for China to become the World’s largest fresh apple producer and exporter. By the early 1990s, Chinese production techniques and infrastructure advanced enough that perishable fruits, such as apples, were marketable in the world market. With improving technology, better infrastructure, and a significant labor-cost advantage due to an abundant labor supply (U.S. International Trade Commission, 2011), Chinese apple production increased by seven-fold from 4.33 MMT to 29.8 MMT (Food and Agricultural Organization, 2011) between 1990 and 2008. In 2008, Chinese apple production was 6.6 times larger than that of the United States, the second largest apple producing country.

Chinese apple consumption steadily increased from 3.64 MMT in 1990 to 20.46 MMT in 2008. However, because production outpaced consumption, Chinese apple exports increased dramatically and surpassed the United States as the largest apple exporter, particularly in the ASEAN market (see Figure 3.1).

In 2004, the Chinese government refocused its economic policies to emphasize the agricultural sector. The "Number 1 Document," which outlines the government's priorities for the upcoming year, concentrated on improving the rural economy with a goal of increasing agricultural exports by \$30 billion over the next 4 - 5 years (Huang and Gale, 2006). As part of this policy, the Chinese Ministry of Agriculture provided a cash subsidy for the purchase of apple bags (U.S. International Trade Commission, 2011; Sanchez and Bugang, 2006). Bagging apples immediately after harvest helps to protect them from weather and pests, thus improving storage efficiency and enhancing exports.

ASEAN countries imposed an applied tariff rate ranging between 5 percent and 30 percent on apple imports from the United States and China before 2010 (World Trade Organization, 2011). However, after a decade of negotiations, the China-ASEAN Free Trade Area (CAFTA) took effect beginning in January 2010 (The Economist, 2010), which eliminated ASEAN tariffs on apple imports from China. The exclusion of the United States from this free trade agreement hinders U.S. fresh apple exports to ASEAN by putting U.S. apples at a price disadvantage.

Given the dominance of U.S. and Chinese apple exporters in ASEAN, in our analysis, we allow for 1) the potential of U.S. and Chinese apple producers to exert market power in both ASEAN and their domestic market and 2) ASEAN consumers to differentiate apples from each exporting region by quality.

Given that the United States and China are large exporting countries with significant market shares, we allow for the possibility that they face downward sloping ASEAN demand functions (as stated above, U.S. and Chinese market shares reached 50 percent and 70 percent, respectively). This allows us to define a model that is general enough to accommodate market structures ranging from perfect collusion/monopoly to perfect competition. We then estimate conjectural elasticities

and demand flexibilities and perform statistical tests of the market structure, as revealed by the data. The interaction between demand flexibilities and conjectural elasticities is central to calculating the Lerner Index, which is our measure of market power.

It is well accepted in the industry that firms that export are generally larger and more efficient than those that do not. Given that U.S. and Chinese producers sell apples both domestically and abroad, there is a concentration of firms at the export level that control a larger portion of production. This increases the potential for these firms to exert market power, particularly at the export level, and we investigate empirically the existence of such market power.

Our analysis also allows for the possibility that ASEAN consumers differentiate U.S. and Chinese apples by quality. Due to advanced crop management, storage, and transportation capabilities in the United States relative to China, Chinese apple are generally considered to be of low quality (U.S. International Trade Commission, 2010) and have been banned by several countries due to phytosanitary reasons. For example, according to U.S. International Trade Commission (2010) and U.S. Apple Association (2010), the United State bans imports of Chinese fresh apples because over 300 pests and diseases of concern are found in Chinese apples. Wheat (2010) reports that there is a lack of infrastructure for Chinese apple exports to meet U.S., Canadian, and European phytosanitary standards and it is cheaper for them to export to countries with lower standards. Taiwan has also banned Chinese apple imports due to phytosanitary reasons (Huang and Gale, 2006). In addition, McCracken et al. (1991) found that Southeast Asian wholesalers consider U.S. apples to be high quality and value apple branding by origin to help differentiate the quality of apple imports. All apples sold within the United States and China are held to the same quality standard and are thus assumed to be homogenous in quality in their respective domestic markets.

The specific objectives of this study are to 1) analyze, using strategic trade theory, and estimate, using methods available in the new empirical industrial organization (NEIO) literature, the degree of market power exercised by U.S. and Chinese apple sellers in ASEAN and their respective domestic markets, 2) examine the impact of agricultural and trade policies on U.S. and

Chinese competition for the ASEAN fresh apple market, and 3) determine the effects of U.S. and Chinese transport cost differentials to the ASEAN market on both countries' apple markets. These objectives are accomplished by developing a model that is general enough to encompass imperfect competition in quality-differentiated products and implementing this model through econometric estimation and simulation analysis. This study is unique in that, to our knowledge, no study has 1) analyzed U.S. and Chinese competition for the ASEAN apple market from the perspective of strategic trade theory, 2) generated econometric and simulation results for this market using strategic trade policy analyses, and 3) estimated region-specific industry conjectural elasticities under the assumption of product differentiation by quality.

The next section develops the conceptual model. Section 3.3 presents analytical results for changes in policy and exogenous variables based on the conceptual model. Section 3.4 presents the econometric specification of the model. Section 3.5 discusses the empirical results, including a description of the data and data sources, presents the results of the econometric estimation, computes the Lerner Indices, and provides simulation results. Section 3.6 summarizes the major findings of the analysis and concludes the paper.

3.2 Model

In this section, we outline the conceptual model from which the analytical results and econometric specification are derived. The model is general enough to allow for estimation and testing of market structures ranging from perfect collusion/monopoly to perfect competition.

Traditional trade theories assert that countries trade because of comparative advantage arising from differences in technology or relative factor abundance. The pioneering studies by Krugman (1979, 1980) and Lancaster (1980) advanced trade theories by showing that under the assumptions of monopolistic competition, increasing returns to scale, and taste for variety, countries with similar factor endowments and comparative advantages do engage in trade. By assuming oligopolistic competition, Brander (1981) and Brander and Krugman (1983) derive two-way trade or cross-hauling in homogenous products. Brander and Spencer (1985) show that under oligopolis-

tic competition in a third market an export subsidy is welfare improving for the home country at the expense of the foreign country.

We develop a strategic trade model with competition between U.S. and Chinese firms for the ASEAN apple market while also allowing for sales in their respective domestic markets. We extend the basic oligopolistic competition model by allowing for product differentiation by quality—which results in cross-regional conjectural elasticities in the econometric specification—while accounting for sales in the domestic market. As is standard with industry-level analyses, a firm-level oligopolistic model underlies the analysis and is aggregated to describe average firm behavior (see Subsection 2.2.1 of Chapter 2).

Because U.S. and Chinese firms do not sell in each other’s domestic market, the issue of heterogeneous quality between the two apple sources does not arise in these markets. Chinese firms have a distinct cost advantage in the ASEAN market due to abundant labor for apple production and low transport costs because of the close proximity to ASEAN. Both the U.S. and Chinese governments have implemented subsidies to augment production and exports. The U.S. and Chinese industry-level profit functions are

$$\pi^i(y^i, y^j, x^i; g^i, \tau^i) = \frac{\hat{p}^i(y^i, y^j)}{1 + \tau^i} y^i + p^i(x^i) x^i - c^i\left(x^i + \frac{y^i}{g^i}\right) - F^i + s^i \left[x^i + \frac{y^i}{g^i}\right], \quad (3.1)$$

where $i, j = U$ (*United States*), C (*China*), \hat{p}^i is the ASEAN price for U.S. or Chinese apples, $\hat{p}^i(\cdot)$ is the ASEAN inverse demand for U.S. or Chinese apples, τ^i is the ad valorem tariff imposed by ASEAN, y^i is the industry-level sales of U.S. or Chinese apples in ASEAN, p^i is the domestic price, $p^i(\cdot)$ is the domestic inverse demand function for apples, x^i is the industry-level domestic sales of apples, $c^i(\cdot)$ is the cost function, s^i is a government subsidy,³ F^i is a fixed cost, and $g^i \in (0, 1)$ is the iceberg transport cost for shipping apples from the United States or China to ASEAN. Note that the higher the value of g^i , the lower the transport cost. The Chinese transport

³The subsidy in this model is a catch-all of the policies implemented by the U.S. and Chinese governments because "significant amounts of financial support are increasingly granted by governments for ostensibly general activities which in fact directly benefit the production of certain products. These disguised subsidies can have equally severe trade-distorting effects and they are potentially much more harmful than more direct subsidies since they confer benefits in a largely non-transparent manner" (World Trade Organization, 2002).

cost is lower than that of the United States, so that $g^C > g^U$.

The transportation cost and tariff level are exogenous for each exporting country; however, the subsidy rate can be optimally chosen by each country's government, which requires that the model be solved in two stages. In the first stage, the government chooses the optimal subsidy level. Given this subsidy level, in the second stage, apple sellers determine their optimal quantity. We use backward induction and first solve the seller's problem and subsequently solve the government's problem.

To obtain the solution for the second stage, we differentiate the profit function with respect to each country's exports to ASEAN and domestic sales of apples to derive the reaction functions

$$\text{Export Market} : \pi_{y^i}^i = y^i \hat{p}_{y^i}^i + \hat{p}^i - \frac{(1 + \tau^i) \partial c^i(\cdot)}{g^i \partial y^i} + \frac{(1 + \tau^i)}{g^i} s^i = 0 \quad (3.2)$$

$$\text{Domestic Market} : \pi_{x^i}^i = x^i \hat{p}_{x^i}^i + p^i - \frac{\partial c^i(\cdot)}{\partial x^i} + s^i = 0, \quad (3.3)$$

which constitute a unique solution only if the reaction functions are downward sloping and the second-order conditions are met.

3.3 Analytical Results

To analyze analytically the effect of a change in the exogenous variables on endogenous variables, the first order conditions are totally differentiated and then Cramer's rule is applied to determine the effect of a change in tariffs, transport costs, and subsidies on trade flows and domestic sales (see Appendix 3.7.1 for the full derivation). The effect of a change in the ASEAN tariff on imports from country i is negative as shown by^{4,5}

$$\frac{dy^i}{d\tau^i} = -\frac{1}{|A|} \pi_{y^i \tau^i}^i \pi_{x^i x^i}^i \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) < 0. \quad (3.4)$$

⁴The determinant of A is:

$|A| = (\pi_{y^u y^u}^u \pi_{x^u x^u}^u - \pi_{y^u x^u}^u \pi_{x^u y^u}^u) (\pi_{y^c y^c}^c \pi_{x^c x^c}^c - \pi_{y^c x^c}^c \pi_{x^c y^c}^c) - \pi_{x^c x^c}^c \pi_{y^u y^c}^u \pi_{y^c y^u}^c \pi_{x^u x^u}^u > 0$ for plausible supply and demand functions.

⁵The own output effect on marginal profits dominate the cross effects, $\pi_{y^i y^i}^i < \pi_{x^i y^i}^i$ and $\pi_{x^i x^i}^i < \pi_{x^i y^i}^i$, implying, $\pi_{y^i y^i}^i \pi_{x^i x^i}^i - \pi_{x^i y^i}^i \pi_{y^i x^i}^i > 0$. The effect of iceberg costs on marginal profits is greater in the export market than in the domestic market, $\pi_{y^i g^i}^i > \pi_{x^i g^i}^i$, which implies $\pi_{x^i g^i}^i \pi_{y^i x^i}^i - \pi_{y^i g^i}^i \pi_{x^i x^i}^i > 0$, $\pi_{y^i g^i}^i \pi_{x^i x^i}^i - \pi_{x^i g^i}^i \pi_{y^i x^i}^i < 0$, and $\pi_{y^i g^i}^i \pi_{x^i y^i}^i - \pi_{x^i g^i}^i \pi_{y^i y^i}^i < 0$. These conditions and plausible supply and demand conditions are used in signing the comparative static results in this and the following subsections.

After the implementation of CAFTA in 2010, ASEAN countries phased out their tariffs on Chinese apples, making China's apples relatively cheaper in ASEAN, which expanded apple exports from China to ASEAN. In contrast, a higher ASEAN tariff on U.S. apples reduces U.S. exports. The effect of this change in tariff on i 's domestic sales is positive:

$$\frac{dx^i}{d\tau^i} = \frac{1}{|A|} \pi_{y^i \tau^i}^i \pi_{x^i y^i}^i \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) > 0. \quad (3.5)$$

As a result of the tariff reduction due to CAFTA, exports from China to ASEAN increased (see (3.4)), which reduced the quantity of apples sold in the Chinese domestic market. Since the elimination of the ASEAN tariff on Chinese apples adversely impacts U.S. exports, more apples are sold in the U.S. domestic market.

A change in the ASEAN tariff on country i 's apples positively impacts country j 's exports as indicated by

$$\frac{dy^j}{d\tau^i} = \frac{1}{|A|} \pi_{y^i \tau^i}^i \pi_{x^j x^j}^j \pi_{y^j y^j}^j \pi_{x^i x^i}^i > 0. \quad (3.6)$$

The removal of tariffs on apple imports from China expands Chinese exports to ASEAN, which displaces U.S. apple exports in ASEAN and reduces the market share of U.S. exporters. In contrast, a higher ASEAN tariff on U.S. apples reduces U.S. exports, which will be met by increased Chinese exports. The effect of a change in τ^i on country j 's domestic sales is negative as indicated by

$$\frac{dx^j}{d\tau^i} = -\frac{1}{|A|} \pi_{y^i \tau^i}^i \pi_{x^i x^i}^i \pi_{x^j y^j}^j \pi_{y^j y^j}^j < 0. \quad (3.7)$$

For example, the higher market share of Chinese exporters in ASEAN due to the trade liberalization under CAFTA reduces U.S. exports, and consequently, more apples are sold in the U.S. domestic market.

The effect of an increase in country i 's transport cost, captured by a reduction in g^i , is to lower i 's exports as shown by

$$\frac{dy^i}{dg^i} = \frac{1}{|A|} \left(\pi_{x^i g^i}^i \pi_{y^i x^i}^i - \pi_{y^i g^i}^i \pi_{x^i x^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) > 0. \quad (3.8)$$

The cost of shipping apples to ASEAN depends heavily on distance and fuel costs due to the

bulky nature of shipping large quantities of apples. Consequently, a rise in the transport cost has a relatively smaller impact on Chinese exports to ASEAN than on U.S. exports because of the close proximity of China to ASEAN relative to the United States. The impact of transport cost on domestic sales is

$$\frac{dx^i}{dg^i} = \frac{1}{|A|} \left[\begin{aligned} & \left(\pi_{y^i g^i}^i \pi_{x^i y^i}^i - \pi_{x^i g^i}^i \pi_{y^i y^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) \\ & + \pi_{x^i g^i}^i \pi_{y^j y^i}^j \pi_{y^i y^j}^i \pi_{x^j x^j}^j \end{aligned} \right] < 0, \quad (3.9)$$

which shows a negative relationship. An increase in shipping costs (decrease in g^i) to ASEAN and the subsequent reduction in exports (3.8) lead to greater availability of apples for the domestic market. Since the United States is farther away from ASEAN than China, an increase in the transport cost would lead to higher domestic sales in the United States than in China.

The effects of an increase in country i 's transport cost (reduction in g^i) will enhance country j 's exports as shown by

$$\frac{dy^j}{dg^i} = \frac{1}{|A|} \left(\pi_{y^i g^i}^i \pi_{x^i x^i}^i - \pi_{x^i g^i}^i \pi_{y^i x^i}^i \right) \pi_{y^j y^i}^j \pi_{x^j x^j}^j < 0. \quad (3.10)$$

For instance, an increase in the U.S. transport cost reduces U.S. apple exports to ASEAN, which will be met by more exports from China. Thus, the higher U.S. transport cost helps to augment the Chinese market share in ASEAN. The impact of country i 's transport cost on country j 's domestic sales is indicated by:

$$\frac{dx^j}{dg^i} = \frac{1}{|A|} \left(\pi_{x^i g^i}^i \pi_{y^i x^i}^i - \pi_{y^i g^i}^i \pi_{x^i x^i}^i \right) \pi_{y^j y^i}^j \pi_{x^j y^j}^j > 0. \quad (3.11)$$

A higher U.S. transport cost (lower g^i) increases Chinese exports to ASEAN which crowds out domestic sales in China.

As for the U.S. and Chinese subsidy provisions, an increase in country i 's subsidy causes

its exports to rise:⁶

$$\frac{dy^i}{ds^i} = \frac{1}{|A|} \left(\pi_{x^i s^i}^i \pi_{y^i x^i}^i - \pi_{y^i s^i}^i \pi_{x^i x^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) > 0. \quad (3.12)$$

In 2004, following the Number 1 Document, the Chinese government provided subsidies to apple growers, which covered improved access to credit and insurance, value-added tax rebates, market information, and apple bagging credits. These policies increased apple production, enhanced post-harvest storage, and mitigated the effects of weather and pests, which augmented the supply and profitability of apple growers and expanded Chinese exports to the ASEAN market. The U.S. government provided its apple growers market loss subsidy payments for the years 2000-2004 because of three years of low prices. This subsidy allowed many U.S. apple growers to remain profitable and not replace apple orchards with alternative crops. As a result, U.S. growers were able to maintain apple production, and U.S. apple exports to ASEAN stabilized. The increase in country i 's subsidy also increases its domestic sales:

$$\frac{dx^i}{ds^i} = \frac{1}{|A|} \left[\begin{aligned} & \left(\pi_{y^i s^i}^i \pi_{x^i y^i}^i - \pi_{x^i s^i}^i \pi_{y^i y^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) \\ & + \pi_{x^i s^i}^i \pi_{y^j y^i}^j \pi_{y^i y^j}^i \pi_{x^j x^j}^j \end{aligned} \right] > 0. \quad (3.13)$$

Subsidies given by both the U.S. and Chinese governments have increased their respective supplies and expanded domestic sales.

The effects of a change in country i 's subsidy on j 's exports is negative:

$$\frac{dy^j}{ds^i} = \frac{1}{|A|} \pi_{y^j y^i}^j \pi_{x^j x^j}^j \left(\pi_{y^i s^i}^i \pi_{x^i x^i}^i - \pi_{x^i s^i}^i \pi_{y^i x^i}^i \right) < 0. \quad (3.14)$$

The subsidy by country i has an adverse impact on country j 's exports to ASEAN. For example, China's subsidies substantially increased exports from China to ASEAN (3.12), which lowered the U.S. market share in ASEAN beginning in the mid-1990s. The effect of country i 's subsidy on j 's

⁶We assume the effect of subsidies on marginal profits are greater in the export market than in the domestic market, $\pi_{x^i s^i}^i < \pi_{y^i s^i}^i$, which implies $\pi_{x^i s^i}^i \pi_{y^i x^i}^i - \pi_{y^i s^i}^i \pi_{x^i x^i}^i > 0$, $\pi_{y^i s^i}^i \pi_{x^i x^i}^i - \pi_{x^i s^i}^i \pi_{y^i x^i}^i < 0$, and $\pi_{y^i s^i}^i \pi_{x^i y^i}^i - \pi_{x^i s^i}^i \pi_{y^i y^i}^i > 0$. These conditions are used in signing the comparative static results in this subsection.

domestic sales is positive as shown by

$$\frac{dx^j}{ds^i} = \frac{1}{|A|} \pi_{y^j y^i}^j \pi_{x^j y^j}^j (\pi_{x^i s^i}^i \pi_{y^i x^i}^i - \pi_{y^i s^i}^i \pi_{x^i x^i}^i) > 0. \quad (3.15)$$

The effect of the Chinese subsidy is to expand Chinese exports to ASEAN, displacing U.S. apple exports to ASEAN and causing the United States to sell more apples in its domestic market.

3.3.1 Welfare Analysis of Subsidies

A country can implement strategic policies by optimally choosing subsidies to increase its welfare, which is the first-stage solution of the backward induction problem described earlier. The domestic welfare from apple sales and exports is derived from consumer surplus, profits from export and domestic sales, and subsidy expenditures:

$$W^i(y^i, y^j, x^i; s^i, s^j) = \left\{ \int_0^{x^i} p^i(v^i) dv^i - p^i(x^i) x^i \right\} + \pi^i(x^i, y^i, y^j; s^i) - s^i \left[x^i + \frac{y^i}{g^i} \right]. \quad (3.16)$$

Totally differentiating the welfare function and dividing by the total change in the subsidy obtains (See Appendix 3.7.2 for the full derivation)

$$\frac{dW^i(\cdot)}{ds^i} = -p_{x^i}^i \frac{\partial x^i}{\partial s^i} x^i + \frac{y^i \hat{p}_{y^j}^i}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} - s^i \left(\frac{\partial x^i}{\partial s^i} + \frac{1}{g^i} \frac{\partial y^i}{\partial s^i} \right). \quad (3.17)$$

The first term indicates that, because more apples are available at a lower price, consumer surplus increases with a rise in the subsidy. The second term shows that country i 's subsidy augments producer surplus by lowering country j 's market share in ASEAN, which also increases i 's prices. The last term has a negative welfare impact due to the cost of the subsidy. The impact of a change in the subsidy on welfare is indeterminate because it is not obvious whether the positive effects of the first two terms dominate the negative effect of the last term. However, the effect is made more definitive by taking the perspective that the initial subsidy is zero and evaluating the marginal change of implementing the subsidy. Starting from the assumption of no initial subsidy (i.e.,

$s^i = 0$), the effect of a change in the subsidy on welfare is explicitly positive as shown by

$$\left. \frac{dW^i(\cdot)}{ds^i} \right|_{s^i=0} = -p_{x^i}^i \frac{\partial x^i}{\partial s^i} x^i + \frac{y^i \hat{p}_{y^j}^i}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} > 0. \quad (3.18)$$

To solve for the optimal subsidy, we set $\frac{dW^i(\cdot)}{ds^i} = 0$ in (3.17) and solve for s^i :

$$s^i = \frac{\left[-p_{x^i}^i \frac{\partial x^i}{\partial s^i} x^i + \frac{\hat{p}_{y^j}^i}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} y^i \right]}{\left[\frac{\partial x^i}{\partial s^i} + \frac{1}{g^i} \frac{\partial y^i}{\partial s^i} \right]} > 0, \quad (3.19)$$

which indicates that the optimal subsidy is positive.

3.4 Econometric Specification

Parallel to the development of New Trade Theory (i.e., the incorporation of imperfect competition into international trade theory), the new empirical industrial organization (NEIO) literature laid the foundation for econometrically estimating market power at the firm or industry level (Appelbaum, 1982; Bresnahan, 1982). The crux of the issue in estimating market power is identification of conjectural elasticities, which is central to measuring the degree of market power. Because apples are differentiated by quality in ASEAN, we draw on Nevo (1998) who derives general conditions for identification under product differentiation in the Bertrand setting. However, we model U.S. and Chinese exporters as choosing quantities of high- and low-quality apple exports to ASEAN, respectively, and allow for implementation of various market structures, ranging from monopoly to perfect competition.

The developments in New Trade Theory and NEIO led to a body of literature that estimated market power in an international setting. For example, Pick and Park (1991) estimated the degree of market power for U.S. corn, wheat, cotton, soybeans, and soybean oil, cake, and meal exports for the period 1979-1988. Their results show that wheat is the only market that deviates from competitive behavior. Yerger (1996) and Arnade et al. (1998) emphasized the strong link between the domestic and export markets. These studies simultaneously estimated market power in both the domestic and export markets for the U.S. wood pulp industry (Yerger, 1996) and poultry, rice, meat,

and cigarette markets (Arnade et al., 1998). More recently, Lavoie (2005) analyzed vertical price discrimination by the Canadian Wheat Board and showed product differentiation led to market power across export markets.

Our econometric specification is unique in that the product differentiation assumption results in cross-regional conjectural elasticities. As is shown in detail below, the cross-regional conjectural elasticities relate the degree of influence a change in region i 's quality-differentiated exports has on region j 's exports.

In addition to the United States and China, Australia, Chile, and New Zealand (Southern Hemisphere region) also export apples to ASEAN. These countries have a relatively small market share compared to those of the United States and China, and we treat them as exogenous in the econometric specification and focus on U.S. and Chinese competition. However, the Southern Hemisphere apples exports are allowed to impact U.S. and Chinese conjectural elasticity estimation by influencing the demand elasticities, which are central to the market power estimation and calculation of the Lerner Index.

From the first-order conditions in the model defined in Section 3.2 ((3.2) and (3.3)) and by expressing the marginal revenues in terms of flexibilities and conjectural elasticities, the industry-level supply relations can be written as:⁷

$$\text{Exp. S. Relation} : \hat{p}^i = \frac{(1 + \tau^i)}{g^i} (mc_y^i - s^i) + \hat{p}^i (\varepsilon_{\hat{p}^i, y^i} \theta_{y^i, y^i}^i + \varepsilon_{\hat{p}^i, y^j} \Theta_{y^j, y^i}^i) \quad (3.20)$$

$$\text{Dom. S. Relation} : p^i = mc_x^i - s^i + p^i \varepsilon_{p^i, x^i} \theta_x^i, \quad (3.21)$$

where $mc_y^i = \frac{\partial c^i(\cdot)}{\partial y^i}$, $\varepsilon_{\hat{p}^i, y^i} = -\frac{\partial \hat{p}^i y^i}{\partial y^i \hat{p}^i}$ is the export own-demand flexibility and $\varepsilon_{\hat{p}^i, y^j} = -\frac{\partial \hat{p}^i y^j}{\partial y^j \hat{p}^i}$ is the export cross-demand flexibility, θ_{y^i, y^i}^i and Θ_{y^j, y^i}^i are respectively regional and cross-regional conjectural elasticities, $mc_x^i = \frac{\partial c^i(\cdot)}{\partial x^i}$, $\varepsilon_{p^i, x^i} = \frac{\partial p^i x^i}{\partial x^i p^i}$ is the domestic demand flexibility, and θ_x^i is the domestic conjectural elasticity. The conjectural elasticities θ_{y^i, y^i}^i and θ_x^i consists of a representative firm's conjectural variation (which indicates the perceived influence a firm has on its market) and its market share. The cross-regional conjectural elasticity, Θ_{y^j, y^i}^i , consists of a

⁷For the purpose of clarity in deriving the conjectural elasticities, we start from a firm-level and aggregate to the industry level, see Appendix A for more detail.

representative firm's conjectural elasticity weighted by perceived influence of region i 's exports on j 's exports to ASEAN.

The degree of oligopoly power is given by the interaction of the demand flexibilities and conjectural elasticities. In the export market, four general cases arise: First, under perfect collusion, apple sellers act as a monopoly. Therefore, the cross-regional conjectural elasticities (Θ_{y^j, y^i}^i) does not exist, and θ_{y^i, y^i}^i is equal to one. Consequently, markup—given by the terms in the last set of parentheses in (3.20)—is based solely on demand flexibility. Second, under Cournot competition, the conjectural variation is one and there is no cross effect of region i 's exports on region j 's exports (thus $\Theta_{y^j, y^i}^i = 0$), and markup is based on the demand flexibility weighted by a representative firm's market share. Third, relaxing the Cournot assumption allows market power to stem from both conjectural elasticities (θ_{y^i, y^i}^i and Θ_{y^j, y^i}^i) in the markup term. Fourth, under perfect competition, each exporting firm faces perfectly elastic excess demand curves; thus markup is zero and marginal cost pricing prevails. Similar interpretations hold for the domestic market: $\theta_x^i = 1$ under monopolistic competition and demand flexibility dictates the degree of market power; under Cournot competition, markup depends on the representative firm's market share and demand flexibility; and $\varepsilon_{p^i, x^i} = 0$ and $\theta_x^i = 0$ under perfect competition and marginal cost pricing exists.

Empirical analysis of market power requires simultaneous estimation of supply relations and demand functions and identification of not only demand and supply parameters, but also conjectural elasticity parameters. Consider the following demand and marginal cost functions:

$$\text{Exp. D.} : \hat{p}^i = \alpha_0^i + \alpha_1^i y^i + \alpha_2^i y^i z^A + \alpha_3^i y^j + \alpha_4^i y^j z^A + \alpha_5^i y^S + \alpha_7^i z^A \quad (3.22)$$

$$\text{Dom. D.} : p^i = \beta_0^i + \beta_1^i x^i + \beta_2^i x^i v^i + \beta_3^i v^i, \quad (3.23)$$

$$\text{Exp. M.C.} : mc_y^i = \frac{1}{g^i} \left(\eta_0^i + \eta_1^i u^i + \eta_2^i \left(x^i + \frac{y^i}{g^i} \right) \right) \quad (3.24)$$

$$\text{Dom. M.C.} : mc_x^i = \eta_0^i + \eta_1^i u^i + \eta_2^i \left(x^i + \frac{y^i}{g^i} \right) \quad (3.25)$$

where α^i 's are export demand coefficients, y^S is apple exports from the southern hemisphere, β^i 's are domestic demand coefficients, z^A and v^i are indexes of the exogenous demand shifting variables (income and cross prices), η_1^i and η_1^i are cost coefficients of exports (y^i) and domestic sales (x^i),

u^i is an input prices index in the domestic and export market, respectively. Our demand function specification is similar to that in Bresnahan (1982); as z^A and v^i change over time, they shift and rotate the demand curves which helps to identify market power. Substitute the marginal costs defined in (3.24) and (3.25) and the demand flexibilities derived from (3.22) and (3.23) into the supply relations (3.20) and (3.21) to obtain:

$$\text{Exp. S. Relation} : \hat{p}^i = \frac{(1 + \tau^i)}{g^i} \left(\eta_0^i + \eta_1^i u^i + \eta_2^i \left(x^i + \frac{y^i}{g^i} \right) - s^i \right) + \theta_{y^i, y^i}^i y^{i*} + \Theta_{y^j, y^i}^i y^{j*} \quad (3.26)$$

$$\text{Dom. S. Relation} : p^i = \eta_0^i + \eta_1^i u^i + \eta_2^i \left(x^i + \frac{y^i}{g^i} \right) - s^i + \theta_x^i x^{i*}, \quad (3.27)$$

where $y^{i*} = -(\alpha_1^i + \alpha_2^i z^A) y^i$, $y^{j*} = -(\alpha_3^i + \alpha_4^i z^A) y^j$, and $x^{i*} = -(\beta_1^i + \beta_2^i v^i) x^i$. Since $\left(x^i + \frac{y^i}{g^i} \right)$ and y^{i*} are separate variables, η_2^i and θ_{y^i, y^i}^i are identified. Similarly, $\left(x^i + \frac{y^i}{g^i} \right)$ and x^{i*} are separate variables, η_2^i and θ_x^i are also identified.

3.5 Quantitative Results

In this section, we describe data sources, econometric estimation, Lerner Indices, and simulation results.

3.5.1 Data

The data period covers the years 1986-2008. Prices and quantities of U.S. and Chinese apples and the quantity of Southern Hemisphere apples sold in ASEAN are obtained from the Detailed Trade Matrix of the Food and Agricultural Organization (Food and Agricultural Organization, 2011). The FOB (free on board) export values and quantities from the United States and China to each of the ASEAN countries are aggregated. To calculate the per unit FOB export price for U.S. (Chinese) apples to ASEAN, the aggregate value is divided by the aggregate quantity of apples sold by the United States (China) in ASEAN. To construct the CIF price of U.S. apples in ASEAN, fresh-fruit shipping cost collected from the Foreign Trade Statistics of the U.S. Census Bureau (2011) between United States and ASEAN are added to the FOB price data. Since shipping cost from China to ASEAN is not available, the U.S. transport cost is scaled using the relative distance

between China and ASEAN vis-a-vis the United States and ASEAN. The distance data is obtained from "www.searates.com."

For the U.S. domestic market, total value and quantity of apples sold in the United States is calculated by adding imports and subtracting exports from the apple production (Food and Agricultural Organization, 2011). The price is the ratio of the value to quantity. For the Chinese domestic market, the total quantity of apples sold (production plus imports minus exports) is derived from the Food Balance Sheet and price data from PriceStat (Food and Agricultural Organization, 2011).

Input prices used for estimating the U.S. marginal cost are the agricultural wage rate, fuel price index, and fertilizer price index, which are collected from the National Agricultural Statistics Service (USDA, 2011). For the Chinese marginal cost estimation, the agricultural wage rate and the fuel price index are used, which are collected from the China Statistical Yearbook (National Bureau of Statistics of China, 2011). To reduce the dimensionality of the cost function with minimal information loss, we apply principal component analysis to input prices and generate an input price index. Specifically, we use the first principal component to capture the majority of the variance of the substantially correlated input prices.⁸

Gross domestic product (GDP), population, and an alternative fruit (orange) price are used in estimating the U.S., Chinese, and ASEAN demand. Income and population data are collected from the World Development Indicators (The World Bank, 2011). For ASEAN income, the GDP weighted average of the ASEAN countries was calculated. Retail price for U.S. oranges are obtained from the International Labour Organization (International Labour Organization, 2011), and prices for Chinese and ASEAN oranges are collected from the PriceStat (Food and Agricultural Organization, 2011). The orange price in ASEAN is a GDP weighted average of the orange prices in ASEAN countries. Principal component analysis is employed to calculate an index of exogenous demand variables. Using the first principal component, the majority of the variation in the highly correlated exogenous demand variables is represented.⁹ To enforce the homogeneity

⁸The ratio of the first eigenvalue to the sum of all three eigenvalues for the United States and China is 0.89 and 0.78, respectively. This indicates that 89% and 78% of the variance in the wage rate, fuel price index, and fertilizer price (wage rate and fuel price index for China) is captured in the first principal component.

⁹The ratio of the first eigenvalue to the sum of all three eigenvalues for the United States, China, and ASEAN is

conditions for the demand function, the GDP deflator is used to divide prices and income, which are collected from the International Monetary Fund (International Monetary Fund, 2011). The applied tariff rate on apples entering each ASEAN country is obtained from Tariff Analysis Online (World Trade Organization, 2011). We calculate the weighted average tariff rate based on import volumes.

3.5.2 Estimation

The demand functions (3.22) and (3.23) and supply relations (3.26) and (3.27) are a system of eight equations and eight endogenous variables $(y^i, x^i, \hat{p}^i, p^i; i = U, C)$. Due to simultaneity in the system and nonlinearity in the supply relations, we apply non-linear three stage least square (N3SLS) to estimate the parameters. N3SLS achieves consistency and increases efficiency by accounting for endogeneity in the system and cross-equation correlation in the errors. The exogenous variables in the system are the instrumental variables; the exogenous demand (supply) variables contribute to identifying the supply relation (demand function). We experimented with several starting values for the parameters to generate confidence that the N3SLS objective function achieved a global minimum.

As seen in Figure 3.1, the Chinese economic reforms and apple subsidies in the mid-1980s caused the composition of market shares in ASEAN to change starting in the mid-1990s. The market share of Chinese apple exports increased from less than 10 percent before 1997 to 64.50 percent by 2003. Concurrently, the market share of U.S. exporters declined from 51.70 percent in 1997 to 15.94 percent by the end of the sample period. To analyze the impact of this structural change on the potential degree of market power, we incorporated a time-varying drift variable, $B(t)$, and defined the regional and cross-regional conjectural elasticities as $\theta_{y^i, y^i}^i = \theta_{y^i, y^i}^{ia} + \theta_{y^i, y^i}^{ib} B(t)$ and $\Theta_{y^j, y^i}^i = \Theta_{y^j, y^i}^{ia} + \Theta_{y^j, y^i}^{ib} B(t)$. The drift variable is piecewise linear and is defined as

$$B(t) = \frac{t - t_0}{t_f - t_0} I_{(t_0, t_f]}(t) + I_{(t_f, t_N]}(t) \quad (3.28)$$

0.92, 0.85, and 0.88, respectively. This indicates that 92%, 85%, and 88% of the variance in the GDP, population, and orange price is captured in the first principal component.

where t is time, t_0 and t_f indicate, respectively, the start and end of the full structural change, t_N is the end of the sample period, and I is an indicator function ($I_{(t_0, t_f]} = 1$ for the period $t_0 < t \leq t_f$ and is zero otherwise, and $I_{(t_f, t_N]} = 1$ for the period $t_f < t \leq t_N$ and zero otherwise). Thus, the regional and cross-regional conjectural elasticities are $\theta_{y^i, y^i}^i = \theta_{y^i, y^i}^{ia}$ and $\Theta_{y^j, y^i}^i = \Theta_{y^j, y^i}^{ia}$ for $t < t_0$, $\theta_{y^i, y^i}^i = \theta_{y^i, y^i}^{ia} + \theta_{y^i, y^i}^{ib} \frac{t - t_0}{t_f - t_0}$ and $\Theta_{y^j, y^i}^i = \Theta_{y^j, y^i}^{ia} + \Theta_{y^j, y^i}^{ib} \frac{t - t_0}{t_f - t_0}$ for the period $t_0 < t \leq t_f$, and $\theta_{y^i, y^i}^i = \theta_{y^i, y^i}^{ia} + \theta_{y^i, y^i}^{ib}$ and $\Theta_{y^j, y^i}^i = \Theta_{y^j, y^i}^{ia} + \Theta_{y^j, y^i}^{ib}$ for the period $t_f < t \leq t_N$. Using Figure 3.1 as a guide, we select $t_0 = 1996$ and $t_f = 2004$.¹⁰

As per the theory, we restrict the estimates of the conjectural elasticity parameters to be between zero and one. Table 3.1 contains variable definitions. Table 3.2 presents the results for U.S. and Chinese export supply relations and demand functions for the ASEAN apple market. The estimated coefficients in the export supply relations are consistent with economic theory and are significant at the 1 or 5 percent level. The positive sign for the estimates of the U.S. and Chinese input price indexes indicates that higher labor, fuel, and fertilizer costs increase marginal costs, which raises the price of both U.S. and Chinese apples in ASEAN.

The results show that the U.S. and Chinese regional and cross-regional conjectural elasticities range between 0 and 1 and are significant at the 1 or 5 percent level. The time path of the regional and cross-regional conjectural elasticities are reported in Table 3.3. During the period 1986 - 1995, U.S. exporters exercised market power in the ASEAN market, as shown by $\hat{\theta}_{y^U, y^U}^U = \hat{\theta}_{y^U, y^U}^{Ua} = 0.586$. However, U.S. exporters' ability to exercise market power diminished as Chinese exporters gained a foothold and increased their market share during the period $t_0 = 1996$ to $t_f = 2004$, which resulted in a negative value for the structural drift estimate ($\hat{\theta}_{y^U, y^U}^{Ub}$) at -0.586 . Consequently, U.S. conjectural elasticity declined from 0.586 in 1996 to 0.007 in 2003, which are computed using $\hat{\theta}_{y^U, y^U}^U = \hat{\theta}_{y^U, y^U}^{Ua} + \hat{\theta}_{y^U, y^U}^{Ub} \frac{t - t_0}{t_f - t_0}$. As Chinese exporters captured about 70 percent of the market share beginning in 2004, the U.S. conjectural elasticity, $\hat{\theta}_{y^U, y^U}^U (= \hat{\theta}_{y^U, y^U}^{Ua} + \hat{\theta}_{y^U, y^U}^{Ub})$, fell to zero and thus eliminated U.S. exporters' ability to exert market power. The estimates show that U.S. exporters did not influence Chinese exports because both the constant ($\hat{\Theta}_{y^C, y^U}^{Ua}$) and

¹⁰We also tried different start and end points for the structural change period, but $t_0 = 1996$ and $t_f = 2004$ yielded both the most significant and defensible estimates.

Table 3.1: Variable Definitions

Variable	Definition
y^U	U.S. exports to ASEAN (1000 tonnes)
y^C	Chinese exports to ASEAN (1000 tonnes)
y^S	Southern Hemisphere exports to ASEAN (1000 tonnes)
x^U	U.S. domestic sales (1000 tonnes)
x^C	Chinese domestic sales (1000 tonnes)
$inputp^U$	U.S. input price index of wage, fuel, and fertilizer
$inputp^C$	Chinese input price index of wage and fuel
z^A	Index of exogenous demand variables in ASEAN: GDP, population, and orange price
v^U	Index of exogenous demand variables in the United States: GDP, population, and orange price
v^C	Index of exogenous demand variables in China: GDP, population, and orange price
g^i	Iceberg transport cost
TG^i	Tariff (τ^i) divided by the iceberg transport cost $(1 + \tau^i) / g^i$

structural drift ($\hat{\Theta}_{y^C, y^U}^{Ub}$) parameter estimates are zero for the cross-regional conjectural elasticity ($\hat{\Theta}_{y^C, y^U}^U$) (see Table 3.2).

Given the small market share of Chinese exporters during the period 1986 to 1995, the estimate of the Chinese regional conjectural elasticity $\hat{\theta}_{y^C, y^C}^C = \hat{\theta}_{y^C, y^C}^{Ca}$ is zero. However, the parameter estimate of the constant term ($\hat{\Theta}_{y^U, y^C}^{Ca}$) for the cross-conjectural elasticity ($\hat{\Theta}_{y^U, y^C}^C$) is 0.465, which suggests that the Chinese exporters were able to exert market power because they recognized the price advantage of their apples compared to the high priced U.S. apples. As Chinese exporters expanded their market share between 1996 and 2004, their ability to mark price above marginal cost increased through the regional conjectural elasticity ($\hat{\theta}_{y^C, y^C}^C$) as revealed by the drift parameter estimate ($\hat{\theta}_{y^C, y^C}^{Cb}$) which is positive at 0.454. Thus, the regional conjectural elasticity increases from 0.057 in 1997 to 0.454 in 2004 (computed using $\hat{\theta}_{y^C, y^C}^C = \hat{\theta}_{y^C, y^C}^{Ca} + \hat{\theta}_{y^C, y^C}^{Cb} \frac{t - t_0}{t_f - t_0}$), and remains at that level through the end of the sample period. The perceived influence of Chinese exporters on U.S. exports increased from 0.465 in 1996 to 1.00 by 2004, as the drift parameter estimate ($\hat{\Theta}_{y^U, y^C}^{Cb}$) is 0.535, which indicates the domination of Chinese exports over U.S. exports.

The parameter estimates of the ASEAN demand functions for U.S. and Chinese apples are consistent with the theoretical expectations (see Table 3.2). The majority of the estimates

Table 3.2: U.S. and Chinese Apple Exports to ASEAN

Variable/Coefficients	United States (U)	China (C)
Export Supply Relations		
<i>intercept</i>	0.1265 (1.28)	0.1185 (4.80***)
$TG^{i*}inputp^i$	–	0.0063 (6.32***)
$TG^{i*}(inputp^i)^{(1/2)}$	0.0710 (5.93***)	–
$TG^{i*}(y^i/g^i+x^i)$	0.0002 (5.82***)	6.84e–6 (2.58**)
$\hat{\theta}_{y^i,y^i}^{ia}$	0.5861 (2.08**)	0.0000 (.)
$\hat{\theta}_{y^i,y^i}^{ib}$	–0.5859 (–2.07**)	0.4536 (3.43**)
$\hat{\Theta}_{y^j,y^i}^{ia}$	0.0000 (.)	0.4653 (2.34**)
$\hat{\Theta}_{y^j,y^i}^{ib}$	0.0000 (.)	0.5346 (2.68***)
Export Demand Functions		
<i>Intercept</i>	3.0894 (12.05***)	0.8320 (9.33***)
y^i	–0.0152 (–2.33**)	–0.0026 (–3.68***)
$y^i \cdot z^A$	0.0001 (2.26**)	0.00001 (2.23**)
y^j	–0.0036 (–1.15)	–0.0004 (–0.30)
$y^j \cdot z^A$	–5.95e–6 (–0.25)	0.00002 (1.82*)
y^S	–0.0173 (–3.92***)	–0.0024 (–1.63)
z^A	0.0008 (0.53)	0.0005 (0.92)

Note: ***, **, * significant at the 1, 5, 10 percent level (two tailed). The (.) indicates a restricted parameter estimate reached its lower bound of zero.

in the ASEAN demand for U.S. and Chinese apples are significant. Over the range of the data, the marginal effect of an increase in apple sales from the United States, China, or the Southern Hemisphere is to lower the price of U.S. or Chinese apples in ASEAN. The marginal impact of an increase in income and the price of oranges (captured by a higher value of z^A) is to raise the price of apples in ASEAN because these variables have positive effects on apple demand.

Table 3.4 presents the results for the U.S. and Chinese domestic apple markets. The estimated coefficients for the domestic supply relations are consistent with economic theory and are largely significant. The positive sign on the input price index, $inputp^i$, shows that higher labor, fuel, and fertilizer prices raise the price of apples in both countries. Table 3.5 reports the U.S. and Chinese domestic conjectural elasticity estimates. The U.S. conjectural elasticity ($\hat{\theta}_x^U$) converges to its lower bound indicating that apple sellers in the U.S. domestic market do not exercise market power and marginal cost pricing prevails. The Chinese conjectural elasticity ($\hat{\theta}_x^C$) estimate is

Table 3.3: Demand Flexibilities and Conjectural Elasticities for the ASEAN Export Market

Year	United States				China			
	Flexibilities		Conj. Elast		Flexibilities		Conj. Elast	
	$-\hat{\varepsilon}_{\hat{p}^{US},y^{US}}$	$-\hat{\varepsilon}_{\hat{p}^{US},y^{CH}}$	$\hat{\theta}_{y^U,y^U}^U$	$\hat{\Theta}_{y^C,y^U}^U$	$-\hat{\varepsilon}_{\hat{p}^{CH},y^{CH}}$	$-\hat{\varepsilon}_{\hat{p}^{CH},y^{US}}$	$\hat{\theta}_{y^C,y^C}^C$	$\hat{\Theta}_{y^U,y^C}^C$
1986	-0.37	-0.01	0.586	0	-0.05	-0.03	0.000	0.465
1987	-0.23	-0.02	0.586	0	-0.05	-0.03	0.000	0.465
...								
1995	-0.22	-0.08	0.586	0	-0.07	-0.08	0.000	0.465
$t_0=1996$	-0.30	-0.13	0.586	0	-0.14	-0.07	0.000	0.465
1997	-0.48	-0.23	0.513	0	-0.18	-0.08	0.057	0.532
...								
2003	-0.99	-1.08	0.073	0	-1.21	-0.06	0.397	0.933
$t_f=2004$	-0.66	-1.04	0.0001	0	-1.33	-0.05	0.454	1.000
2005	-0.79	-1.14	0.0001	0	-1.32	-0.06	0.454	1.000
2006	-0.54	-1.04	0.0001	0	-1.06	-0.04	0.454	1.000
2007	-0.34	-1.13	0.0001	0	-1.24	-0.03	0.454	1.000
$t_N=2008$	-0.33	-0.99	0.0001	0	-1.06	-0.02	0.454	1.000

only 0.085 and it is not significant. This result indicates that Chinese apple sellers are not able to exert market power in the domestic market because, as elaborated in the introduction, there are numerous producers and sellers with many avenues for marketing apples in China.

For both the U.S. and Chinese domestic demand functions, the parameter estimates have the anticipated sign. Over the range of data, the marginal impact of an increase in apple sales in the domestic market is to reduce the price of apples. The marginal effect of an increase in income, population, and orange prices is positive as these variables augment the demand for apples.

3.5.3 Lerner Index

We analyze the overall degree of oligopoly market power by computing the Lerner index—defined as the percent that price is marked above marginal cost—using the demand flexibilities and conjectural elasticities. Rearranging (3.20) and (3.21) the Lerner Indices are expressed as

$$\text{Exp. Market} : \frac{\hat{p}^i - \frac{(1 + \tau^i)}{g^i} (mc_y^i - s^i)}{\hat{p}^i} = \varepsilon_{\hat{p}^i, y^i} \theta_{y^i, y^i}^i + \varepsilon_{\hat{p}^i, y^j} \Theta_{y^j, y^i}^i \quad (3.29)$$

$$\text{Dom. Market} : \frac{p^i - (mc_x^i - s^i)}{p^i} = \varepsilon_{p^i, x^i} \theta_{x^i, x^i}^i \quad (3.30)$$

Table 3.4: U.S. and Chinese Domestic Apple Markets

Variable/Coefficient	United States (U)	China (C)
Domestic Supply Relations		
<i>intercept</i>	0.1265 (1.28)	0.1185 (4.80 ^{***})
<i>inputpⁱ</i>	–	0.0063 (6.32 ^{***})
$(inputp^i)^{(1/2)}$	0.0710 (5.93 ^{***})	–
(y^i/g^i+x^i)	0.0002 (5.82 ^{***})	6.84e–6 (2.58 ^{**})
$\hat{\theta}_x^i$	0.0000 (.)	0.0848 (0.64)
Domestic Demand Functions		
<i>Intercept</i>	4.1465 (2.18 ^{**})	0.8764 (10.71 ^{***})
x^i	–0.0015 (–1.79 [*])	–9.19e–6 (–1.42)
$x^i \cdot v^i$	–4.56e–7 (–1.48)	6.48e–8 (4.92 ^{***})
v^i	0.0017 (1.47)	0.0005 (2.24 ^{**})

z-values are in parentheses. ^{***}, ^{**}, ^{*} significant at the 1, 5, 10 percent level (two tailed). The (.) indicates a restricted parameter estimate reached its lower bound of zero.

Table 3.5: U.S. and Chinese Domestic Markets

Year	United States			China		
	Flexibility	Conj. E.	Lerner	Flexibility	Conj. E.	Lerner
ave. '86 - '08	$\hat{\epsilon}_{p^U, x^U}$	$\hat{\theta}_x^U$		$\hat{\epsilon}_{p^C, x^C}$	$\hat{\theta}_x^C$	
	–2.57	0	0	–0.57	0.085	0.048

In the ASEAN market, the percent that the apple price is marked above the tariff, transport cost, and subsidy adjusted marginal cost is equal to the export demand flexibility times the regional conjectural elasticity plus the export cross-demand flexibility times the cross-regional conjectural elasticity. In the domestic market, the percent that the apple price is marked above marginal costs adjusted for the subsidy is equal to the demand flexibility times the conjectural elasticity.

For the export market, we analyze the time path of the Lerner Indices by calculating the conjectural elasticities and point-demand flexibilities for each year in the sample. The flexibilities are computed using the coefficient estimate times the price/quantity for each year. In the mid-1980s, as shown by the own- and cross-demand flexibilities ($-\hat{\epsilon}_{\hat{p}^{US}, y^{US}}$ and $-\hat{\epsilon}_{\hat{p}^{US}, y^{CH}}$) in Table 3.3, the price of U.S. apples in ASEAN responded modestly to a change in apple sales: a 1 percent rise in U.S. (Chinese) exports lowered the price of U.S. apples by 0.37(0.01) percent in 1986. However, as the ASEAN demand for apples increased, the price responsiveness to higher

exports became more pronounced; a 1 percent rise in U.S. (Chinese) exports lowered the price of U.S. apples by 0.99(1.08) percent in 2003. By the end of the sample period, $\hat{\varepsilon}_{\hat{p}^{US},y^{US}}$ fell to 0.33 and $\hat{\varepsilon}_{\hat{p}^{US},y^{CH}}$ declined slightly to 0.99. In the mid-1980s, the demand flexibilities ($-\hat{\varepsilon}_{\hat{p}^{CH},y^{CH}}$) and cross-flexibilities ($-\hat{\varepsilon}_{\hat{p}^{CH},y^{US}}$) for Chinese apples in ASEAN were also low at -0.05 and -0.03 , and became slightly more responsive at -0.14 and -0.07 by 1996. After the Chinese exporters established their dominance and the ASEAN demand for apples gained momentum, the own-demand flexibility peaked at 1.33 and the cross-demand flexibility is 0.06 in 2004. As the Chinese market share plateaued, $\hat{\varepsilon}_{\hat{p}^{CH},y^{CH}}$ decreased to 1.06 and $\hat{\varepsilon}_{\hat{p}^{CH},y^{US}}$ fell to 0.02 by the end of the sample period.

Table 3.6 reports the Lerner Indices for both U.S. and Chinese exporters in the ASEAN apple market, which are also plotted in Figure 3.2. Note that the absolute value of the flexibilities are used in computing the Lerner Indices. Even though the regional conjectural elasticity was 0.586 for U.S. apples for the period 1986 - 1996, the relatively low demand flexibilities early in the sample period hindered the exporters ability to markup the price of apples exported to ASEAN. As a result, the Lerner Index for 1986 and 1987 was 0.219 and 0.136. However, as the demand flexibility for U.S. apples increased, the Lerner Index for U.S. apple exports also rose, reaching a peak of 0.383 in 1999. After the late 1990s, as Chinese exporters began displacing U.S. exports and expand their market share, the markup on the price of U.S. apple exports declined to nearly zero by 2008.

Because of limited Chinese apple exports in the first 10 years of the sample period, Chinese exporters charged close to competitive prices as shown by the Lerner Index, which ranges from 0.016 in 1986 to 0.035 in 1996. Even though the cross-regional conjectural elasticity was 0.465 for this period, the demand flexibilities for Chinese apples were also low, which resulted in small values for the Lerner Index. This also indicates that, in order to establish a market, Chinese exporters covered only their marginal costs in the early years. After 1996, as the Chinese exporters became dominant, both the demand flexibilities and regional conjectural elasticities increased, which resulted in the markup of Chinese apple price increasing from 5.44 percent in 1997 to a

Table 3.6: Lerner Indices for the Export Market

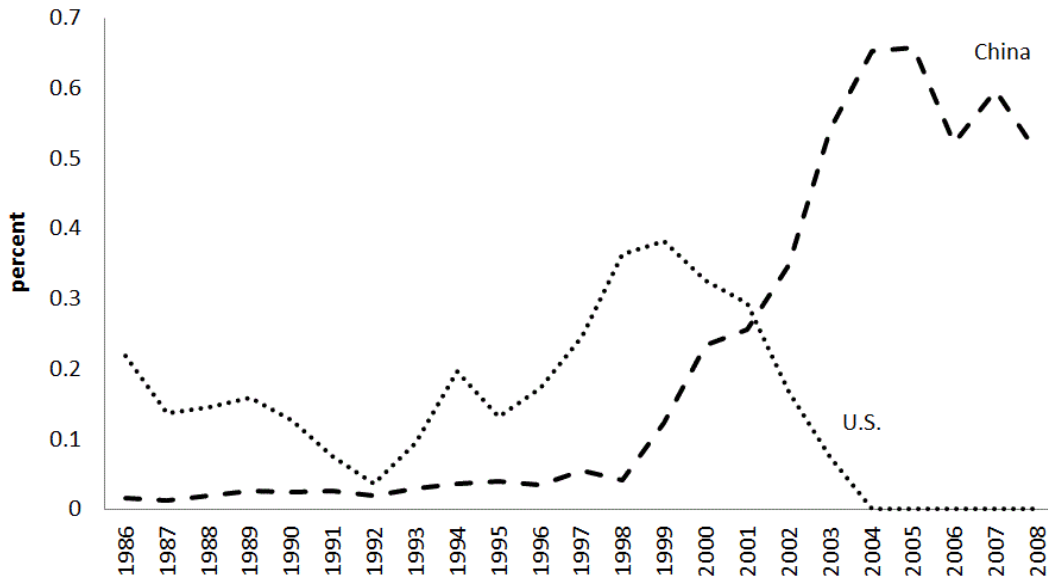
Year	United States	China
1986	0.2193	0.0159
1987	0.1364	0.0125
...		
1995	0.1312	0.0392
$t_0 = 1996$	0.1730	0.0353
1997	0.2451	0.0544
...		
2002	0.1679	0.3487
2003	0.0733	0.5416
$t_f = 2004$	0.00007	0.6532
2005	0.00008	0.6571
2006	0.00006	0.5220
2007	0.00004	0.5965
$t_N = 2008$	0.00004	0.5087

maximum 65.71 percent in 2005 after surpassing the U.S. Lerner Index in 2002. For both the U.S. and Chinese domestic markets, we calculate the demand flexibilities as an average over the sample period. In the U.S. and Chinese domestic markets, the demand flexibilities average -2.57 and -0.57 , respectively (see Table 3.5). Thus, a 1 percent increase in domestic apple sales in the United States and China lowered the price by 2.57 percent and 0.57 percent, respectively.

In the U.S. domestic market, the conjectural elasticity is zero, thus the Lerner Index is also zero (see Table 3.5) and apples are competitively priced at their marginal cost. The rationale for this result is that in the domestic market, there are a large number of apple suppliers, and consumers have many outlets (grocery stores, super markets, cooperatives, and farmers markets) to purchase apples. In the Chinese domestic market, the Lerner Index averages at 0.048 and is not statistically different from zero, indicating that the apple sellers do not exert market power.

In summary, the results suggest that even though apple sellers in the U.S. domestic market charge competitive prices, the cost of establishing an export link to ASEAN leads to only a small fraction of firms serving this market, and as a result, these firms are able to exercise market power, particularly during the middle of the sample. Our results suggest that this is due to the high quality of apples supplied by U.S. exporters. However, as the Chinese market share increased

Figure 3.2: U.S. and Chinese Lerner Indexes



from less than 10 percent to about 70 percent, U.S. exporters' ability to earn oligopoly profits is lost. Furthermore, Chinese exporters could exercise market power in ASEAN only after they established high market share for their low-quality apples.

3.5.4 Simulation Results

This subsection presents simulation analyses of the removal of the tariff on Chinese apples in ASEAN, an increase in the U.S. and Chinese transportation cost, and the implementation of subsidies for U.S. and Chinese producers. We focus on the last 10 years of the sample period for the simulation analyses because they closely resemble the current U.S. and Chinese market shares in ASEAN.

To examine the impact of the China-ASEAN Free Trade Area, we analyze the effects of eliminating the tariff on Chinese apples. This tariff removal causes Chinese exports to expand by 13.81 percent and U.S. exports to contract by 19.24 percent, which results in the Chinese apple price in ASEAN to decrease by 11.68 percent and U.S. apple price in ASEAN to increase by 1.46 percent (Table 3.7). As Chinese exports increased, the domestic sale of apple contracted by 0.11 percent, which caused the domestic price of apples to rise by 0.03 percent. Since Chinese exports

Table 3.7: Simulation Results of Tariff and Transport Cost Changes, Average for 1999-2008

	Elimination of Tariff on Chinese Apples	Increase in U.S. Transport Cost (10%)	Increase in Chinese Transport Cost (10%)
Export Market (Percent Changes)			
y^{US}	-19.24	-37.35	44.80
\hat{p}^{US}	1.46	20.04	-3.31
y^{CH}	13.81	10.58	-30.93
\hat{p}^{CH}	-11.68	-11.99	26.81
Domestic Market (Percent Changes)			
x^{US}	0.23	0.34	-0.53
p^{US}	-0.23	-0.36	0.53
x^{CH}	-0.12	-0.10	0.15
p^{CH}	0.03	0.03	-0.05

displaces U.S. exports, more apples (0.23 percent) are sold in the U.S. domestic market and the U.S. price declines by 0.23 percent. These results are consistent with the qualitative prediction of the theoretical analysis.

Next, we consider the effect of a 10 percent rise in the U.S. and Chinese transport costs individually (captured by a reduction in the iceberg cost g^i) to reflect the increasing trend in fuel costs. A 10 percent increase in shipping costs from the United States to ASEAN decreases U.S. exports by 37.35 percent, which increases the price of U.S. apple in ASEAN by 20.04 percent (see Table 3.7). In response, Chinese apple exports increase by 10.58 percent, which lowers the price of Chinese apples in ASEAN by 11.99 percent. The reduced U.S. exports to ASEAN leads to a small increase in U.S. domestic sales, causing a domestic price decline. The increase in Chinese exports to ASEAN results in a modest decrease in Chinese domestic sales, leading to a price increase. A 10 percent increase in Chinese transport cost causes Chinese exports to ASEAN to decline by 30.93 percent, which causes the Chinese apple price to increase by 26.81 percent. The market lost by China is captured by U.S. exports, which increase by 44.80 percent, leading to a 3.31 percent decline in the U.S. apple price in ASEAN. Since China is exporting less to ASEAN, Chinese domestic sales increase only modestly. The increased U.S. exports to ASEAN crowds out domestic sales and increases the domestic price. As presented in the theoretical analysis, a 10 percent increase in the Chinese transport cost has a smaller negative impact on Chinese exports

(−30.93 percent), whereas a 10 percent increase in the U.S. transport cost has a larger adverse impact on U.S. exports (−37.35 percent).

Finally, we evaluate the impact of a 10 percent increase in production subsidy by the U.S. and Chinese governments (Table 3.8). We consider this policy to reflect the short-term production subsidies frequently offered by both the U.S. and Chinese governments, which have played an important role in both the domestic and export apple markets. A 10 percent increase in U.S. production subsidy leads to an increase in U.S. exports to ASEAN and domestic sales, respectively, by 18.59 percent and 9.02 percent. The higher supply of apples causes both the export and domestic price to decline, respectively, by 3.09 percent and 9.21 percent. The increase in U.S. exports to ASEAN reduces Chinese exports by 10.84 percent and expands domestic sales by 0.10 percent. The Chinese subsidy augments Chinese exports and domestic sales by, respectively, 42.82 percent and 30.91 percent. The increase in sales drives the export price down by 31.95 percent and the domestic price by 8.66 percent. As a result of the Chinese subsidy, U.S. exports to ASEAN decrease by 57.31 percent and domestic sales increase by 0.76 percent, which causes the export price to raise by 9.47 percent and the domestic price to reduce by 0.74 percent.

Countries provide subsidies not only to increase production and exports but also to effectively compete with other exporters in the foreign market. That is, countries engage in strategic trade policies to drive out competition and increase their welfare to the detriment of competing countries. In the subsidy simulation analysis, a 10 percent increase in Chinese production subsidy augments Chinese welfare by \$124.5 million, and this subsidy lowers the U.S. welfare by \$14.0 million because the Chinese increased exports displaces U.S. exports in ASEAN. Similarly, a 10 percent increase in U.S. production subsidy raises U.S. welfare by \$3.7 million and reduces Chinese welfare by \$1.2 million as higher U.S. exports lowers Chinese exports in ASEAN. It is worth noting that the Chinese subsidy has a larger adverse impact on U.S. exports and welfare than the U.S. subsidy has on Chinese exports and welfare. The subsidy's effect of benefiting the home country at the expense of the foreign country is known as rent shifting in the new trade theory literature.

Table 3.8: Simulation Results of Production Subsidies, Average for 1999-2008

	U.S. Subsidy	Chinese Subsidy
Export Market (Percent Changes)		
y^{US}	18.59	-57.31
\hat{p}^{US}	-3.09	9.47
y^{CH}	-10.84	42.82
\hat{p}^{CH}	9.84	-31.95
Domestic Market (Percent Changes)		
x^{US}	9.02	0.76
p^{US}	-9.21	-0.74
x^{CH}	0.10	30.91
p^{CH}	-0.03	-8.66
Welfare Changes		
W^U	\$3,715,279	\$ - 14,030,611
W^C	\$ - 1,154,174	\$124,496,566

3.6 Conclusions

U.S. apple exports played a dominant role in the ASEAN market until the mid-1990s when Chinese apple exports gained momentum and surpassed U.S. exports. The dramatic increase in Chinese exports to ASEAN was a result of the economic reforms in the early 1980s which led to the relinquishing of state control of apple orchards and subsidies to boost production. In ASEAN, U.S. and Chinese apples are differentiated by quality because of differences in phytosanitary standards. U.S. exporters supply high quality apples, whereas Chinese exporters compete with low-cost, lower-quality, apples. The additional costs associated with exporting apples to ASEAN—which leads to market concentration in ASEAN—and the quality differences provide incentives for U.S. and Chinese exporters to exercise market power.

Using strategic trade theory under product differentiation, we analyze the competition between U.S. and Chinese apple exporters in the ASEAN market and apple sellers in the domestic market. We derive analytical results of the effects of changes in the ASEAN tariff on U.S. and Chinese apples, the transport cost of shipping apples from the United States and China, and the production subsidies implemented by both governments. The results show that an increase in the ASEAN tariff and transport costs hinders own-country's exports and expands domestic sales, but

increases competitor's exports and reduces their domestic sales. Higher production subsidies promote own country's exports to ASEAN and domestic sales but displaces the competitor's exports. Furthermore, as is well documented in the strategic trade literature, it is welfare improving for a government to subsidize production at the expense of the competitor.

The empirical analysis follows the NEIO literature for econometrically estimating the model. The results from the structural estimation and Lerner Indices indicate the existence of oligopolistic competition between U.S. and Chinese exporters in the ASEAN apple market. The U.S. Lerner Index shows that the markup on U.S. apples exports to ASEAN were high in the 1990s and declined drastically thereafter. The markup on Chinese apples was very low until 1998, and increased sharply thereafter. Furthermore, the analysis indicates perfect competition in the U.S. and Chinese domestic markets.

The simulation results from a lower ASEAN tariff on Chinese apples, an increase in transport costs, and a rise in subsidies are all consistent with theoretical predictions. The elimination of the tariff on Chinese apples leads to higher ASEAN apple imports from China and a lower price for Chinese apples. Conversely, U.S. apples exports to ASEAN decline and the U.S. apple price increases. An increase in the transport cost has larger negative impacts on U.S. exports than on Chinese exports because of the latter's close proximity to ASEAN. Finally, a country's subsidy augments its production which increases exports and welfare at the expense of the other country's export sales and welfare.

From a policy perspective, given that the U.S. domestic market is a mature market for apples, expanding exports is important for the viability of the U.S. apple industry. Given the size and continued increase in demand for apples, a U.S.-ASEAN trade agreement would help U.S. apple exporters maintain a competitive edge in the ASEAN apple market.

3.7 Appendix

This section shows the derivation of the comparative statics and optimal subsidy.

3.7.1 Comparative Statics

The profit equations are

$$\pi^i(y^i, y^j, x^i; g^i, \tau^i) = \frac{\hat{p}^i(y^i, y^j)}{1 + \tau^i} y^i + p^i(x^i) x^i - c^i\left(x^i + \frac{y^i}{g^i}\right) - F^i + s^i \left[x^i + \frac{y^i}{g^i} \right].$$

The first order condition and implicit reaction functions are

$$\pi_{y^i}^i = \frac{y^i \hat{p}_{y^i}^i + \hat{p}^i}{(1 + \tau^i)} - \frac{\partial c^i(\cdot)}{\partial y^i} + \frac{s^i}{g^i} = 0, \quad \pi_{x^i}^i = x^i p_{x^i}^i + p^i - \frac{\partial c^i(\cdot)}{\partial x^i} + s^i = 0$$

which constitute solutions only if the second order conditions are satisfied. The second order condition are

$$\pi_{y^i y^i}^i = \frac{y^i \hat{p}_{y^i y^i}^i + 2\hat{p}_{y^i}^i}{(1 + \tau^i)} - \frac{\partial^2 c^i(\cdot)}{\partial y^i \partial y^i} < 0, \quad \pi_{x^i x^i}^i = x^i p_{x^i x^i}^i + 2p_{x^i}^i - \frac{\partial^2 c^i(\cdot)}{\partial x^i \partial x^i} < 0.$$

The cross-partials imply a downward sloping reaction function

$$\begin{aligned} \pi_{y^i x^i}^i &= -\frac{\partial^2 c^i(\cdot)}{\partial y^i \partial x^i} < 0, & \pi_{y^i y^j}^i &= \frac{y^i \hat{p}_{y^i y^j}^i + \hat{p}_{y^j}^i}{(1 + \tau^i)} < 0, & \pi_{x^i x^j}^i &= 0, \\ \pi_{y^i x^j}^i &= 0, & \pi_{x^i y^i}^i &= -\frac{\partial^2 c^i(\cdot)}{\partial x^i \partial y^i} < 0, & \pi_{x^i y^j}^i &= 0. \end{aligned}$$

To sign the derivatives of the cost function, we assume a convex quadratic cost function:

$$c^i\left(x^i + \frac{y^i}{g^i}\right) = \left(x^i + \frac{y^i}{g^i}\right)^2 + x^i + \frac{y^i}{g^i}.$$

Using this function, the first and second derivative with respect to output are

$$\begin{aligned} \frac{\partial c^i(\cdot)}{\partial x^i} &= 2\left(x^i + \frac{y^i}{g^i}\right) + 1 > 0, & \frac{\partial^2 c^i(\cdot)}{\partial x^i \partial x^i} &= 2 > 0, \\ \frac{\partial c^i(\cdot)}{\partial y^i} &= \frac{2}{g^i}\left(x^i + \frac{y^i}{g^i}\right) + \frac{1}{g^i} > 0, & \frac{\partial^2 c^i(\cdot)}{\partial y^i \partial y^i} &= \frac{2}{(g^i)^2} > 0, \\ \frac{\partial^2 c^i(\cdot)}{\partial x^i \partial y^i} &= \frac{\partial^2 c^i(\cdot)}{\partial y^i \partial x^i} = \frac{2}{g^i} > 0, & \frac{\partial^2 c^i(\cdot)}{\partial x^i \partial g^i} &= -\frac{2y^i}{(g^i)^2} < 0, \\ \frac{\partial^2 c^i(\cdot)}{\partial y^i \partial g^i} &= -\frac{2y^i}{(g^i)^2} \left(\frac{x^i}{y^i} + \frac{1}{2y^i} + \frac{2}{g^i}\right) < 0. \end{aligned}$$

Using these results, we analyze the impact of a change in policy on the marginal change in profits.

These results are central in signing the comparative statics below,

$$\begin{aligned}\pi_{y^i g^i}^i &= \frac{2y^i}{(g^i)^2} \left(\frac{x^i}{y^i} + \frac{1}{2y^i} + \frac{2}{g^i} \right) + \frac{s^i}{(g^i)^2} > 0, & \pi_{x^i g^i}^i &= \frac{2y^i}{(g^i)^2} > 0, \\ \pi_{y^i \tau^i}^i &= -\frac{y^i \hat{p}_{y^i}^i + \hat{p}^i}{(1 + \tau^i)^2} < 0, & \pi_{x^i \tau^i}^i &= 0, \\ \pi_{y^i s^i}^i &= \frac{1}{g^i} > 0, & \pi_{x^i s^i}^i &= 1 > 0\end{aligned}$$

The following results are also implemented in signing the comparative statics:

$$\pi_{y^i y^i}^i \pi_{x^i x^i}^i - \pi_{x^i y^i}^i \pi_{y^i x^i}^i > 0, \quad \underbrace{\pi_{x^u g^u}^u \pi_{y^u x^u}^u}_{+} - \underbrace{\pi_{y^u g^u}^u \pi_{x^u x^u}^u}_{-} > 0$$

because $\pi_{y^i g^i}^i > \pi_{x^i g^i}^i$ and $\pi_{x^i x^i}^i < \pi_{y^i x^i}^i$;

$$\pi_{y^i g^i}^i \pi_{x^i y^i}^i - \pi_{x^i g^i}^i \pi_{y^i y^i}^i > 0, \quad \pi_{y^i g^i}^i \pi_{x^i x^i}^i - \pi_{x^i g^i}^i \pi_{y^i x^i}^i < 0, \quad \pi_{x^i s^i}^i \pi_{y^i x^i}^i - \pi_{y^i s^i}^i \pi_{x^i x^i}^i > 0$$

because $\pi_{x^i x^i}^i < \pi_{y^i x^i}^i$, and $\pi_{x^i s^i}^i < \pi_{y^i s^i}^i$ because $1 < \frac{(1 + \tau^i)}{g^i}$;

$$\pi_{y^i s^i}^i \pi_{x^i x^i}^i - \pi_{x^i s^i}^i \pi_{y^i x^i}^i < 0, \quad \pi_{y^i s^i}^i \pi_{x^i y^i}^i - \pi_{x^i s^i}^i \pi_{y^i y^i}^i > 0.$$

Totally differentiating the FOCs and writing them as a system of equations we get

$$\begin{bmatrix} \pi_{y^i y^i}^i & \pi_{y^i x^i}^i & \pi_{y^i y^j}^i & 0 \\ \pi_{x^i y^i}^i & \pi_{x^i x^i}^i & 0 & 0 \\ \pi_{y^j y^i}^j & 0 & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ 0 & 0 & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{bmatrix} \begin{bmatrix} dy^i \\ dx^i \\ dy^j \\ dx^j \end{bmatrix} = - \begin{bmatrix} \pi_{y^i g^i}^i dg^i + \pi_{y^i \tau^i}^i d\tau^i + \pi_{y^i s^i}^i ds^i + \pi_{y^i s^i}^i ds^i \\ \pi_{x^i g^i}^i dg^i + \pi_{x^i s^i}^i ds^i + \pi_{x^i s^i}^i ds^i \\ \pi_{y^j g^j}^j dg^j + \pi_{y^j \tau^j}^j d\tau^j + \pi_{y^j s^j}^j ds^j + \pi_{y^j s^j}^j ds^j \\ \pi_{x^j g^j}^j dg^j + \pi_{x^j s^j}^j ds^j + \pi_{x^j s^j}^j ds^j \end{bmatrix}$$

$$Ax = d.$$

The determinant of A is

$$|A| = \begin{vmatrix} \pi_{y^i y^i}^i & \pi_{y^i x^i}^i & \pi_{y^i y^j}^i & 0 \\ \pi_{x^i y^i}^i & \pi_{x^i x^i}^i & 0 & 0 \\ \pi_{y^j y^i}^j & 0 & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ 0 & 0 & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{vmatrix}$$

$$= (\pi_{y^i y^i}^i \pi_{x^i x^i}^i - \pi_{y^i x^i}^i \pi_{x^i y^i}^i) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) - \pi_{x^j x^j}^j \pi_{y^i y^j}^i \pi_{y^j y^i}^j \pi_{x^i x^i}^i > 0,$$

under plausible demand and supply function, we can ascertain that the determinant is positive.

Using Cramer's Rule, we are able to analyze the effects of g^i , τ^i , and s^i on y^i

$$\begin{aligned} dy^i &= \frac{1}{|A|} \begin{vmatrix} -\left(\pi_{y^i g^i}^i dg^i + \pi_{y^i \tau^i}^i d\tau^i + \pi_{y^i s^i}^i ds^i\right) & \pi_{y^i x^i}^i & \pi_{y^i y^j}^i & 0 \\ -\left(\pi_{x^i g^i}^i dg^i + \pi_{x^i s^i}^i ds^i\right) & \pi_{x^i x^i}^i & 0 & 0 \\ 0 & 0 & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ 0 & 0 & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{vmatrix} \\ &= -\left(\pi_{y^i g^i}^i dg^i + \pi_{y^i \tau^i}^i d\tau^i + \pi_{y^i s^i}^i ds^i\right) \pi_{x^i x^i}^i \frac{1}{|A|} \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j\right) \\ &\quad + \left(\pi_{x^i g^i}^i dg^i + \pi_{x^i s^i}^i ds^i\right) \frac{1}{|A|} \pi_{y^i x^i}^i \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j\right). \end{aligned}$$

Therefore,

$$\begin{aligned} \frac{dy^i}{dg^i} &= \frac{1}{|A|} \left(\pi_{x^i g^i}^i \pi_{y^i x^i}^i - \pi_{y^i g^i}^i \pi_{x^i x^i}^i\right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j\right) > 0 \\ \frac{dy^i}{d\tau^i} &= -\pi_{y^i \tau^i}^i \pi_{x^i x^i}^i \frac{1}{|A|} \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j\right) < 0 \\ \frac{dy^i}{ds^i} &= \frac{1}{|A|} \left(\pi_{x^i s^i}^i \pi_{y^i x^i}^i - \pi_{y^i s^i}^i \pi_{x^i x^i}^i\right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j\right) > 0 \end{aligned}$$

The effects of g^j , τ^j , and s^j on y^i is

$$\begin{aligned} dy^i &= \frac{1}{|A|} \begin{vmatrix} 0 & \pi_{y^i x^i}^i & \pi_{y^i y^j}^i & 0 \\ 0 & \pi_{x^i x^i}^i & 0 & 0 \\ -\left(\pi_{y^j g^j}^j dg^j + \pi_{y^j \tau^j}^j d\tau^j + \pi_{y^j s^j}^j ds^j\right) & 0 & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ -\left(\pi_{x^j g^j}^j dg^j + \pi_{x^j s^j}^j ds^j\right) & 0 & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{vmatrix} \\ &= \left(\pi_{y^j g^j}^j dg^j + \pi_{y^j \tau^j}^j d\tau^j + \pi_{y^j s^j}^j ds^j\right) \pi_{x^i x^i}^i \frac{1}{|A|} \pi_{y^i y^j}^i \pi_{x^j x^j}^j \\ &\quad - \left(\pi_{x^j g^j}^j dg^j + \pi_{x^j s^j}^j ds^j\right) \frac{1}{|A|} \pi_{x^i x^i}^i \pi_{y^i y^j}^i \pi_{y^j x^j}^j. \end{aligned}$$

Therefore,

$$\begin{aligned}\frac{dy^i}{dg^j} &= \frac{1}{|A|} \left(\pi_{y^j g^j}^j \pi_{x^j x^j}^j - \pi_{x^j g^j}^j \pi_{y^j x^j}^j \right) \pi_{y^i y^j}^i \pi_{x^i x^i}^i < 0 \\ \frac{dy^i}{d\tau^j} &= \pi_{y^j \tau^j}^j \pi_{x^i x^i}^i \frac{1}{|A|} \pi_{y^i y^j}^i \pi_{x^j x^j}^j > 0 \\ \frac{dy^i}{ds^j} &= \frac{1}{|A|} \left(\pi_{y^j s^j}^j \pi_{x^j x^j}^j - \pi_{x^j s^j}^j \pi_{y^j x^j}^j \right) \pi_{y^i y^j}^i \pi_{x^i x^i}^i < 0.\end{aligned}$$

The effects of g^i , τ^i , and s^i on x^i is

$$\begin{aligned}dx^i &= \frac{1}{|A|} \begin{vmatrix} \pi_{y^i y^i}^i - \left(\pi_{y^i g^i}^i dg^i + \pi_{y^i \tau^i}^i d\tau^i + \pi_{y^i s^i}^i ds^i \right) & \pi_{y^i y^j}^i & 0 \\ \pi_{x^i y^i}^i & - \left(\pi_{x^i g^i}^i dg^i + \pi_{x^i s^i}^i ds^i \right) & 0 & 0 \\ \pi_{y^j y^i}^j & 0 & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ 0 & 0 & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{vmatrix} \\ &= \left(\pi_{y^i g^i}^i dg^i + \pi_{y^i \tau^i}^i d\tau^i + \pi_{y^i s^i}^i ds^i \right) \pi_{x^i y^i}^i \frac{1}{|A|} \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) \\ &\quad - \left(\pi_{x^i g^i}^i dg^i + \pi_{x^i s^i}^i ds^i \right) \frac{1}{|A|} \left(\pi_{y^i y^i}^i \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) - \pi_{y^j y^i}^j \pi_{y^i y^j}^i \pi_{x^j x^j}^j \right).\end{aligned}$$

Therefore,

$$\begin{aligned}\frac{dx^i}{dg^i} &= \frac{1}{|A|} \left[\left(\pi_{y^i g^i}^i \pi_{x^i y^i}^i - \pi_{x^i g^i}^i \pi_{y^i y^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) \right. \\ &\quad \left. + \frac{1}{|A|} \pi_{x^i g^i}^i \pi_{y^j y^i}^j \pi_{y^i y^j}^i \pi_{x^j x^j}^j \right] < 0 \\ \frac{dx^i}{d\tau^i} &= \pi_{y^i \tau^i}^i \pi_{x^i y^i}^i \frac{1}{|A|} \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{x^j y^j}^j \pi_{y^j x^j}^j \right) > 0 \\ \frac{dx^i}{ds^i} &= \frac{1}{|A|} \left(\left(\pi_{y^i s^i}^i \pi_{x^i y^i}^i - \pi_{x^i s^i}^i \pi_{y^i y^i}^i \right) \left(\pi_{y^j y^j}^j \pi_{x^j x^j}^j - \pi_{y^j x^j}^j \pi_{x^j y^j}^j \right) \right. \\ &\quad \left. + \pi_{x^i s^i}^i \pi_{y^j y^i}^j \pi_{y^i y^j}^i \pi_{x^j x^j}^j \right) > 0.\end{aligned}$$

The effects of g^j , τ^j , and s^j on x^i is

$$dx^i = \frac{1}{|A|} \begin{vmatrix} \pi_{y^i y^i}^i & 0 & \pi_{y^i y^j}^i & 0 \\ \pi_{x^i y^i}^i & 0 & 0 & 0 \\ \pi_{y^j y^i}^j & - \left(\pi_{y^j g^j}^j dg^j + \pi_{y^j \tau^j}^j d\tau^j + \pi_{y^j s^j}^j ds^j \right) & \pi_{y^j y^j}^j & \pi_{y^j x^j}^j \\ 0 & - \left(\pi_{x^j g^j}^j dg^j + \pi_{x^j s^j}^j ds^j \right) & \pi_{x^j y^j}^j & \pi_{x^j x^j}^j \end{vmatrix}$$

$$\begin{aligned}
&= \left(\pi_{y^j g^j}^j dg^j + \pi_{y^j \tau^j}^j d\tau^j + \pi_{y^j s^j}^j ds^j \right) \pi_{x^j x^j}^j \frac{1}{|A|} \left(-\pi_{x^i y^i}^i \pi_{y^i y^j}^i \right) \\
&\quad - \left(\pi_{x^j g^j}^j dg^j + \pi_{x^j s^j}^j ds^j \right) \frac{1}{|A|} \pi_{y^j x^j}^j \left(-\pi_{x^i y^i}^i \pi_{y^i y^j}^i \right).
\end{aligned}$$

Therefore,

$$\begin{aligned}
\frac{dx^i}{dg^j} &= \frac{1}{|A|} \left(\pi_{x^j g^j}^j \pi_{y^j x^j}^j - \pi_{y^j g^j}^j \pi_{x^j x^j}^j \right) \pi_{y^i y^j}^i \pi_{x^i y^i}^i > 0 \\
\frac{dx^i}{d\tau^j} &= -\pi_{y^j \tau^j}^j \pi_{x^j x^j}^j \frac{1}{|A|} \pi_{x^i y^i}^i \pi_{y^i y^j}^i < 0 \\
\frac{dx^i}{ds^j} &= \frac{1}{|A|} \left(\pi_{x^j s^j}^j \pi_{y^j x^j}^j - \pi_{y^j s^j}^j \pi_{x^j x^j}^j \right) \pi_{y^i y^j}^i \pi_{x^i y^i}^i > 0.
\end{aligned}$$

3.7.2 Optimal Subsidy

Totally differentiating the welfare function we obtain

$$\begin{aligned}
dW^i(\cdot) &= \left\{ p^i \frac{\partial x^i}{\partial s^i} ds^i - p_{x^i}^i \frac{\partial x^i}{\partial s^i} ds^i x^i - p^i \frac{\partial x^i}{\partial s^i} ds^i \right\} + d\pi(x^i, y^i; s) \\
&\quad - s^i \frac{\partial x^i}{\partial s^i} ds^i - x^i ds^i - s^i \frac{1}{g^i} \frac{\partial y^i}{\partial s^i} ds^i - \frac{y^i}{g^i} ds^i
\end{aligned}$$

where

$$\begin{aligned}
d\pi(x^i, y^i; s) &= \underbrace{\left[\frac{y^i \hat{p}_{y^i}^i + \hat{p}^i}{(1 + \tau^i)} - \frac{\partial c^i}{\partial y^i} + s^i \frac{1}{g^i} \right] \frac{\partial y^i}{\partial s^i} ds^i}_{= 0 \text{ by FOC}} + \underbrace{\left[p_{x^i}^i x^i + p^i - \frac{\partial c^i}{\partial x^i} + s^i \right] \frac{\partial x^i}{\partial s^i} ds^i}_{= 0 \text{ by FOC}} \\
&\quad + \frac{y^i \hat{p}_{y^j}^j}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} ds^i + x^i ds^i + \frac{y^i}{g^i} ds^i
\end{aligned}$$

Dividing through by the total change in the subsidy we get

$$\begin{aligned}
\frac{dW^i(\cdot)}{ds^i} &= \left\{ -p_{x^i}^i \frac{\partial x^i}{\partial s^i} x^i \right\} + \frac{y^i \hat{p}_{y^j}^j}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} + \frac{y^i}{g^i} + x^i \\
&\quad - s^i \left(\frac{\partial x^i}{\partial s^i} + \frac{1}{g^i} \frac{\partial y^i}{\partial s^i} \right) - \left(\frac{y^i}{g^i} + x^i \right)
\end{aligned}$$

Simplifying the above equation we obtain

$$\frac{dW^i(\cdot)}{ds^i} = -p_{x^i}^i \frac{\partial x^i}{\partial s^i} x^i + \frac{y^i \hat{p}_{y^j}^j}{(1 + \tau^i)} \frac{\partial y^j}{\partial s^i} - s^i \left(\frac{\partial x^i}{\partial s^i} + \frac{1}{g^i} \frac{\partial y^i}{\partial s^i} \right).$$

Chapter 4

Imperfect Competition between Florida and São Paulo (Brazil) Orange Juice Producers in the U.S. and European Markets

4.1 Introduction

Orange juice production is highly concentrated both geographically and economically. Florida is the largest orange juice producing state in the United States and similarly the state of São Paulo is in Brazil. Florida and São Paulo orange juice processors control an average of 89 percent of the U.S. market, while São Paulo processors supply an average of 84 percent of the European market (Foreign Agricultural Service, 2012). Florida supplied an average of 92 percent of all U.S. processed oranges for the period 1986-2010 (Economic Research Service, 2012b). For the same period, an average of 23 percent of the total U.S. orange juice supply was imported, and São Paulo shipped 74 percent of all U.S. imports (Food and Agricultural Organization, 2012).

Orange juice production in Florida and São Paulo is highly concentrated. According to Florida Department of Agriculture and Consumer Services (2012), the number of orange processors in Florida declined from 45 in 1997 to 16 in 2010.¹ In São Paulo, four firms produced about 85 percent of the total Brazilian supply during the 2004/2005 season (U.S. International Trade Commission, 2006). The high concentration of processors in Florida and São Paulo makes it conducive for these processors to exercise market power by engaging in oligopolistic competition. Hart (2004) reports that orange juice processors in both countries have high bargaining power with their buyers and exert oligopoly power. But, oligopsony power by juice demanders is unlikely because of the lack of concentration or collusion among buyers. Orange growers are likely to op-

¹Orange juice processors are a subset of orange processors. According to Florida Department of Agriculture and Consumer Services (2012), there were 35 orange processors in Florida during the 2000/2001 season, and Spreen and Fernandes (2000) reports a total of 18 orange juice processors in Florida during the 2000/2001 season.

erate under perfect competition because of the large number of growers² and intense rivalry, which results in minimal collective bargaining power with processors. Thus, orange juice processors are the only group in the supply chain with a potential to influence the U.S. or European orange juice price and extract oligopoly rents.

São Paulo and Florida are the number one and two orange juice producing states, while the United States and Europe rank first and second in terms of per capita orange juice consumption in the world (Hart, 2004). Even though Florida produces large volumes of orange juice, because of the high level of U.S. consumption, the United States exports only 6 percent of its total production (Economic Research Service, 2012b). Consequently, the European orange juice market is dominated by São Paulo orange juice producers. Brazil exports 99 percent of its processed oranges because Brazilians mainly drink fresh squeezed orange juice (Hart, 2004; Mendes, 2011). Europe produces a relatively small amount of orange juice and accounts for about 80 percent of total world imports.

The U.S. and European orange juice markets are protected by tariffs. The U.S. citrus juice tariff has protected juice producers in Florida from overseas competition since 1930. In the United States, the most-favored-nation applied tariff for frozen-concentrated orange juice (FCOJ) was \$0.3501 per SSE (single strength equivalent) gallon until 1994 when the Uruguay Round of the General Agreement on Tariffs and Trade mandated that the tariff decrease by 15 percent to \$0.2971 per SSE gallon by 2000 (Brown et al., 2004; Spreen et al., 2003). Europe imposed an ad valorem tariff of 19 percent until the Uruguay Round, after which the tariff was reduced to 15.20 percent by 2000.

The Summit of the Americas in 1994 was the first meeting where 34 "democracies" of the Western Hemisphere discussed the Free Trade Area of the Americas (FTAA) with the goal of liberalizing trade among member nations. Florida orange juice processors will face even more competition under the FTAA because the U.S. orange juice tariff will be subject to reduction or elimination. Supporters of free trade argued that removal of the tariff will provide U.S. consumers

²Wang et al. (2006) reports that there were over 7,500 orange farms in Florida in 2002.

with the lowest cost orange juice possible (LaVigne, 2003). However, proponents of the tariff contend that without the tariff, Brazilian processors, which are already highly concentrated, will control an even larger market share in the United States. This could lead to high market power and prices for U.S. consumers. However, so far no agreement on FTAA has been reached, and the U.S. tariff has not changed since 2000 (World Trade Organization, 2012).

Spreen et al. (2003) developed a spatial equilibrium model of processed oranges and estimated the demand and new planting of orange trees to project the impact of the elimination of the U.S. orange juice tariff on U.S. production, prices, and imports. Their results showed that the domestic FCOJ price declined by \$0.22 per SSE gallon when the U.S. tariff was removed. Brown et al. (2004) also examined the impact of the removal of the U.S. tariff on FCOJ prices. Their results revealed that while unilateral elimination of the U.S. tariff resulted in a reduction of the U.S. FCOJ price by \$0.22 per SSE gallon, simultaneous elimination of the U.S., European, and Japanese tariff reduced the U.S. price by only \$0.13 per SSE gallon. Brown (2010) estimated the European demand for FCOJ to gain insight into the price response in Europe and found the ordinary least squares and instrumental variable estimates of demand elasticities to be -0.45 and -0.69, respectively.

Wang et al. (2006) analyzed the impact of a supply shock due to weather on competition between oligopolistic firms in the U.S. orange juice market. They estimated market power using the grower's price and include quantity, an indicator variable for crop freezes, and a trend in their marginal cost function, and found that a supply shock decreases the market power of orange juice processors even as the price increases.

In this study, given the dominance of Florida and São Paulo, we analyze the oligopolistic competition and market power of FCOJ processors of these states using the U.S. national FCOJ retail price and European FCOJ price. We focus on FCOJ because the majority of trade is in the form FCOJ rather than not-from-concentrate orange juice due to the convenience of international shipping, and time series data for the national price of FCOJ is readily available making

econometric estimation possible.³

Strategic trade theory analyzes policies implemented by governments to improve their firms' (or industries') position in international markets operating under imperfect competition.⁴ Brander and Spencer (1985) in their seminal work on strategic trade theory showed that unlike under perfect competition, an export subsidy can result in a net welfare gain for the home country at the expense of the competitor's welfare due to rent shifting from the foreign to the home industry. We follow this literature to theoretically analyze the U.S. and European FCOJ markets under imperfect competition. Econometric estimation of market power gained momentum in the 1980s with the development of the New Empirical Industrial Organization (NEIO) literature. Identification issues related to estimating market power is a central focus of the NEIO literature.⁵ We draw on several empirical studies that have estimated industry-level market power in an international setting (Yerger, 1996; Lavoie, 2005) for our empirical work.

The specific objectives of this study are to 1) develop a strategic trade model to analyze the oligopolistic competition of Florida and São Paulo FCOJ processors, 2) derive analytical results to theoretically examine the effect of a change in the U.S. and European tariffs on the FCOJ market in the United States and Europe, 3) specify and estimate an econometric model based on the strategic trade model and compute the degree of market power exerted by Florida and São Paulo FCOJ processors, and 4) simulate the effect of exogenous changes in the U.S. and European tariffs on prices, sales, and welfare in the United States, São Paulo, and Europe.

The next section develops the strategic trade model and presents the analytical results for a change in the U.S. and European tariffs. Section 4.3 derives the empirical specification, describes the data and sources, explains the results of the econometric estimation, discusses the market power in the United States and Europe using estimated Lerner Indices, and presents the results of the simulation analysis. Section 4.4 summarizes the major findings of the study.

³An extensive data series for the national price for fresh orange juice is not available.

⁴Strategic trade policy is part of the new trade theory developed in the late 1970s and 1980s. This theory integrates increasing returns to scale, Dixit-Stiglitz preferences, and imperfect competition into models of international trade to show countries with similar factor endowments and comparative advantages engage in trade.

⁵See Bresnahan (1989) for a review of this literature.

4.2 Theoretical Analysis

Based on the above FCOJ market description, we formulate a strategic trade model and derive the comparative statics and welfare results of a change in the U.S. and European tariffs.

4.2.1 Strategic Trade Model

Consider the U.S. and European FCOJ markets where Florida processors sell in the U.S. market and São Paulo processors export to both the United States and Europe. Florida and São Paulo processors face downward sloping demand functions, allowing for the potential to exert market power. São Paulo firms have a distinct cost advantage due to lower input prices, but incur transport costs and face tariffs to export to the United States and Europe. The U.S. and European governments impose tariffs on FCOJ imports. The profit function for the representative FCOJ processor in Florida is⁶

$$\pi^f = p^u(q^u)q^f - C^f(q^f) - F^f \quad (4.1)$$

where p^u is the price of FCOJ in the United States, $p^u(q^u)$ is the U.S. demand for FCOJ, $q^u = q^f + q^{su}$ is total quantity of FCOJ sold in the United States, q^f is the quantity of FCOJ sold by Florida processors, q^{su} is the quantity of FCOJ sold in the United States by São Paulo processors, and $C^f(\cdot)$ and F^f are the variable and fixed costs of production in Florida. The profit function for the representative processor in São Paulo is

$$\pi^s = \frac{p^u(q^u)}{(1 + \tau^u)}q^{su} + \frac{p^e(q^{se})}{(1 + \tau^e)}q^{se} - C^s\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e}\right) - F^s \quad (4.2)$$

where τ^i ($i = u, e$) is the tariff on FCOJ entering the United States and Europe, p^e is the price of FCOJ in Europe, $p^e(q^{se})$ is the European demand for FCOJ produced in São Paulo, q^{se} is the total quantity of FCOJ sold in Europe by São Paulo processors, $C^s(\cdot)$ and F^s are the variable and fixed costs of production in São Paulo, and g^i ($i = u, e$) is the iceberg transport cost of shipping FCOJ from Brazil to the United States or Europe.

⁶This is an industry-level analysis, but a firm-level oligopolistic model that is aggregated to describe average firm behavior is at the root of the analysis.

The profit functions are differentiated with respect to q^f , q^{su} , and q^{se} to derive the first-order conditions that implicitly determine the reaction or best-response functions as

$$\pi_{q^f}^f = \frac{\partial p^u}{\partial q^f} q^f + p^u - \frac{\partial C^f}{\partial q^f} = 0 \quad (4.3)$$

$$\pi_{q^{su}}^s = \frac{1}{(1 + \tau^u)} \left(\frac{\partial p^u}{\partial q^{su}} q^{su} + p^u \right) - \frac{\partial C^s}{\partial q^{su}} = 0 \quad (4.4)$$

$$\pi_{q^{se}}^s = \frac{1}{(1 + \tau^e)} \left(\frac{\partial p^{se}}{\partial q^{se}} q^{se} + p^e \right) - \frac{\partial C^s}{\partial q^{se}} = 0 \quad (4.5)$$

The reaction function imply a unique solution if they are downward sloping and satisfy the second-order conditions.

4.2.2 Tariff Analysis

As elaborated in the introduction, the Uruguay Round agreement reduced the U.S. and European tariff. Furthermore, if the FTAA or the Doha round are finalized, FCOJ tariffs could be further lowered. Consequently, it is worth examining the impacts of a U.S. and European tariff reduction on FCOJ markets and welfare.

To analyze the effect of changes in U.S. and European tariffs on Florida and São Paulo FCOJ sales, we totally differentiate the reaction functions (4.3)-(4.5) and represent them in matrix form of $Ax = d$:

$$\begin{bmatrix} \pi_{q^f q^f}^f & \pi_{q^f q^{su}}^f & 0 \\ \pi_{q^{su} q^f}^s & \pi_{q^{su} q^{su}}^s & \pi_{q^{su} q^{se}}^s \\ 0 & \pi_{q^{se} q^{su}}^s & \pi_{q^{se} q^{se}}^s \end{bmatrix} \begin{bmatrix} dq^f \\ dq^{su} \\ dq^{se} \end{bmatrix} = - \begin{bmatrix} \pi_{q^f \tau^u}^f d\tau^u + \pi_{q^f \tau^e}^f d\tau^e \\ \pi_{q^{su} \tau^u}^s d\tau^u + \pi_{q^{su} \tau^e}^s d\tau^e \\ \pi_{q^{se} \tau^u}^s d\tau^u + \pi_{q^{se} \tau^e}^s d\tau^e \end{bmatrix}. \quad (4.6)$$

To study the welfare impacts of tariff changes, we define the welfare functions for the United States, São Paulo, and Europe. In the United States, FCOJ is produced in Florida, consumed nation wide, and tariff revenues are collected by the government. Thus U.S. welfare consists of profits, consumer surplus, and tariff revenues:

$$W^u(q^u, q^{su}; \tau^u, \tau^e) = \pi^f + \left\{ \int p^u(q^u) dq^u - p^u(q^u) q^u \right\} + \tau^u q^{su}. \quad (4.7)$$

In São Paulo, because all FCOJ is exported and there is no consumption, welfare consists of only

profits from sales to the United States and Europe:

$$W^s(q^u, q^{su}, q^{se}; \tau^u, \tau^e) = \pi^s. \quad (4.8)$$

In Europe, because there is no production, FCOJ consumption is only from imports, and tariff revenues are collected by the government, welfare consists of consumer surplus and tariff revenues:

$$W^e(q^{se}; \tau^u, \tau^e) = \left\{ \int p^e(q^{se}) dq^{se} - p^e(q^{se}) q^{se} \right\} + p^e(q^{se}) \tau^e q^{se}. \quad (4.9)$$

Effects of U.S. Tariff

By applying Cramer's rule to (4.6), the results for a change in the U.S. tariff, τ^u , are obtained by (see Appendix 4.5 for the derivation)⁷

$$\frac{dq^{su}}{d\tau^u} = \frac{1}{|A|} \pi_{q^f q^f}^f \pi_{q^{se} q^{se}}^s \pi_{q^{su} \tau^u}^s < 0 \quad (4.10)$$

$$\frac{dq^{se}}{d\tau^u} = -\frac{1}{|A|} \pi_{q^f q^f}^f \pi_{q^{se} q^{su}}^s \pi_{q^{su} \tau^u}^s > 0 \quad (4.11)$$

$$\frac{dq^f}{d\tau^u} = -\frac{1}{|A|} \pi_{q^f q^{su}}^f \pi_{q^{se} q^{se}}^s \pi_{q^{su} \tau^u}^s > 0. \quad (4.12)$$

A reduction in the U.S. tariff decreases the price of São Paulo's FCOJ in the U.S. market. As a result, exports from São Paulo to the United States increase (4.10) at the expense of their exports to Europe (4.11). The higher imports from São Paulo displaces Florida's FCOJ sales in the U.S. market (4.12). The effect of a U.S. tariff reduction on total U.S. sales is determined by adding (4.10) and (4.12): $\frac{dq^u}{d\tau^u} = \frac{dq^{su}}{d\tau^u} + \frac{dq^f}{d\tau^u}$, which is indeterminate, but q^u will likely increase because the direct effect $\left(\frac{dq^{su}}{d\tau^u}\right)$ will dominate the indirect effect $\left(\frac{dq^f}{d\tau^u}\right)$.

Welfare results for the tariff analysis consists of producer surplus (PS), consumer surplus (CS), and tariff revenue (TR) effects, and the signs in the parentheses for these three effects in the following equations indicate the direction of the changes. To examine the effect of U.S. tariff reduction on U.S. welfare, we totally differentiate 4.7 (see Appendix 4.5 for the derivation) to

⁷The determinant of A is given by $|A| = \pi_{q^f q^f}^f \pi_{q^{su} q^{su}}^s \pi_{q^{se} q^{se}}^s - \pi_{q^f q^f}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} q^{su}}^s - \pi_{q^f q^{su}}^f \pi_{q^{su} q^f}^s \pi_{q^{se} q^{se}}^s$, and is positive for plausible supply and demand functions.

obtain

$$\frac{dW^u}{d\tau^u} = \overbrace{q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u}}^{PS (+)} - \overbrace{q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^u}}^{CS (-)} + \overbrace{\frac{\partial q^{su}}{\partial \tau^u} \tau^u + q^{su}}^{TR (?)}$$

As Florida loses market share to São Paulo, Florida's producer surplus declines. U.S. consumers benefit from lower prices and higher consumption resulting from increased sales in the United States. Changes in tariff revenues could be positive or negative depending on the location of the initial tariff on the Laffer curve. Consequently, the net effect of a U.S. tariff reduction on U.S. welfare is ambiguous because of the conflicting signs of the three components. However, U.S. welfare is likely to increase because the gain in consumer surplus can exceed the loss in producer surplus and any tariff revenue losses.

To analyze a change in São Paulo's welfare arising from a decrease in the U.S. tariff, we totally differentiate (4.8) to get

$$\frac{dW^s}{d\tau^u} = \overbrace{\frac{q^{su}}{(1 + \tau^u)} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^u} - \frac{p^u q^{su}}{(1 + \tau^u)^2}}^{PS (-)} < 0.$$

As São Paulo exporters capture U.S. market share from Florida, their producer surplus rises.

To investigate the European welfare change arising from a lower U.S. tariff, we totally differentiate (4.9) to obtain

$$\frac{dW^e}{d\tau^u} = \overbrace{-q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u}}^{CS (+)} + \overbrace{\left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) \tau^e \frac{\partial q^{se}}{\partial \tau^u}}^{TR (+)} > 0.$$

Because São Paulo exports more to the United States, its exports to Europe decline, leading to a higher price, less consumption, and a decline in consumer surplus in Europe. Fewer imports by Europe also contracts tariff revenues (note that only imports decline and τ^e is constant). Consequently, Europe experiences welfare reduction.

Effects of European Tariff

The effects of a change in the European tariff , τ^e , on quantities sold by Florida and São Paulo producers are given by

$$\frac{dq^{se}}{d\tau^e} = -\frac{1}{|A|} \left(\pi_{q^f q^{su}}^f \pi_{q^{su} q^f}^s \pi_{q^{se} \tau^e}^s + \pi_{q^f q^f}^f \pi_{q^{su} q^{su}}^s \pi_{q^{se} \tau^e}^s \right) < 0 \quad (4.13)$$

$$\frac{dq^{su}}{d\tau^e} = -\frac{1}{|A|} \pi_{q^f q^f}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} \tau^e}^s > 0 \quad (4.14)$$

$$\frac{dq^f}{d\tau^e} = \frac{1}{|A|} \pi_{q^f q^{su}}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} \tau^e}^s < 0. \quad (4.15)$$

A decrease in the European tariff lowers the price of São Paulo's FCOJ in Europe. Consequently, São Paulo exporters reallocate their exports from the United States to Europe, (4.14) and (4.13). As exports from São Paulo to the United States decrease, Florida's FCOJ sales in the U.S. market expands (4.15). To examine the effect of European tariff reduction on total sales in the United States, we add (4.14) and (4.15): $\frac{dq^u}{d\tau^e} = \frac{dq^{su}}{d\tau^e} + \frac{dq^f}{d\tau^e}$. The net effect of q^u is ambiguous, but the direct effect $\left(\frac{dq^{su}}{d\tau^e}\right)$ is likely to dominate the indirect effect $\left(\frac{dq^f}{d\tau^e}\right)$, leading to a decline in the quantity sold in the United States.

To determine the effect of a reduction in the European tariff on U.S. welfare, we totally differentiate (4.7) to get

$$\frac{dW^u}{d\tau^e} = \overbrace{q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^e}}^{PS (-)} - \overbrace{q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^e}}^{CS (+)} + \overbrace{\tau^u \frac{\partial q^{su}}{\partial \tau^e}}^{TR (+)}.$$

As São Paulo diverts its exports from the United States to Europe, Florida processors capture a higher share of the U.S. market and their producer surplus rises. As imports from São Paulo fall, total sales in the United States decline and the FCOJ price goes up, resulting in lower consumer surplus. Lower U.S. imports also causes tariff revenues to fall. The net change in U.S. welfare is ambiguous, but it will likely decline as consumer surplus and tariff revenue losses can offset the producer surplus gain.

To ascertain the change in São Paulo's welfare arising from a decrease in the European

tariff, we totally differentiate (4.8) to obtain

$$\frac{dW^s}{d\tau^e} = \frac{\overbrace{\left(\overbrace{q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^e}}^{(+)} - \overbrace{p^e q^{se}}^{(-)} \right)}^{PS (?)}}{(1 + \tau^u)^2}.$$

As São Paulo reallocates its exports from the United States to Europe, profits from U.S. exports decline (first term on the right-hand-side), but profits from European exports increase (second term on the right-hand-side). As a result, the net effect on producer surplus is ambiguous; however, welfare will likely increase because higher profits from the European market (direct effect) can dominate the reduction in profits from the U.S. market (indirect effect). Note that because there is no FCOJ production in Europe, all the profit changes accrue to São Paulo and there is no diversion of profits from Europe to São Paulo.

To analyze the change in European welfare arising from a reduction in the European tariff, we totally differentiate (4.9) to get

$$\frac{dW^e}{d\tau^e} = \overbrace{-q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^e}}^{CS (-)} + \overbrace{\left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) \tau^e \frac{\partial q^{se}}{\partial \tau^e} + p^e q^{se}}^{TR (?)}$$

As European imports rise, the FCOJ price in Europe declines and consumption expands, resulting in a gain in consumer surplus. Tariff revenues can increase or decrease depending on the initial location of the tariff on the Laffer curve. Consequently, the change in European welfare is indeterminate, but it will likely increase because the consumer surplus gain can outweigh the tariff revenue effect (if it is negative).

4.3 Empirical Analysis

In this section, we derive the econometric model based on the strategic trade model, discuss data and sources, present the estimation results, calculate the Lerner index, and present the simulation analysis and results.

4.3.1 Econometric Model

In the U.S. FCOJ market, other countries such as Mexico, Costa Rica, and Belize also supply FCOJ. However, their market shares relative to Florida and São Paulo are small, and we considered them exogenous in the model. Total sales in the United States are defined as $q^u = q^f + q^{su} + q^o$, where q^o is the quantity sold by processors other than Florida and São Paulo processors.⁸

We specify the econometric model by rewriting the first-order conditions (4.3)-(4.5) as

$$p^u = \frac{\partial C^f}{\partial q^f} + \theta^f \varepsilon^u p^u \quad (4.16)$$

$$p^u = (1 + \tau^u) \frac{\partial C^s}{\partial q^{su}} + \theta^{su} \varepsilon^u p^u \quad (4.17)$$

$$p^e = (1 + \tau^e) \frac{\partial C^s}{\partial q^{se}} + \theta^{se} \varepsilon^e p^e \quad (4.18)$$

where $\theta^f = \frac{\partial q^u}{\partial q^f} \frac{q^f}{q^u}$ is the conjectural elasticity for Florida processors, $\varepsilon^u = -\frac{\partial p^u}{\partial q^u} \frac{q^u}{p^u}$ is the U.S. price flexibility of demand, $\theta^{su} = \frac{\partial q^u}{\partial q^{su}} \frac{q^{su}}{q^u}$ is the conjectural elasticity for São Paulo processors exporting to the United States, $\varepsilon^e = -\frac{\partial p^e}{\partial q^{se}} \frac{q^{se}}{p^e}$ is the European price flexibility of demand, and $\theta^{se} = \frac{\partial q^{se}}{\partial q^{se}} \frac{q^{se}}{q^{se}}$ (note that θ^{se} is not necessarily equal to one because it is based on weighted average of each firm's conjectural elasticity; also see footnote 6 and Porter (1983), p. 304) is the conjectural elasticity for São Paulo processors exporting to Europe.

As seen by the second term on the right-hand-side of (4.16)-(4.18), an industry's ability to set price above marginal cost is driven by the interaction of the demand flexibilities and conjectural elasticities. Four cases are possible. First, under perfect collusion, orange juice processors act as a monopoly, and the conjectural variation and market share are one (e.g., $\partial q^u / \partial q^f = q^f / q^u = 1$). This implies that the conjectural elasticity is equal to one, and the markup is determined by the demand flexibilities. Second, if the orange juice processors operate under Cournot competition, the conjectural variation is equal to one (e.g., $\partial q^u / \partial q^f = 1$) and markup depends on the interaction of the demand flexibility and the representative firm's market share. Third, under a fully flexible market structure, market power is given by the conjectural elasticity weighted by the demand

⁸Combined FCOJ exports by Mexico, Costa Rica, and Belize are about 10% of total sales in the United States.

flexibility. Fourth, under perfect competition, the orange juice processors' market share is small enough so they cannot influence the FCOJ price. This implies that the markup is zero and price is equal to the marginal cost.

For estimable supply relations, we define marginal cost and demand functions and consider identification of demand and supply parameters and the conjectural elasticities. The marginal cost functions for Florida and São Paulo processors are defined as

$$\frac{\partial C^f}{\partial q^f} = \beta_0^f + \beta_1^f q^f + \beta^f \mathbf{x}^f \quad (4.19)$$

$$\frac{\partial C^s}{\partial q^{su}} = \frac{1}{g^u} \left(\beta_0^{su} + \beta_1^{su} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \beta^{su} \mathbf{x}^s \right) \quad (4.20)$$

$$\frac{\partial C^s}{\partial q^{se}} = \frac{1}{g^e} \left(\beta_0^{se} + \beta_1^{se} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \beta^{se} \mathbf{x}^s \right) \quad (4.21)$$

where β_j^i s are marginal cost coefficients and \mathbf{x}^i s ($i = f, su, \text{ and } se$) are supply shifters. The U.S. and European demand functions are

$$p^u = \alpha_0^u + \alpha_1^u q^u + \alpha^u \mathbf{Z}^u \quad (4.22)$$

$$p^e = \alpha_0^e + \alpha_1^e q^{se} + \alpha^e \mathbf{Z}^e \quad (4.23)$$

where α_j^i s are demand coefficients, and \mathbf{Z}^i s are U.S. and European demand shifters.

Using the first-order conditions (4.16)-(4.18), the marginal cost functions (4.19)-(4.21), and the demand flexibilities derived from the demand functions (4.22) and (4.23), the supply relations for Florida and São Paulo processors are represented as:

$$p^u = \beta_0^f + \beta_1^f q^f + \beta^f \mathbf{x}^f + \theta^f \alpha_1^u q^u \quad (4.24)$$

$$p^u = \frac{(1 + \tau^u)}{g^u} \left(\beta_0^{su} + \beta_1^{su} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \beta^{su} \mathbf{x}^s \right) + \theta^{su} \alpha_1^u q^u \quad (4.25)$$

$$p^e = \frac{(1 + \tau^e)}{g^e} \left(\beta_0^{se} + \beta_1^{se} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \beta^{se} \mathbf{x}^s \right) + \theta^{se} \alpha_1^e q^{se}. \quad (4.26)$$

The parameters in the U.S. demand function (4.22) are identified if the number of excluded exogenous variables from the demand function is greater than or equal to the number of endogenous variables p^u and q^u . The parameters in the U.S. supply relation (4.24), including $\theta^f \alpha_1^u$ are iden-

tified if the number of excluded exogenous variables is greater than or equal to the number of endogenous variables p^u, q^u, q^f . Estimation of the system of equations will yield an estimate for α_1^u and a combined estimate for $\theta^f \alpha_1^u$. Using the estimate of α_1^u , the conjectural elasticity θ^f can be identified from the estimate of $\theta^f \alpha_1^u$. Applying analogous identification rule to the European demand function (4.23) and São Paulo's supply relations for the United States (4.25) and Europe (4.26), we can confirm that the demand and supply parameters and the conjectural elasticities θ^{su} and θ^{se} can be uniquely identified and thus estimated.

4.3.2 Data

The data set consists of annual observations for the period 1986-2009. The total supply, imports, and exports for the U.S. orange juice industry was collected from Economic Research Service (2012a). From the domestic supply for all orange juice, we obtained the domestic FCOJ supply, which is decomposed into the Florida FCOJ supply and other U.S. FCOJ supply using Tables C21 and C28-C30 from the Fruit and Tree Nut Yearbook of the Economic Research Service (2012b). Total U.S. orange juice imports were disaggregated to obtain total FCOJ imports, and the portion of FCOJ imports supplied by Brazil, using U.S. FCOJ import percentages by country from Food and Agricultural Organization (2012). The U.S. national price of FCOJ was constructed using two sources. First, for the years 1995-2009, we obtained the national FCOJ price from the Nielson report provided by the Florida Department of Citrus (2012). Next, we collected the U.S. FCOJ price index for the years 1986-2009 from the Bureau of Labor Statistics (2012). The correlation for the overlapping data from these two sources is 0.99. Therefore, the price index was used to backcast the Nielson price data for the period 1994-1986.

Price and quantity data for the European orange juice market are not available. We follow Brown et al. (2004) and Brown (2010) and use Brazil's export data to Europe because Brazil is the dominant FCOJ supplier in this market. Brazil's exports and unit price were obtained from Food and Agricultural Organization (2012).

For input price variables in Florida's and São Paulo's marginal cost functions, we used an

aggregate cost measure comprised of labor, machinery, and other inputs. We constructed this aggregate measure using two data sources. Wade et al. (2001)⁹ reports the data for the period 1986-2000 and the Foreign Agricultural Service (2012) has the data for 2004, and 2006-2009. We used a combination of forward and backcasting to fill the missing data for 2001-2003, and 2005. We included the producer price of oranges as the major input price in Florida's marginal cost equation, which was collected from Food and Agricultural Organization (2012). We were not able to use the producer price of oranges in São Paulo's marginal cost equation because of irreconcilable inconsistencies in their data. We added a trend variable in both marginal cost equations to account for technological advances. In São Paulo's marginal cost function, we included an indicator variable—one for the period 2004-2009 and zero otherwise—to account for discrepancies between the two data sources.

Demand shifters are income, population, and a substitute good. All prices and income were converted into real terms using a GDP deflator to satisfy the homogeneity condition. Income, population, and the GDP deflators for the United States and Europe were collected from The World Bank (2012). In the U.S. demand function, the quantity of grapefruit juice sold, collected from Economic Research Service (2012a), was included as a substitute good. In the European demand function, the quantity of lemon juice, Brazil's second largest juice export to Europe, obtained from Food and Agricultural Organization (2012) was used as a substitute good. In the demand functions, a dummy variable—one for 2008 and 2009 and zero otherwise—interacts with income to account for the current economic turmoil.

We collect tariff data from the World Trade Organization (2012). As per the Uruguay Round agreement, the U.S. applied specific tariff is reduced from \$0.3501 per SSE (single strength equivalent) gallon in 1994 to 0.2971 per SSE gallon by 2000, and the European applied ad valorem tariff is reduced from 19 percent in 2004 to 15.20 percent by 2000. We proxy transport costs from Brazil to the United States by taking the difference between the CIF and FOB fruit juice exports collected from the U.S. Census Bureau (2012). This transport cost data was used to construct

⁹We thank Ron Muraro at the University of Florida for assistance with this data.

the transport cost from São Paulo to Europe based on the distance between the latter two regions, which was obtained from "www.searates.com."

4.3.3 Estimation

The demand functions (4.22) and (4.23) and supply relations (4.24)-(4.26) are a system of 5 equations with 5 endogenous variables $(p^u, p^e, q^{su}, q^{se}, q^f)$. We estimate the parameters using nonlinear two-stage least square to account for the endogeneity, which allows for consistent estimates of the parameters, and nonlinearity in the system. The exogenous demand and marginal cost variables are used as instruments. To ensure that the objective function in the nonlinear estimation is at a global minimum, we considered a range of initial parameter values for estimating the coefficients.

As discussed in the Introduction section, the data for U.S. tariff is a specific tariff and for the European tariff is an ad valorem tariff, which are used for the empirical analysis. Since the transportation costs are available only on a per-unit basis (as opposed to an iceberg cost used in the analytical analysis), we use this per-unit cost for the analysis.

Table 4.1 presents variable definitions. Table 4.2 presents the estimation results for the U.S. and European demand functions. The signs for the estimated coefficients are consistent with economic theory. In the demand for U.S. FCOJ, the estimated coefficients for the intercept, quantity, population, and an indicator variable interacting with real income are significant at the $\alpha = 5$ percent level or better. The flexibility of demand is -0.48 (or an elasticity of -2.08), which is higher than the elasticities estimated by Brown et al. (2004) at -0.70 and Davis et al. (2008) at -0.99 . The negative coefficient estimate for population indicates that the demand for FCOJ has declined as the U.S. population has grown. This is consistent with the trend that consumers are substituting toward not-from-concentrate and fresh orange juice. In the U.S. market, the estimated income coefficient is positive indicating that as income increases, so does FCOJ consumption. The marginal impact of grapefruit juice is negative, implying that FCOJ and grapefruit juice are complements because an increase in grapefruit juice consumption will reduce the FCOJ price and

Table 4.1: Variable Definitions

Variable	Definition
q^u	Total U.S. sales of FCOJ, gallons of single strength equivalent (SSE)
q^f	Florida's FCOJ sales in the United States, gallons of SSE
q^{su}	São Paulo's sales of FCOJ in the United States, gallons of SSE
q^{se}	São Paulo's exports to Europe, gallons of SSE
$inputp^j$	Aggregate production cost of Florida's ($j = f$) and São Paulo's ($j = s$) processors, real cost \$/gal SSE
$prop^u$	U.S. producer price of oranges, real price \$/gal SSE
$tcost^i$	Transport cost for São Paulo to export to the U.S. ($i = u$) and Europe ($i = e$), index 1986=1
$trend$	trend
$D1$	Indicator variable: 1 for 2008 and 2009, zero otherwise
Pop^i	U.S. and European populations, in 100 millions
$RInc^i$	U.S. and European real income, in 100 billions
cq^u	U.S. grapefruit juice sales, gallons of SSE
cq^e	Brazilian exports of lemon juice to Europe, gallons of SSE
$D2$	Indicator variable: 1 for years 2004-2009, zero otherwise

increase FCOJ consumption. The estimated coefficient for the interaction of $D1$ with real income is positive, which indicates that the current economic crisis reinforced the income effect.

In the demand for European FCOJ, the estimated coefficients for the intercept, quantity, population, real income, cross-quantity of lemon juice, and dummy interaction with real income are significant at the $\alpha = 10$ percent level or better. The flexibility of demand is -0.80 (or an elasticity of -1.25). Brown et al. (2004) reports a price elasticity of demand for European FCOJ at -0.41 , and Brown (2010) estimate the European price elasticity of demand at -0.45 and -0.68 for ordinary least squares and instrumental variable estimations, respectively. As in the U.S. market, the negative estimated coefficient for population implies the demand for FCOJ decreased in Europe as the population grew in this region. The coefficient for income is positive, implying that as income rises consumption of FCOJ increases. Lemon juice exports from São Paulo to Europe are complements with FCOJ because the estimated coefficient is negative, indicating that an increase in lemon juice quantity reduces FCOJ price and increases FCOJ consumption. The current economic crisis augments the income effect on FCOJ because the estimated coefficient on $D1$ interacting with real income is positive.

Table 4.2: U.S. and European Demand Functions

Variable/Coefficients	United States ($i = u$)	Europe ($i = e$)
<i>intercept</i>	18.45 (0.000)	25.40 (0.000)
q^u	-0.21 (0.000)	—
q^{se}	—	-0.08 (0.001)
Pop^i	-5.24 (0.001)	-8.85 (0.000)
$RInc^i$	0.03 (0.129)	0.06 (0.005)
cq^i	-1.88 (0.215)	-3.98 (0.107)
$(cq^i)^2$	0.83 (0.219)	—
$D1 * RInc^i$	0.01 (0.001)	0.005 (0.073)

p-values are in parentheses

Table 4.3: Supply Relation for Florida Processors

Variable/Coefficients	Florida
<i>intercept</i> ^f	1.100 (0.482)
q^f	1.290 (0.008)
$(q^f)^2$	-0.120 (0.008)
<i>inputp</i> ^f	3.930 (0.201)
<i>prop</i> ^u	0.005 (0.002)
<i>trend</i>	-0.060 (0.007)
θ^f	0.720 (0.019)

p-values are in parentheses.

Table 4.3 reports the estimated supply relation for Florida processors. The estimated coefficients are consistent with economic theory, and quantity supplied, price of oranges, trend, and conjectural elasticity are significant at the $\alpha = 5$ percent level or better. An increase in the quantity supplied, input prices, and the producer price for oranges increase the cost of production and thus the FCOJ price. The estimated coefficient for the trend variable is negative, implying that as technology advances production costs declined. The conjectural elasticity estimate is 0.72; this suggests that processors in Florida act as oligopolists.

Table 4.4 presents the estimated supply relation for São Paulo exports to the United States and Europe. The signs for the estimated coefficients are consistent with economic theory. For exports from São Paulo to the United States, the estimated coefficients for the intercept, input prices, trend, transport cost, and conjectural elasticity are all significant at the $\alpha = 5$ percent level or better. An increase in output and input prices will increase the marginal costs and thus the FCOJ

price. The negative sign on the estimated coefficient for the trend variable indicates that marginal costs have decreased over time, which can be due to advances in technology. The estimated coefficient on the transport cost is positive, implying that higher shipping costs will raise the FCOJ price. The conjectural elasticity estimate is 1.07; while this is greater than the theoretical upper bound, it is not statistically different from one.

For exports from São Paulo to Europe, the estimated coefficients for the intercept, transport cost, and $D2$ are significant at the $\alpha = 5$ percent level or better. With higher quantities of output and input prices, the marginal costs increases, leading to an increase in the FCOJ price. The negative sign on the estimated coefficient for the trend variable suggests that technological advances in FCOJ production lowers the marginal cost and thus decreases the FCOJ price. As in the supply relation for exports to the United States, the positive estimate for transport costs means that an increase in the cost of shipping to Europe increases the FCOJ price. The conjectural elasticity estimate is 1.06. Again, even though the theoretical bound for this parameter estimate is one, it is not statistically different from one.

The conjectural elasticity estimates show that both the Florida and São Paulo processors act as oligopolists, but São Paulo processors are estimated to have greater market power. The conjectural elasticity estimates for São Paulo exporters to the United States and Europe are close to one. This suggests a high level of concentration and collusive behavior for FCOJ processing plants in São Paulo, which is consistent with industry evidence. As stated in the introduction, four firms in São Paulo were responsible for about 85 percent of total Brazilian production for the 2004/2005 season (U.S. International Trade Commission, 2006). In addition, Hart (2004) reports that São Paulo orange juice processors have a high level of bargaining power.

4.3.4 Lerner Index

The Lerner Index measures the markup of price over marginal cost and is equal to the conjectural elasticity times the demand flexibility. That is, an industry's ability to exercise oligopoly power and set price above its marginal costs depends on both the supply (conjectural elasticities) and

Table 4.4: Supply Relations for Sao Paulo Processors

Variable/Coefficients	Exp to U.S. ($i = su$)	Exp to Europe. ($i = se$)
<i>intercept</i>	2.80 (0.089)	0.88 (0.030)
$(q^{su} + q^{se})$	0.01 (0.876)	0.02 (0.737)
<i>inputp^s</i>	123.58 (0.018)	8.59 (0.474)
$(inputp^s)^2$	-1706.71 (0.008)	-48.84 (0.489)
$(inputp^s)^3$	6831.12 (0.007)	—
<i>trend</i>	-0.04 (0.019)	-0.23 (0.156)
<i>tcostⁱ</i>	1.35 (0.000)	0.67 (0.000)
<i>D2</i>	—	-0.49 (0.000)
θ^f	1.07 (0.002)	1.06 (0.184)

p-values are in parentheses.

demand (price flexibilities) conditions. Rearranging the supply relations, (4.16)-(4.18), the Lerner Indices are expressed as

$$\frac{p^u - \frac{\partial C^f}{\partial q^f}}{p^u} = \theta^f \varepsilon^u = 0.72 * 0.48 = 0.35 \quad (4.27)$$

$$\frac{p^u - (1 + \tau^u) \frac{\partial C^s}{\partial q^{su}}}{p^u} = \theta^{su} \varepsilon^u = 1.07 * 0.48 = 0.51 \quad (4.28)$$

$$\frac{p^e - (1 + \tau^e) \frac{\partial C^s}{\partial q^{se}}}{p^e} = \theta^{se} \varepsilon^e = 1.06 * 0.80 = 0.84 \quad (4.29)$$

The results of the Lerner Index show that in the U.S. market, Florida (São Paulo) processors set their price above marginal cost by 35 percent (51 percent). Thus, both Florida and São Paulo processors earn oligopolistic rents, and São Paulo processors exert greater market power than Florida processors in the U.S. market. This is consistent with evidence that São Paulo processors are more concentrated (U.S. International Trade Commission, 2006; Florida Department of Agriculture and Consumer Services, 2012) and have lower production costs (Foreign Agricultural Service, 2012) than Florida processors. For the European market, the Lerner Index shows that São Paulo exporters set price 84 percent above their marginal cost. They are able to exert more market power in the European market than the U.S. market because the demand elasticity (i.e., $1/\varepsilon^i$, $i = u, e$) for São Paulo FCOJ in Europe is less elastic than that in the United States. The

rationale for this result is that São Paulo is the largest supplier in Europe controlling 84 percent of the market, whereas in the U.S. market, São Paulo has to compete with Florida.

4.3.5 Simulation Results

The Free Trade Agreement of the Americas (FTAA) and the Doha round have been under negotiations since 1994 and 2000, respectively. If these negotiations are completed, the U.S. and European tariffs on FCOJ could again be reduced. In this section, we analyze the effect of a 25 percent reduction of the U.S. and European tariffs. For the baseline simulation, we implement the existing tariff and solve the parameterized econometric model as a system of 5 equations (4.22)-(4.26) in 5 endogenous price and quantity variables (p^u , p^e , q^f , q^{su} , and q^{se}). We also compute total sales in the United States as the sum of sales for Florida, São Paulo, and other region's FCOJ ($q^u = q^f + q^{su} + q^o$). We consider two alternate scenarios: a 25 percent reduction in the U.S. tariff and a 25 percent reduction in the European tariff. In both of these scenarios, tariffs are 25 percent less in each year for the period 2006-2009. We then take the average over this period for both the baseline and alternate scenarios, and compare the results for each of the alternate scenarios to those of the baseline to quantify the impacts of these two trade liberalization policies. Table 4.5 presents the simulation results, which are qualitatively consistent with the analytical results of section 4.2.2.

A 25 percent reduction in the U.S. tariff causes São Paulo exporters to divert their exports from Europe to the United States resulting in a 36.16 percent increase in their U.S. sales and a 10.65 percent decrease in their European sales. As a result of higher U.S. imports, Florida's sales are displaced by 1.67 percent. Consequently, São Paulo captures Florida's market share in the United States, leading to an increase in São Paulo's market share by 26.58 percent and a decrease in Florida's by 8.27 percent. While the higher imports and lower Florida sales led to indeterminate analytical results for total U.S. sales, the quantitative results show that the direct (import) effect dominates the indirect (Florida) effect and total U.S. sales are 7.35 percent higher, which reduces the U.S. national price by 2.45 percent. Lower exports to Europe resulted in a 6.21 percent rise in

Table 4.5: Impacts of Tariff Reductions, Ave. 2006-09

Variables	A 25% Tariff Reduction by	
	U.S.	Europe
p^u (%)	-2.45	0.49
p^e (%)	6.21	-34.39
q^f (%)	-1.67	0.35
q^{su} (%)	36.16	-7.53
q^{se} (%)	-10.65	61.16
$q^u (= q^f + q^{su} + q^o)$ (%)	7.35	-1.50
Florida's market share in U.S. (%)	-8.27	1.88
São Paulo's market share U.S. (%)	26.58	-5.90
Change in Total U.S. Welfare (Million \$)	25.44	-7.03
Change in Producer Surplus (Million \$)	-41.52	8.22
Change in Consumer Surplus (Million \$)	62.20	-12.18
Change in Tariff Revenue Change (Million \$)	4.77	-3.07
Change in Total São Paulo Welfare (Million \$)	12.76	19.78
Change in Producer Surplus (Million \$)	12.76	19.78
Change in Total European Welfare (Million \$)	-41.42	202.33
Change in Consumer Surplus (Million \$)	-37.78	203.96
Change in Tariff Revenue (Million \$)	-3.64	-1.63

their FCOJ price.

The welfare analysis of the U.S. tariff reduction shows that the gain in U.S. consumer surplus (\$62.20 million) and tariff revenues (\$4.77 million) outweigh the loss in producer surplus (\$41.52 million), resulting in a net increase in U.S. welfare of \$25.44 million. The increase in tariff revenues indicates that the United States is operating on the negatively sloped part of the Laffer curve, and thus a decline in the tariff causes the tariff revenues to rise. The higher sales in the U.S. market augments São Paulo's welfare, i.e., producer surplus, by \$12.76 million. Fewer exports to Europe reduce the consumer surplus (\$37.78 million) and tariff revenues (\$3.64 million), leading to a net reduction in welfare of \$41.42 million. The European tariff revenues decrease because FCOJ imports declines but the European tariff rate remains constant in this scenario.

A 25 percent decrease in the European tariff results in a reallocation of São Paulo's exports

from the United States to Europe, leading to a 61.16 percent increase in exports to Europe and a 7.53 percent decrease in exports to the United States, which causes Florida's sales in the United States to expand by 0.35 percent. Because of this reallocation, Florida's market share in the United States rises by 1.88 percent, while São Paulo's market share falls by 5.90 percent. Higher European imports depresses their FCOJ price by 34.39 percent. In the theoretical analysis, the lower imports and higher Florida sales indicate ambiguous comparative static results for total U.S. sales, but the simulation results show that the direct effect outweighs the indirect effect and total U.S. sales fall by 1.50 percent, which raises the U.S. national price by 0.49 percent.

The welfare analysis indicates that as a result of this European tariff reduction, the gain in U.S. producer surplus (\$8.22 million) is insufficient to compensate for the reduction in consumer surplus (\$12.18 million) and tariff revenues (\$3.07 million), resulting in a net U.S. welfare loss of \$7.03 million. Higher sales in the European market lead to a net increase in São Paulo's welfare of \$19.78 million. The benefit to European consumers (\$203.96 million) from higher imports is more than the loss in tariff revenues (\$1.63 million) leading to a net European welfare gain of \$202.33 million. The loss of tariff revenues suggest that Europe is functioning on the positively sloped part of the Laffer curve and as the tariff declines, tariff revenues increase.

Spreen et al. (2003) developed a spatial equilibrium model with implicit supply functions to forecast the behavior of the orange juice industry. They simulated two scenarios for out-of-sample projections. In the first scenario, both U.S. and European tariffs are phased out over a 15 year period beginning in 2002. Their results showed minimal effects on both orange juice prices and sales in both the United States and Europe. In the second scenario, both tariffs are eliminated in 2002. In this case, the U.S. FCOJ price falls by 20 percent, which causes U.S. consumption to increase by 8 percent. The European price rises by 13 percent which resulted in a 9 percent decline in consumption. Using a demand model, Brown et al. (2004) examined the effect of tariff elimination on prices and found results similar to those of Spreen et al. (2003).

Our simulation analysis differ from Spreen et al. (2003) in three notable ways. First, Spreen et al. (2003) applied a dynamic spatial-equilibrium model under perfect competition, whereas our

model is a static strategic trade model based on imperfect competition. Second, Spreen et al. (2003) estimated demand equations for the United States, Europe, and Japan and supply functions for Florida and São Paulo individually, whereas we estimate demand equations for the United States and Europe and supply relations for Florida and São Paulo FCOJ processors simultaneously. Third, Spreen et al. (2003) used their model to project the impact of phasing out and elimination of the tariffs for an out-of-sample period, whereas we simulate the effect of a 25 percent tariff reduction over an in-sample period.

4.4 Conclusions

World orange juice production is highly concentrated in the states of Florida and São Paulo (Brazil), who supply about 85 percent of the total world supply. Also, these orange juice processing states supply an average of 89 percent of the total U.S. market, and São Paulo processors control about 84 percent of the total European market. Furthermore, the two largest orange juice consuming regions are the United States and Europe.

We develop a strategic trade model based on the new trade theory. Because Florida and São Paulo processors are dominant in the FCOJ market, they face downward sloping demand functions. Our analytical results indicate that a reduction in the U.S. tariff causes São Paulo to reallocate its exports from Europe to the United States, which displaces FCOJ processing in Florida. A tariff reduction by Europe causes São Paulo to divert its exports from the United States to Europe. Florida captures the market lost by São Paulo in the United States. We also analyze the qualitative effects of these tariff reductions on the welfare of the United States, São Paulo, and Europe.

A structural econometric model, based on the strategic trade model and the new empirical industrial organization literature, is specified and estimated. The downward sloping demand function allows the estimation of market structures ranging from perfect competition to perfect collusion/monopoly. The empirical results show that both Florida and São Paulo FCOJ processors exert market power in the United States, but São Paulo exerts greater market power. Since São Paulo processors control 84 percent of the European market, they exert more market power in

Europe than in the United States.

The estimated structural model is simulated to quantify the impact of a 25 percent reduction in both the U.S. and European tariffs. The simulation results corroborate the qualitative results of the analytical model and also provide quantitative measures of effects. The reduction in the U.S. tariff causes Florida's market share to decline and São Paulo's market share to increase in the United States. This also leads to higher U.S. and São Paulo welfare and lower European welfare. The decline in the European tariff causes São Paulo to reallocate their exports from the United States to Europe, resulting in a higher U.S. market share for Florida and a lower market share for São Paulo. This tariff reduction causes European and São Paulo welfare to rise and U.S. welfare to decline.

Our analysis shows that further reduction in the U.S. tariff, which may result from trade negotiations, will increase competition and adversely impact Florida processors, but U.S. consumer will benefit. Consequently, for Florida processors to effectively compete with São Paulo processors, it is in their best interest to continue to make progress in cost reducing technology both in orange juice and orange production.

4.5 Appendix

This appendix derives the comparative statics and changes in welfare for the subsection 4.2.2.

4.5.1 Comparative Statics

The profit functions for Florida and São Paulo FCOJ processors are

$$\begin{aligned}\pi^f &= p^u(q^u)q^f - C^f(q^f) - F^f \\ \pi^s &= \frac{p^u(q^u)}{(1 + \tau^u)}q^{su} + \frac{p^e(q^{se})}{(1 + \tau^e)}q^{se} - C^s\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e}\right) - F^s.\end{aligned}$$

The reaction functions are defined by the first-order conditions:

$$\begin{aligned}\pi_{q^f}^f &= \frac{\partial p^u}{\partial q^f} q^f + p^u - \frac{\partial C^f}{\partial q^f} = 0 \\ \pi_{q^{su}}^s &= \frac{1}{(1 + \tau^u)} \left(\frac{\partial p^u}{\partial q^{su}} q^{su} + p^u \right) - \frac{\partial C^s}{\partial q^{su}} = 0 \\ \pi_{q^{se}}^s &= \frac{1}{(1 + \tau^e)} \left(\frac{\partial p^{se}}{\partial q^{se}} q^{se} + p^e \right) - \frac{\partial C^s}{\partial q^{se}} = 0.\end{aligned}$$

Since the demand functions are downward sloping and the cost function is convex, we know the reaction function constitute a solution because the profit functions are globally concave implying the second-order conditions for a maximum are satisfied. Specifically, the second-order conditions are:¹⁰

$$\begin{aligned}\pi_{q^f q^f}^f &= \frac{\partial^2 p^u}{\partial q^f \partial q^f} q^f + 2 \frac{\partial p^u}{\partial q^f} - \frac{\partial^2 C^f}{\partial q^f \partial q^f} < 0, \\ \pi_{q^f q^{su}}^f &= \frac{\partial^2 p^u}{\partial q^f \partial q^{su}} q^f + \frac{\partial p^u}{\partial q^{su}} < 0, \\ \pi_{q^f q^{se}}^f &= 0, \\ \pi_{q^{su} q^f}^s &= \frac{\partial^2 p^u}{\partial q^{su} \partial q^f} q^{su} + \frac{\partial p^u}{\partial q^f} < 0, \\ \pi_{q^{su} q^{su}}^s &= \frac{\partial^2 p^u}{\partial q^{su} \partial q^{su}} q^{su} + 2 \frac{\partial p^u}{\partial q^{su}} - (1 + \tau^u) \frac{\partial^2 C^s}{\partial q^{su} \partial q^{su}} < 0,\end{aligned}$$

The impact of a change in the tariff on the marginal change in profits is given by

$$\begin{aligned}\pi_{q^f \tau^u}^f &= 0, \quad \pi_{q^f \tau^e}^f = 0, \quad \pi_{q^{se} \tau^u}^s = 0, \quad \pi_{q^{su} \tau^e}^s = 0, \\ \pi_{q^{su} \tau^u}^s &= -\frac{1}{(1 + \tau^u)^2} \left(\frac{\partial p^u(q^u)}{\partial q^{su}} q^{su} + p^u(q^u) \right) < 0 \\ \pi_{q^{se} \tau^e}^s &= -\frac{1}{(1 + \tau^e)^2} \left(\frac{\partial p^{se}(q^{se})}{\partial q^{se}} q^{se} + p^e(q^{se}) \right) < 0.\end{aligned}$$

Totally differentiating the FOCs yields a system of three equations, written in the form

¹⁰To derive analytical results, we assume Cournot competition.

$Ax = d$ we get,

$$\begin{bmatrix} \pi_{q^f q^f}^f & \pi_{q^f q^{su}}^f & 0 \\ \pi_{q^{su} q^f}^s & \pi_{q^{su} q^{su}}^s & \pi_{q^{su} q^{se}}^s \\ 0 & \pi_{q^{se} q^{su}}^s & \pi_{q^{se} q^{se}}^s \end{bmatrix} \begin{bmatrix} dq^f \\ dq^{su} \\ dq^{se} \end{bmatrix} = - \begin{bmatrix} \pi_{q^f \tau^u}^f d\tau^u + \pi_{q^f \tau^e}^f d\tau^e \\ \pi_{q^{su} \tau^u}^s d\tau^u + \pi_{q^{su} \tau^e}^s d\tau^e \\ \pi_{q^{se} \tau^u}^s d\tau^u + \pi_{q^{se} \tau^e}^s d\tau^e \end{bmatrix}.$$

The determinant of A is positive as shown by $|A| = \pi_{q^f q^f}^f \pi_{q^{su} q^{su}}^s \pi_{q^{se} q^{se}}^s - \pi_{q^f q^f}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} q^{su}}^s - \pi_{q^f q^{su}}^f \pi_{q^{su} q^f}^s \pi_{q^{se} q^{se}}^s > 0$.

We analyze the effect of a change in τ^u and τ^e on q^f , q^{su} , and q^{se} by applying Cramer's rule. First, consider the effect of a change in the tariffs on q^f :

$$dq^f = \frac{1}{|A|} \begin{vmatrix} \pi_{q^f \tau^u}^f d\tau^u + \pi_{q^f \tau^e}^f d\tau^e & \pi_{q^f q^{su}}^f & 0 \\ \pi_{q^{su} \tau^u}^s d\tau^u + \pi_{q^{su} \tau^e}^s d\tau^e & \pi_{q^{su} q^{su}}^s & \pi_{q^{su} q^{se}}^s \\ \pi_{q^{se} \tau^u}^s d\tau^u + \pi_{q^{se} \tau^e}^s d\tau^e & \pi_{q^{se} q^{su}}^s & \pi_{q^{se} q^{se}}^s \end{vmatrix}$$

$$\frac{dq^f}{d\tau^u} = -\frac{1}{|A|} \pi_{q^f q^{su}}^f \pi_{q^{se} q^{se}}^s \pi_{q^{su} \tau^u}^s = -(+)(-)(-)(-) > 0$$

$$\frac{dq^f}{d\tau^e} = \frac{1}{|A|} \pi_{q^f q^{su}}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} \tau^e}^s = (+)(-)(-)(-) < 0.$$

Next, we determine the impact of a change in the tariffs on q^{su} :

$$dq^{su} = \frac{1}{|A|} \begin{vmatrix} \pi_{q^f q^f}^f & \pi_{q^f \tau^u}^f d\tau^u + \pi_{q^f \tau^e}^f d\tau^e & 0 \\ \pi_{q^{su} q^f}^s & \pi_{q^{su} \tau^u}^s d\tau^u + \pi_{q^{su} \tau^e}^s d\tau^e & \pi_{q^{su} q^{se}}^s \\ 0 & \pi_{q^{se} \tau^u}^s d\tau^u + \pi_{q^{se} \tau^e}^s d\tau^e & \pi_{q^{se} q^{se}}^s \end{vmatrix}$$

$$\frac{dq^{su}}{d\tau^u} = \frac{1}{|A|} \left(\pi_{q^f q^f}^f \pi_{q^{se} q^{se}}^s \pi_{q^{su} \tau^u}^s \right) = (+)(-)(-)(-) < 0$$

$$\frac{dq^{su}}{d\tau^e} = -\frac{1}{|A|} \pi_{q^f q^f}^f \pi_{q^{su} q^{se}}^s \pi_{q^{se} \tau^e}^s = -(+)(-)(-)(-) > 0.$$

Next, we analyze the effect of a change in the tariffs on q^{se} :

$$dq^{se} = \frac{1}{|A|} \begin{vmatrix} \pi_{q^f q^f}^f & \pi_{q^f q^{su}}^f & \pi_{q^f \tau^u}^f d\tau^u + \pi_{q^f \tau^e}^f d\tau^e \\ \pi_{q^{su} q^f}^s & \pi_{q^{su} q^{su}}^s & \pi_{q^{su} \tau^u}^s d\tau^u + \pi_{q^{su} \tau^e}^s d\tau^e \\ 0 & \pi_{q^{se} q^{su}}^s & \pi_{q^{se} \tau^u}^s d\tau^u + \pi_{q^{se} \tau^e}^s d\tau^e \end{vmatrix}$$

$$\frac{dq^{se}}{d\tau^u} = \frac{1}{|A|} \left(-\pi_{q^f q^f}^f \pi_{q^{se} q^{su}}^s \pi_{q^{su} \tau^u}^s \right) = -(+)(-)(-)(-) > 0$$

$$\begin{aligned} \frac{dq^{se}}{d\tau^e} &= \frac{1}{|A|} \left(-\pi_{q^f q^{su}}^f \pi_{q^{su} q^f}^s \pi_{q^{se} \tau^e}^s + \pi_{q^f q^f}^f \pi_{q^{su} q^{su}}^s \pi_{q^{se} \tau^e}^s \right) \\ &= \frac{1}{|A|} ((-)(-)(-) + (-)(-))(-) < 0 \end{aligned}$$

because the own effects on marginal profits dominate the cross effects: $\pi_{q^f q^{su}}^f \pi_{q^{su} q^f}^s < \pi_{q^f q^f}^f \pi_{q^{su} q^{su}}^s$.

Finally, we analyze the effect of a change in the tariffs on q^u :

$$\begin{aligned} \frac{dq^u}{d\tau^u} &= \frac{dq^{su}}{d\tau^u} + \frac{dq^f}{d\tau^u} \\ &= \frac{1}{|A|} \pi_{q^{se} q^{se}}^s \pi_{q^{su} \tau^u}^s \left(\pi_{q^f q^f}^f - \pi_{q^f q^{su}}^f \right) \\ &= (+)(-)(-) [(-) - (-)] \end{aligned}$$

This result is indeterminate, but the direct effect $\left(\frac{dq^{su}}{d\tau^u} \right)$ will dominate the indirect effect $\left(\frac{dq^f}{d\tau^u} \right)$.

$$\begin{aligned} \frac{dq^u}{d\tau^e} &= \frac{dq^{su}}{d\tau^e} + \frac{dq^f}{d\tau^e} \\ &= \frac{1}{|A|} \pi_{q^{su} q^{se}}^s \pi_{q^{se} \tau^e}^s \left(-\pi_{q^f q^f}^f + \pi_{q^f q^{su}}^f \right) \\ &= (+)(-)(-) [(+) + (-)] \end{aligned}$$

This result is indeterminate, but the direct effect $\left(\frac{dq^{su}}{d\tau^e} \right)$ will dominate the indirect effect $\left(\frac{dq^f}{d\tau^e} \right)$.

4.5.2 Welfare Analysis of Tariff Changes

The welfare function for the United States is:

$$W^u(q^u, q^{su}; \tau^u, \tau^e) = \pi^f + CS + TR$$

where $\pi^f = p^u(q^u)q^f - C^f(q^f) - F^f$, $CS = \int p^u(q^u) dq^u - p^u(q^u)q^u$, and $TR = \tau^u q^{su}$. The welfare function for the São Paulo is:

$$W^s(q^u, q^{su}, q^{se}; \tau^u, \tau^e) = \pi^s$$

where $\pi^s = \frac{p^u(q^u)}{(1 + \tau^u)}q^{su} + \frac{p^e(q^{se})}{(1 + \tau^e)}q^{se} - C^s\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e}\right) - F^s$. Since Europe only consumes FCOJ and collects tariff revenues, the European welfare is:

$$W^e(q^{se}; \tau^e, \tau^u) = CS + TR$$

where $CS = \int p^e(q^{se}) dq^{se} - p^e(q^{se})q^{se}$ and $TR = p^e(q^{se})\tau^e q^{se}$.

U.S. Tariff

The change in Florida's profit with respect to a change in the U.S. tariff is:¹¹

$$\begin{aligned} \frac{d\pi^f}{d\tau^u} &= \underbrace{\left(q^f \frac{\partial p^u}{\partial q^u} + p^u - \frac{\partial C^f}{\partial q^f} \right)}_{=0 \text{ by } FOC} \frac{\partial q^f}{\partial \tau^u} + q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u} \\ &= q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u}. \end{aligned}$$

The change in U.S. consumer surplus with respect to a change in the U.S. tariff is:

$$\frac{dCS}{d\tau^u} = -q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^u}.$$

The change in U.S. tariff revenues with respect to a change in the U.S. tariff is:

$$\frac{dTR}{d\tau^u} = \tau^u \frac{\partial q^{su}}{\partial \tau^u} + q^{su}.$$

¹¹By the Cournot assumption $\frac{\partial q^u}{\partial q^f}$ and $\frac{\partial q^u}{\partial q^{su}}$ are equal to 1.

Therefore, we can express the total change in welfare as:

$$\frac{dW^u(\cdot)}{d\tau^u} = \underbrace{q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u}}_{+} - \underbrace{\frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^u} q^u}_{-} + \underbrace{\frac{\partial q^{su}}{\partial \tau^u} \tau^u}_{-} + \underbrace{q^{su}}_{+}.$$

The above results show that the welfare could be positive or negative.

The change in São Paulo welfare arising from a change in U.S. and European tariff is

$$\begin{aligned} \frac{dW^s(\cdot)}{d\tau^u} &= \underbrace{\left(\frac{1}{(1+\tau^u)} \left(q^{su} \frac{\partial p^u}{\partial q^u} + p^u \right) - \frac{\partial C^s}{\partial q^{su}} \right) \frac{\partial q^{su}}{\partial \tau^u}}_{=0 \text{ by } FOC} \\ &+ \underbrace{\left(\frac{1}{(1+\tau^e)} \left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) - \frac{\partial C^s}{\partial q^{se}} \right) \frac{\partial q^{se}}{\partial \tau^u}}_{=0 \text{ by } FOC} \\ &+ \frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^u} - \frac{p^u q^{su}}{(1+\tau^u)^2} \\ &= \underbrace{\frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^u}}_{-} - \underbrace{\frac{p^u q^{su}}{(1+\tau^u)^2}}_{-} < 0. \end{aligned}$$

Thus, São Paulo's welfare increase as the U.S. reduces its tariff.

The change in European consumer surplus arising from a change in U.S. tariff is

$$\frac{dCS}{d\tau^u} = -q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u}.$$

The change in European tariff revenue arising from a change in U.S. tariff is

$$\frac{dTR}{d\tau^u} = \tau^e q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u} + p^e (q^{se}) \tau^e \frac{\partial q^{se}}{\partial \tau^u}.$$

The total change in the European welfare is expressed as:

$$\frac{dW^e(\cdot)}{d\tau^u} = \underbrace{-q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u}}_{+} + \underbrace{\left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) \tau^e \frac{\partial q^{se}}{\partial \tau^u}}_{+} > 0.$$

Thus, the above result shows that European welfare decreases as the United States reduces its tariff.

European Tariff

The change in Florida's profits with respect to a change in τ^e is:

$$\begin{aligned}\frac{d\pi^f}{d\tau^e} &= \underbrace{\left(q^f \frac{\partial p^u}{\partial q^u} + p^u - \frac{\partial C^f}{\partial q^f} \right)}_{=0 \text{ by } FOC} \frac{\partial q^f}{\partial \tau^e} + q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^e} \\ &= q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^e}.\end{aligned}$$

The change in the U.S. consumer surplus with respect to a change in τ^e is:

$$\frac{dCS}{d\tau^e} = -q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^e}.$$

The change in the U.S. tariff revenue with respect to a change in τ^e is:

$$\frac{dTR}{d\tau^e} = \tau^u \frac{\partial q^{su}}{\partial \tau^e}.$$

Thus the total change in U.S. welfare with respect to τ^e is:

$$\frac{dW^u(\cdot)}{d\tau^e} = \underbrace{q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^e}}_{-} \underbrace{-q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^e}}_{+} + \underbrace{\tau^u \frac{\partial q^{su}}{\partial \tau^e}}_{+}.$$

The above results show that the U.S. welfare can increase or decrease as Europe reduces the tariff.

The change in São Paulo welfare arising from a change in the European tariff is

$$\begin{aligned}\frac{dW^s}{d\tau^e} &= \underbrace{\left(\frac{1}{(1+\tau^u)} \left(q^{su} \frac{\partial p^u}{\partial q^u} + p^u \right) - \frac{\partial C^s}{\partial q^{su}} \right)}_{=0 \text{ by } FOC} \frac{\partial q^{su}}{\partial \tau^e} \\ &\quad + \underbrace{\left(\frac{1}{(1+\tau^e)} \left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) - \frac{\partial C^s}{\partial q^{se}} \right)}_{=0 \text{ by } FOC} \frac{\partial q^{se}}{\partial \tau^e} \\ &\quad + \frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^e} - \frac{p^e q^{se}}{(1+\tau^e)^2} \\ &= \underbrace{\frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^e}}_{+} \underbrace{- \frac{p^e q^{se}}{(1+\tau^e)^2}}_{-}\end{aligned}$$

The São Paulo Welfare can go up or fall (most likely go up) when Europe reduces its tariff. São Paulo is going to gain from the European market as it can sell more, leading to a positive gain,

but will lose in the United States as it switches exports from the United States to Europe and lose market share to Florida.

The change in the European consumer surplus arising from a change in the European tariff is:

$$\frac{dCS}{d\tau^e} = -q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^e}.$$

The change in the European tariff revenues arising from a change in the European tariff is:

$$\frac{dTR}{d\tau^e} = \tau^e q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^e} + p^e \tau^e \frac{\partial q^{se}}{\partial \tau^e} + p^e q^{se}.$$

The total change in welfare is:

$$\frac{dW^e(\cdot)}{d\tau^e} = \underbrace{-q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^e}}_{-} + \underbrace{\left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) \tau^e \frac{\partial q^{se}}{\partial \tau^e}}_{-} + \underbrace{p^e q^{se}}_{+}.$$

As Europe reduces its tariff its consumer surplus will increase but tariff revenues will go down, but the net results will likely be positive as the gain in consumer surplus will most likely outweigh the loss in tariff revenues.

Chapter 5

The Dynamics of Subsidy Removal with Heterogeneous Firms

5.1 Introduction

We quantify the dynamic effects of subsidy removal in a growth model with heterogeneous firms. Given the importance of measured total factor productivity (TFP) in accounting for macroeconomic fluctuations, it is crucial to understand how government policies affect this residual over time. In almost all economies there are at least some sectors in which inefficient establishments are propped up by government subsidies. For example, both U.S. and European governments have decoupled their agricultural subsidies to minimize market distortions Femenia et al. (2010). While static models show decoupled subsidies eliminate market distortions, in reality they influence producer's entry and shutdown decisions, which distorts the agricultural markets in both the short- and long-run. Another prominent example is New Zealand's comprehensive economic reforms in 1984 following a decade long great depression Evans et al. (1996). At the center of the reforms was the agricultural sector where extensive subsidies were eliminated. Prior to the reforms, these subsidies caused producers to operate at an inefficient scale and propped up inefficient firms that would have otherwise exited, which induced additional market distortions.

We consider how the removal of a variety of subsidies—including lump-sum operating (or income), output, intermediate input, and interest rate subsidies—affects not only the steady state of the economy but also the entire equilibrium transition path. To highlight the role of intrasectoral reallocation, we compare the effects of subsidy removal in an environment with heterogeneous firms to an environment with a representative firm. We conclude that modeling heterogeneous firms is important for capturing the full effects of subsidy removal on measured TFP. Moreover, steady-state analysis may lead one to conclude that eliminating some distortions lowers social

welfare, when in fact the opposite is the case.

We take a one-sector neoclassical growth model and incorporate the competitive industrial organization theory of Hopenhayn (1992), but in a general equilibrium setting as in Hopenhayn and Rogerson (1993), though their application is employment distortions. The theory allows for endogenous entry, operating, and exit decisions of firms. All firms have technologies that allow them to operate with decreasing returns to scale but, because of fixed costs of operating, some firms may choose to not operate.

There is a growing literature that focuses on the link between factor misallocation and cross-country differences in productivity and GDP per worker. These papers have two commonalities: 1) they feature a dynamic model with heterogeneous production and 2) the government imposes idiosyncratic policies—generally the high-productivity firms are taxed while the low-productivity firms are subsidized. This policy scheme leads to unique prices for each firm and reallocates resources across establishments. Guner et al. (2008) find that, when governments promote small firms and tax establishments with employment over a certain threshold, the average size of the establishment and output per establishment are reduced by 20 percent and 26 percent, respectively. Restuccia and Rogerson (2008) focus on a set policies that impact the firm dynamics by subsidizing firms while the expanding and taxing them while they contract. They also account for the distribution of establishments across productivity levels. Their results show that this policy output and productivity decrease by 30 to 50 percent, respectively. Fattal (2012) extends the analysis by allowing for endogenous entry and exit decisions. Without endogenous entry and exit, removing the policies results in a 35 percent gain in TFP and welfare; with entry and exit the gain in TFP is cut by more than one-third while the welfare gains remains are over 40 percent. Da Rocha and Pujolas (2011) extend Fattal (2012) by incorporating an endogenous distribution of plants using Brownian motion. Their model shows that the failure to account for firm-level idiosyncratic shocks and endogenous exit overestimates the TFP gain when policy distortions are removed. Buera et al. (2013) develop a model in which heterogeneous individuals optimally choose between being an entrepreneur or a worker. Productive entrepreneurs are initially subsidized, which leads to positive

short-run effects. However, as entrepreneurs lose their competitive edge, they remain propped up by subsidized capital, resulting in substantial long-run drops in both output and productivity.

The model developed in this paper is also related to work by Chu (2003) and Gourio and Miao (2011). Chu (2003) specifies a dynamic two-sector general equilibrium model with firm-level heterogeneity and endogenous entry and exit in the industrial sector to analyze the effects of import-substitution policies on equilibrium transition paths of aggregate GDP, real income, the measures of entrants and firms, capital, and the real wage. The subsidies support low-productivity firms and result in economy-wide inefficiencies. In the long run, import substitution policy drives down GDP and has high welfare costs.

Gourio and Miao (2011) develop a dynamic model with heterogenous firms to analyze the optimal transition path of a cut in both dividend and capital gains taxes. Two cases for the tax cut are considered: 1) permanent and unexpected and 2) temporary and unexpected. In the first case, the aggregate quantities of output, consumption, labor, investment, and capital increase. However, in the second case, steady state values remain unchanged; the transition dynamics show in the short-run aggregate investment decreases, dividend payments increases, and aggregate labor, capital, and output rise.

We differ from the above papers along several dimensions. First, we measure TFP in our model as it is typically measured in the data, which makes our analysis directly applicable to the many studies showing the importance of measured TFP in accounting for macroeconomic fluctuations. Second, we consider the impact of removing an interest rate subsidy, which distorts intertemporal decisions. Third, while most papers consider only steady-state analysis, we compute equilibrium transition paths. Fourth, most papers emphasize idiosyncratic distortions to firms' behavior, but we consider only aggregate policies.

The next section details the baseline model and the equilibrium. Section 5.3 defines the measurement statistics for welfare, real GDP, and TFP. Section 5.4 outlines the calibration of the model. Section 5.5 presents the results for the policy experiments, compares the results for the model with heterogeneous firms to a similar model with a representative firm, and analyzes the

transition dynamics through a growth accounting exercise. Section 5.6 summarizes the key results and concludes the paper.

5.2 Model

We develop a competitive dynamic general equilibrium model in which heterogeneous firms make endogenous entry, operating, and exit decisions. The model also has a representative consumer, a bank that finances the entry and operation of firms, and a government that offers subsidies.

5.2.1 Consumers

There is a representative consumer who is endowed with \bar{L} units of time available for market work in each period t , $t = 0, 1, \dots$, and amount \bar{A}_0 of initial assets. The consumer derives utility from consumption and leisure according to the lifetime utility function

$$\sum_{t=0}^{\infty} \beta^t u(C_t, \bar{L} - L_t^s), \quad (5.1)$$

where $\beta \in (0, 1)$ is the discount factor, $u(\cdot, \cdot)$ is a standard period utility function, C_t is consumption, L_t^s is labor supply, and $\bar{L} - L_t^s$ is leisure. The consumer splits after-tax income between consumption and bank deposits. The government subsidizes interest income at rate σ_t^i . The consumer's after-tax income is equal to labor and interest income less taxes. The consumer's budget constraint is

$$C_t + A_{t+1} = w_t L_t^s + (1 + (1 + \sigma_t^i) i_t) A_t - T_t, \quad (5.2)$$

where A_{t+1} is bank deposits made in period t , w_t is the wage rate, i_t is the interest rate, and T_t is the lump-sum tax. In Subsection 5.2.3 we specify the consumer's initial endowment of assets.

From the consumer's problem we can derive the intratemporal and intertemporal first-order conditions:

$$\frac{u_L(C_t, \bar{L} - L_t^s)}{u_C(C_t, \bar{L} - L_t^s)} = w_t \quad (5.3)$$

$$\frac{u_C(C_t, \bar{L} - L_t^s)}{\beta u_C(C_{t+1}, \bar{L} - L_{t+1}^s)} = 1 + (1 + \sigma_t^i) i_t. \quad (5.4)$$

5.2.2 Firms

There is a continuum of heterogeneous firms that differ in productivity z . The firms competitively produce a homogeneous good and are subject to idiosyncratic productivity shocks.

Static Firm Decisions

A firm with productivity z in period t has the technology

$$y_t(z) = z^{1-\nu} F(k_t(z), l_t(z), x_t(z))^\nu, \quad (5.5)$$

where $y_t(z)$ is output and defined as the numeraire, $F(\cdot, \cdot, \cdot)$ is a standard production function with constant returns to scale, $k_t(z)$ is capital, $l_t(z)$ is labor, and $x_t(z)$ is intermediate inputs. Here $\nu \in (0, 1)$ so that individual firms face decreasing returns to scale. The government gives each firm a lump-sum operating (or income) subsidy of σ_t^o , an output subsidy of σ_t^y , and an intermediate input subsidy of σ_t^x . The fixed cost of operating is f_o units of output. The firm's profits are

$$\pi_t(z) = (1 + \sigma_t^y) y_t(z) - r_t k_t(z) - w_t l_t(z) - (1 - \sigma_t^x) x_t(z) - f_o + \sigma_t^o. \quad (5.6)$$

Dynamic Firm Decisions

In each period, a firm can either operate or exit forever. This makes each firm's operating decision dynamic. A firm's productivity evolves according to the Markov transition function $q(z, z')$. The present value ($v_t(z)$) of a firm with productivity z in period t is then defined recursively as

$$v_t(z) = \max \left\{ \pi_t(z) + \frac{1}{1 + i_{t+1}} \sum_{z'} v_{t+1}(z) q(z, z'), 0 \right\}. \quad (5.7)$$

Firms discount future profits according to the market rate of interest.

In the aggregate, the operating decisions ($\iota_t(z)$) of firms constitute a mixed complementarity problem given by

$$\begin{cases} \iota_t(z) = 1 & \text{if } \pi_t(z) + \frac{1}{1 + i_{t+1}} \sum_{z'} v_{t+1}(z) q(z, z') > 0 \\ 0 \leq \iota_t(z) \leq 1 & \text{if } \pi_t(z) + \frac{1}{1 + i_{t+1}} \sum_{z'} v_{t+1}(z) q(z, z') = 0 \\ \iota_t(z) = 0 & \text{if } \pi_t(z) + \frac{1}{1 + i_{t+1}} \sum_{z'} v_{t+1}(z) q(z, z') < 0 \end{cases}. \quad (5.8)$$

Firms with a continuation value of zero are indifferent between exiting and continuing to operate, so the shares are determined in equilibrium.

In period t , the bank finances the entry of measure E_t of new firms. These firms draw their productivities from probability distribution $g(z)$ and can choose to start operating in period $t + 1$. Let $m_t(z)$ denote the measure of firms with productivity z in period t before operating decisions have been made. The distribution of firms by productivity then evolves according to

$$m_{t+1}(z) = \sum_{\zeta} \iota_t(\zeta) m_t(\zeta) q(\zeta, z) + E_t g(z). \quad (5.9)$$

The measure of firms with productivity shock z in period $t + 1$ is the measure of incumbent firms that find it optimal to operate and receive shock z plus the measure of entrants with productivity draw z .

Aggregation

We define the aggregates for output Y_t , capital K_t , labor used for production L_t^p , inputs X_t , measure M_t , and profits Π_t as the sum of the firm-level variables over the measure of firms that are operating

$$Y_t = \sum_z y_t(z) \iota_t(z) m_t(z) \quad (5.10)$$

$$K_t = \sum_z k_t(z) \iota_t(z) m_t(z) \quad (5.11)$$

$$L_t^p = \sum_z l_t(z) \iota_t(z) m_t(z) \quad (5.12)$$

$$X_t = \sum_z x_t(z) \iota_t(z) m_t(z) \quad (5.13)$$

$$M_t = \sum_z \iota_t(z) m_t(z) \quad (5.14)$$

$$\Pi_t = \sum_z \pi_t(z) \iota_t(z) m_t(z). \quad (5.15)$$

5.2.3 Bank

There is a bank that takes in deposits from the representative consumer and invests in capital and new firms. The bank holds capital and ownership of firms as assets and rents capital to firms. The

bank maximizes the present discounted value of profits

$$\sum_{t=0}^{\infty} p_t (r_t K_t + \Pi_t + A_{t+1} - (1 + i_t) A_t - I_t - w_t f_e E_t). \quad (5.16)$$

Here p_t is the bank's discount factor in period t and, given $p_0 = 1$, it can be specified recursively as

$$p_{t+1} = \frac{p_t}{1 + i_{t+1}}. \quad (5.17)$$

The bank maximizes (5.16) subject to the the law of motion of the distribution of firms (5.9), the law of motion of capital

$$K_{t+1} = (1 - \delta) K_t + I_t, \quad (5.18)$$

the condition that assets equal liabilities

$$K_t + \frac{1}{1 + i_t} \sum_z v_t(z) m_t(z) = A_t, \quad (5.19)$$

and initial conditions on the capital stock and the measure of firms

$$K_0 = \bar{K}_0 \quad (5.20)$$

$$m_0(z) = \bar{m}_0(z). \quad (5.21)$$

To be consistent, it must be the case that the representative consumer's endowment of initial assets is

$$\bar{A}_0 = \bar{K}_0 + \frac{1}{1 + i_0} \sum_z v_0(z) \bar{m}_0(z). \quad (5.22)$$

From the bank's problem we can derive two no-arbitrage conditions. The no-arbitrage condition for investment in capital is

$$r_{t+1} - \delta \leq i_{t+1}, = \text{ if } I_t > 0. \quad (5.23)$$

The no-arbitrage condition for investment in new firms is

$$w_t f_e \leq \frac{1}{1 + i_{t+1}} \sum_z v_{t+1}(z) g(z), = \text{ if } E_t > 0. \quad (5.24)$$

The bank earns zero profits each period.

5.2.4 Government

The government collects lump-sum taxes from the consumer and offers lump-sum operating, output, and intermediate input subsidies to producers and an interest rate subsidy to the consumer.

The government's budget constraint is

$$T_t = \sigma_t^o M_t + \sigma_t^y Y_t + \sigma_t^x X_t + \sigma_t^i i_t A_t. \quad (5.25)$$

5.2.5 Market-Clearing Conditions

Output can be used for consumption, for investment, as an intermediate good, and for the payment of fixed costs of operating. Clearing in the goods market requires that

$$Y_t = C_t + I_t + X_t + f_o M_t. \quad (5.26)$$

Labor can be used as an input to production and for the payment of fixed costs of entry. Clearing in the labor market requires that

$$L_t^s = L_t^p + f_e E_t. \quad (5.27)$$

5.2.6 Equilibrium

A *competitive equilibrium* consists of sequences of aggregates $\{\hat{Y}_t, \hat{L}_t^s, \hat{L}_t^p, \hat{C}_t, \hat{K}_t, \hat{I}_t, \hat{X}_t, \hat{\Pi}_t, \hat{M}_t, \hat{E}_t, \hat{A}_t, \hat{T}_t\}$, prices $\{\hat{w}_t, \hat{r}_t, \hat{i}_t, \hat{p}_t\}$, and firm decision rules $\{\hat{k}_t(z), \hat{l}_t(z), \hat{x}_t(z), \hat{y}_t(z), \hat{\pi}_t(z), \hat{v}_t(z), \hat{\iota}_t(z)\}$ such that:

1. Given $\{\hat{w}_t, \hat{i}_t, \hat{T}_t\}$, the representative consumer chooses $\{\hat{C}_t, \hat{L}_t^s, \hat{A}_t\}$ to maximize utility (5.1) subject to the budget constraint (5.2), the initial condition on assets $A_0 = \bar{A}_0$ (where \bar{A}_0 satisfies (5.22)), $C_t \geq 0$, $0 \leq L_t^s \leq \bar{L}$, and $A_t \geq 0$.
2. Given $\{\hat{w}_t, \hat{r}_t\}$, a firm with efficiency z in period t chooses $\{\hat{k}_t(z), \hat{l}_t(z), \hat{x}_t(z), \hat{y}_t(z), \hat{\pi}_t(z)\}$ to maximize profits (5.6) subject to the technology constraint (5.5). The value functions $\{\hat{v}_t(z)\}$ satisfy (5.7) and the operating decision rules $\{\hat{\iota}_t(z)\}$ satisfy (5.8).

3. Given $\{\hat{A}_t, \hat{i}_t, \hat{v}_t(z), \hat{l}_t(z), \hat{\pi}_t(z), \hat{p}_t\}$, the bank chooses $\{\hat{K}_t, \hat{I}_t, \hat{m}_t(z), \hat{E}_t\}$ to maximize profits (5.16) subject to the law of motion of capital (5.18), the balance sheet condition (5.19), the law of motion of the distribution of firms (5.9), and the initial conditions (5.20) and (5.21). The bank's sequence of discount factors $\{\hat{p}_t\}$ satisfies (5.17).
4. The aggregation conditions (5.10)–(5.15) hold.
5. The government's budget constraint (5.25) holds.
6. The market-clearing conditions for goods (5.26) and labor (5.27) hold.

5.3 Measurement

Here we specify the measurement of social welfare, gross domestic product (GDP), and TFP.

5.3.1 Social Welfare

We consider two measures of social welfare. The first measure of social welfare is lifetime real income (*LRI*). The real income index, $\tilde{u}(\cdot, \cdot)$, for each period is given by a monotonic transformation of the period utility function $u(\cdot, \cdot)$ so as to make it homogeneous of degree one. Lifetime real income is given by

$$LRI = \sum_{t=0}^{\infty} \beta^t \tilde{u}(C_t, \bar{L} - L_t^s). \quad (5.28)$$

The second measure of social welfare is lifetime consumption equivalents. Suppose we want to calculate the change in welfare in going from allocation $\{\hat{C}_t, \hat{L}_t^s\}$ to allocation $\{\tilde{C}_t, \tilde{L}_t^s\}$. Let g be the factor change in welfare in terms of lifetime consumption equivalents. Then g is the solution to

$$\sum_{t=0}^{\infty} \beta^t u(g\hat{C}_t, \bar{L} - \hat{L}_t^s) = \sum_{t=0}^{\infty} \beta^t u(\tilde{C}_t, \bar{L} - \tilde{L}_t^s). \quad (5.29)$$

5.3.2 Gross Domestic Product

GDP can be measured in three different, yet equivalent, ways: the expenditure approach, the product approach, and the income approach. We consider each below.

An issue that arises in the calculation of GDP is how to treat investment in new firms. Creation of a new firm that can start operating in period $t + 1$ requires an investment of $w_t f_e$ in period t . Some of this may be investment in fixed capital, which is counted in GDP, while some of this may be investment in intangible capital, which is not. Rather than making the extreme assumption that investment in new firms is all of one type, we let θ denote the fraction that is investment in fixed capital.

The expenditure approach to GDP is the sum of consumption, investment in capital, and fraction θ of investment in new firms:

$$GDP_t = C_t + I_t + \theta w_t f_e E_t. \quad (5.30)$$

The product approach to GDP is gross output minus intermediate inputs:

$$GDP_t = Y_t + \theta w_t f_e E_t - X_t - f_o M_t. \quad (5.31)$$

The income approach to GDP is the sum of wages, rental income, and profits, less subsidies to business:

$$GDP_t = w_t L_t^s + r_t K_t + (\Pi_t - (1 - \theta) w_t f_e E_t) - (\sigma_t^y Y_t + \sigma_t^x X_t + \sigma_t^o M_t). \quad (5.32)$$

Notice that investments in intangible capital are expensed by firms. Using the market clearing condition (5.26) and the consumer's budget constraint (5.2), it is straightforward to verify that the three measures of GDP are equal.

Now that we have specified nominal GDP, we specify how to obtain real GDP. We use a chain-weighted GDP deflator. This involves calculating a Fisher price index, which is the geometric mean of the Paasche and Laspeyres price indexes. Letting $P_0 = 1$, we use expenditures to recursively calculate the chain-weighted GDP deflator as

$$P_{t+1} = \left(\frac{C_{t+1} + I_{t+1} + \theta w_{t+1} f_e E_{t+1}}{C_{t+1} + I_{t+1} + \theta w_t f_e E_{t+1}} \right)^{1/2} \left(\frac{C_t + I_t + \theta w_{t+1} f_e E_t}{C_t + I_t + \theta w_t f_e E_t} \right)^{1/2} P_t. \quad (5.33)$$

Notice that the relative price of investment in new firms is the wage and, if $\theta = 0$, then the price

index is constant at one. Real GDP is

$$RGDP_t = \frac{GDP_t}{P_t}. \quad (5.34)$$

5.3.3 Total Factor Productivity

We consider two measures of TFP: *measured* and *theoretical*. With our measure of real GDP, we can approach the calculation of measured TFP in the model as a macroeconomist typically would using data. We assume a standard Cobb-Douglas form for the aggregate production function and calculate measured TFP as the residual

$$TFP_t = \frac{RGDP_t}{\tilde{K}_t^\alpha \tilde{L}_t^{1-\alpha}}, \quad (5.35)$$

where \tilde{K}_t is the measured input of fixed capital, \tilde{L}_t is the measured input of labor, and $1 - \alpha$ is labor's share of income. In the context of this model, and given our assumptions on the role of fixed capital in the creation of new firms, we have measured inputs of

$$\tilde{K}_t = K_t + \frac{\theta}{1 + i_t} \sum_z v_t(z) m_t(z) \quad (5.36)$$

$$\tilde{L}_t = L_t^p. \quad (5.37)$$

We set labor's share of income according to its steady-state value with no subsidy in place:

$$1 - \alpha = \frac{wL^p}{GDP}. \quad (5.38)$$

Theoretical TFP is seen by expressing output in the model as

$$Y_t = Z_t G(K_t, L_t^p, X_t, M_t).$$

Here

$$Z_t = \left(\frac{1}{M_t} \sum_z z \iota_t(z) m_t(z) \right)^{1-\nu} \quad (5.39)$$

is theoretical TFP and

$$G(K, L, X, M) = F(K, L, X)^\nu M^{1-\nu}. \quad (5.40)$$

Since individual firms face decreasing returns to scale, $G(\cdot, \cdot, \cdot, \cdot)$ includes the measure of operating

Table 5.1: Calibration of the Model

Parameter	Calibrated Value	Description
\bar{L}	1.000	Total labor hours
γ	0.350	Consumption weight
β	0.960	Discount rate
ν	0.850	Firm-level returns to scale
ψ_1	0.167	Capital output share
ψ_2	0.333	Labor output share
f_e	1.000	Fixed entry cost
f_o	0.040	Fixed operating cost
δ	0.065	Depreciation rate

firms. Notice that, since $F(\cdot, \cdot, \cdot)$ is homogeneous of degree one, $G(\cdot, \cdot, \cdot, \cdot)$ is also homogenous of degree one. This makes it clear that there are constant returns to scale in the aggregate.

By contrasting the two types of TFP, it is clear that measured TFP is a more complete measure of productivity gains. Following the removal of a subsidy, measured TFP accounts for the reallocation of resources from low- to high-productivity firms and from the adjustment in the firms to their Pareto-optimal scale. Whereas the theoretical TFP only account for the reallocation of resources from low- to high-productivity firms.

5.4 Calibration

Rather than calibrating the model to a specific country and time, we make our analysis as widely applicable as possible by using standard functional forms and parameter values. We calibrate the model to the steady state with no policy distortions. Table 5.1 summarizes the calibration.

We choose standard functional forms. We specify the period utility function in (5.1) as

$$u(C, \bar{L} - L^s) = \gamma \log C + (1 - \gamma) \log (\bar{L} - L^s), \quad (5.41)$$

where $\gamma \in (0, 1)$, and the constant-returns-to-scale production function in (5.5) as

$$F(k, l, x) = k^{\psi_1} l^{\psi_2} x^{1-\psi_1-\psi_2}, \quad (5.42)$$

where $\psi_1 \in (0, 1)$ and $\psi_2 \in (0, 1)$.

We choose standard parameter values. We normalize units of labor so that $\bar{L} = 1$ and set

$\gamma = 0.35$ to achieve a ratio of total labor supply to total available labor of $L^s/\bar{L} = 0.3$. Assuming that 100 hours of time are available for market work each week, this implies 30 hours of market work per week. We set $\beta = 0.96$ to obtain a standard long-term real interest rate of 4 percent. Following Restuccia and Rogerson (2008), we set $\nu = 0.85$. We assume that intermediate inputs to production account for 1/2 of the total value of output. Then, based on income shares for capital and labor of 1/3 and 2/3, we set $\psi_1 = 0.167$ and $\psi_2 = 0.333$. We assume that the fixed cost of investment in a firm is $f_e = 1$ units of labor. We target an investment to GDP ratio of 15 percent, which is achieved with a depreciation rate of $\delta = 0.065$.

Next we specify firm productivity levels and the Markov transition function. We purposely choose a very simple but transparent specification. Similar to Chu (2003), we allow for two possible types of operating firms, which we refer to as *efficient* and *inefficient* firms. Efficient firms are at the frontier of technology, while inefficient firms have fallen behind by half. There is also an absorbing state with zero productivity. Thus $z \in \{0, 1, 2\}$. We assume that all firms enter at the frontier of technology, so $g(z) = 1$ if $z = 2$ and $g(z) = 0$ otherwise. With 10 percent probability, efficient firms fall behind the technological frontier and become inefficient firms. With 15 percent probability, inefficient firms die. The Markov transition matrix is

$$q = \begin{bmatrix} 1 & 0 & 0 \\ 0.15 & 0.85 & 0 \\ 0 & 0.1 & 0.9 \end{bmatrix}. \quad (5.43)$$

We are interested in the case where inefficient firms cannot survive without government assistance. Accordingly we set the fixed cost of operating sufficiently high at $f_o = 0.04$ units of output.

5.5 Policy Experiments

In this section, we conduct policy experiments. Not only do we analyze the effects of removing a subsidy on the steady-state values of welfare, real GDP, and TFP, but we also numerically solve for the entire equilibrium transition path. We contrast the results of the heterogeneous firms model to a model with a representative firm.

Table 5.2: Long-Run Effects: Steady State Comparison

Variable	Percentage change with subsidy elimination			
	σ^o (0.01)	σ^y (13.3%)	σ^x (25.5%)	σ^i (50%)
Real GDP	-6.5	-27.6	-27.3	-9.2
Capital stock	-8.6	-42.5	-46.0	-21.0
Labor supply	-4.3	-19.7	-24.5	-3.2
Intermediate inputs	-8.4	-42.5	-59.8	-9.2
Measured TFP	0.8	3.9	11.1	0.9
Theoretical TFP	0.7	0.7	0.7	0.0
Real income index	-0.4	-1.0	3.0	-1.2
Consumption	-4.6	-21.4	-18.3	-5.9
Leisure	2.0	12.1	16.7	1.5
Real interest rate	0.0	0.0	0.0	50.0

We consider the following transition path. In period 0, the economy is in the steady state with a policy distortion. In period 1, all decision makers learn that there will be a permanent policy change in period 5. In period 5, the economy begins converging to the new steady state without policy distortions. We consider four policy experiments: removal of 1) lump-sum operating, 2) output, 3) input, and 4) interest rate subsidies. In the baseline scenario one of the above four subsidies is implemented, and in the alternate scenario the subsidy is removed. We then compare the transition dynamics of removing the lump-sum operating and output subsidies to those in the model with a representative firm. The algorithms for calculating the steady states and transition paths are given in Appendix 5.7.

We specify lump-sum operating, output, and input subsidies at the minimum (threshold) level required for the inefficient firms to operate. The interest rate subsidy is the only subsidy without a threshold level because it indirectly impacts firm's choice of inputs, this is elaborated on below. In the initial steady state, the government offers an operating subsidy (σ_t^o) of 0.01, an output subsidy (σ^y) of 13.3 percent, an input subsidy (σ^x) of 25.5 percent, or interest rate subsidy (σ_t^i) of 50 percent. Table 5.2 summarizes the steady state effects of subsidy removal. Table 5.3 reports the impact of the policy reform on the measure of firms as a percent of the total measure. Table 5.4 describes the effect of policy reform on welfare in terms of lifetime real income (calculated using (5.28)) and in terms of lifetime consumption equivalents (calculated using (5.29)).

Table 5.3: Measure of Firms Before and After Reform, Percent of Total Measure

	σ^o		σ^y		σ^x		σ^i	
	0.01	0.00	13.3%	0%	25.5%	0%	50%	0%
Share for $z = 1$	9.4	0.5	9.0	0.5	9.7	0.5	0.5	0.5
Share for $z = 2$	90.5	99.5	91.0	99.5	90.3	99.5	99.5	99.5

Table 5.4: Change in Welfare with Subsidy Removal

	Percent change with reform			
	σ^o	σ^y	σ^x	σ^i
Lifetime real income	0.3	2.2	6.1	0.2
Lifetime consumption equivalents	0.8	6.4	18.1	0.5

5.5.1 Lump-Sum Operating Subsidy

If the government offers a lump-sum operating subsidy, it lowers the firms' fixed operating cost and increases the value and measure of operating firms, which leads to higher aggregate output. Given our calibration, if the government offers a subsidy of $\sigma_t^o = 0.01$, which is 25 percent of the fixed operating cost or 5 percent of GDP, then firms that receive a low productivity shock and become inefficient remain profitable and continue to operate, which results in an additional boost in output. We use this threshold subsidy level for the baseline in the simulation.

With the operating subsidy in place, efficient and inefficient firms account for 9.4 and 90.5 percent of the total measure, as shown in Table 5.3. (The percent of total measure for the low- and high-productivity firms does not sum to 100 because we approximate $\iota_t(z)$ in the algorithm with a standard Heaviside step function to achieve continuity, see Appendix 5.7.) After the reform is implemented, profits plus future value of the low-productivity firms becomes negative and they exit the market; this results in a reallocation of resources to the high-productivity firms. The measure of the low-productivity firms declines to 0.5 percent of the total measure while the measure of the high-productivity firms increases to 99.5 percent of the total measure.

The subsidy removal results in firms readjusting their size, through adjustments in capital, labor, and intermediate inputs to their Pareto-optimal scale. The aggregate levels of capital, labor, and intermediate inputs drop by 8.6, 4.3, and 8.4 percent, which drives real GDP down by 6.5

percent (real GDP is calculated using (5.30), (5.33), and (5.34) defined in Subsection 5.3.2).

As the measure, inputs to production, and scale of firms adjust to their Pareto-optimal levels, aggregate productivity, as defined in Subsection 5.3.3, increases. Measured TFP (5.35) captures productivity gains following the reform from resource misallocation due to inefficient levels of capital, labor, and intermediate inputs and the reallocation of resources from low- to high-productivity firms. Theoretical TFP (5.39), in contrast, is driven only by the reallocation of resources from low- to high-productivity firms. (If the subsidy level is below the threshold level low-productivity firms do not operate, and following the reform, the theoretical measure is constant.) Measured TFP increases by 0.8 percent, while theoretical TFP increases by 0.7 percent. We conclude that 0.7 percent of the productivity gain is from resource reallocation from low- to high-productivity firms and 0.1 percent of the productivity gain is from adjustment in the scale of firms.

The effect of the drop in real GDP and labor supply has two opposing implications for welfare. The decrease in output reduces consumption (having a negative welfare effect) while the decrease in the labor supply increases leisure (having a positive welfare effect) to their Pareto-optimal levels for the representative consumer. The net effect on welfare is sensitive to whether the full transition path is taken into account. When comparing steady states of the real income index (Table 5.2), the loss of consumption outweighs the gain in leisure and the real income index declines by 0.4 percent. However, taking the full transition path into account has significant implications on welfare, as shown in Table 5.4. Lifetime real income (5.28) is 0.3 percent higher with the reform than without the reform. The welfare change as measured by the lifetime consumption equivalents indicates that if the operating subsidy remained in place, the consumer would require a 0.8 percent increase in consumption each period to be as well off as without the subsidy.

5.5.2 Output Subsidy

An output subsidy causes firms to operate above their Pareto-optimal scale, which raises real GDP. As a result, the firms' value increases making entry more attractive and augments the measure of

operating firms. The threshold output subsidy at which the inefficient firms operate is 13.3 percent ($\sigma^o = 0.133$) of total output, or 27 percent of real GDP, which is used in our baseline simulation.

The effect of output subsidy removal on the percent of the total measure for low- and high-productivity firms is similar to that in operating subsidy case (see Table 5.3). This is because at the threshold subsidy level, the value, and thus measure, are the similar regardless of the type of subsidy.

The removal of the subsidy causes firms to readjust to their Pareto-optimal scale. Aggregate levels of capital, labor, and intermediate inputs decline by 42.5, 19.7, and 42.5 percent, causing real GDP to drop by 27.6 percent. This readjustment results in measured TFP increasing by 3.9 percent and theoretical TFP increasing by 0.7 percent. Therefore, resource reallocation from low- to high-productivity firms accounts for 0.7 percent of the productivity gain, while the adjustment in the scale of the firms augments productivity by 3.2 percent. Note that for the first three subsidy scenarios, at the threshold level, the proportions of the total measure for the low-productivity firms, and thus productivity gain due to resource reallocation from low- to high-productivity firms, is similar. As the subsidies increase above the threshold level, the low-productivity firms will account for a larger portion of the total measure and productivity gains due to resource reallocation from low- to high-productivity firms will increase as a result of the subsidy removal.

The steady state comparison for the real income index suggests welfare declined by 1.0 percent. But, the lifetime real income is 2.2 percent higher with the reform than without it. Also, the lifetime consumption equivalent suggest that the consumer would require a 6.4 percent increase in consumption each period to be as well off as without the subsidies.

5.5.3 Intermediate Input Subsidy

The main difference between an input and an output subsidy is the threshold level required for inefficient firms to operate is higher for an input subsidy than it is for an output subsidy. This is because an input subsidy only directly impacts the choice of the intermediate inputs while an output subsidy directly impacts the scale of the firms through a distortion of the output level.

The threshold input subsidy level is $\sigma^x = 25.5$ percent, which is 14.6 percent of output or 36.3 percent of GDP. Following the reform, while the changes in real GDP capital, and labor are relatively similar to that in the output subsidy case, measured TFP increases by 11.1 percent. This is 2.8 times more than in the output subsidy case. This boost in TFP was accompanied by a 6.1 percent increase in lifetime real income or an 18.1 percent increase in terms of lifetime consumption equivalents, which are 2.7 and 2.8 times higher than in the output subsidy case, respectively.

5.5.4 Interest Rate Subsidy

We implement an interest rate subsidy of 50 percent in the baseline because there is no threshold level where inefficient firms operate. This is because an interest rate subsidy on the returns to consumer's assets indirectly distorts capital, and thus labor and intermediate input, decisions by lowering the rental rate of capital (see (5.4) and (5.23)). The lower rental rate of capital increases each firm's capital decision which raises the marginal product of labor and the wage rate; the net effect is a decline in profits. (Note that, for all other subsidy cases, the subsidy directly enters each firm's profit equation and leads to an increase in profits.) Conversely, the fall in the real interest rate raises the firms' discount factor which increases each firm's discounted future profits. Consequentially, the decline in profits is large enough to offset the increase in the discounted future value so that the inefficient firms do not find it optimal to operate for any subsidy level. Because low-productivity firms do not operate in the baseline, the percent of total measure is constant before and after the reform, and all changes in output, productivity, and welfare are due to the readjustment of inputs and firm scale to their Pareto-optimal level in the alternate scenario.

As shown in Table 5.2, following the reform, the steady state comparison shows the real interest rate increases by the amount of the subsidy (for all other subsidy scenarios, the steady-state real interest rate is unaffected). The decline of the capital stock to its Pareto-optimal level (a 21.0 percent reduction) is large relative to labor (a 3.2 percent decrease) because the subsidy directly impacts the rental rate at which capital is purchased. The adjustment of capital and labor cause real

GDP to decline by 9.2 percent. Steady-state real income declines by 1.2 percent. However, when taking the full transition path into account, the lifetime real income and the lifetime consumption equivalents increases by 0.2 and 0.5 percent, respectively (see Table 5.4).

5.5.5 Comparison to a Representative Firm Model

In this subsection, we compare the results of the model with heterogeneous firms and endogenous entry and exit (HF), presented in Section 5.2, to the model with a representative firm (RF). The representative firm uses the technology given by (5.42). Of course there is no entry or exit or fixed cost of entry or operating.

An operating subsidy is non-distortionary in the RF model because there is no endogenous entry and exit. The HF model must be implemented to quantify distortions from this policy because operating subsidies directly impact entry and exit decisions.

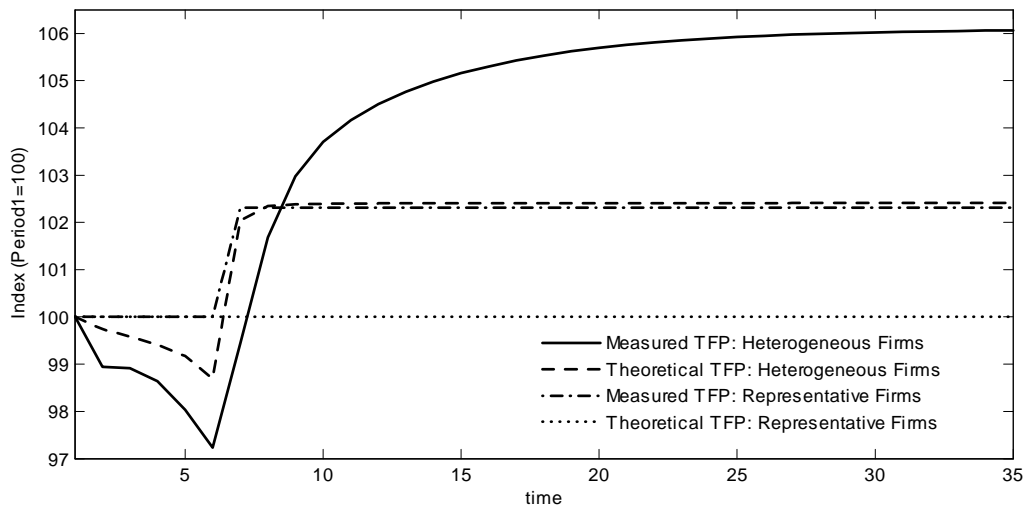
In what follows, we focus on the effects of removing an output subsidy of 15 percent, which higher than the threshold level, to allow for a greater measure of inefficient firms. The long-run impacts, summarized in Table 5.5 for both models, of removing this subsidy are slightly larger in the RF model for real GDP, capital, and labor, than the HF model. However, the measured TFP gain of 6.1 percent in the HF model is higher than the 2.3 percent increase in the RF model. The RF model understates the gain in TFP by a factor of 2.7 because it only captures productivity increases from the reallocation of capital, labor, intermediate inputs, and output to their Pareto-optimal levels, whereas the HF model not only captures this effect, but also productivity gains from the resource reallocation from low- to high-productivity firms. Figure 5.1 graphs the short-run (optimal transition) paths for both measured and theoretical TFP for both models. While productivity gains are largest for the HF model, TFP falls for the period leading up to the implementation of the reform; as we will see in the next subsection, this is largely driven by capital accumulation relative to the level of GDP after the announcement of the reform.

Comparison of the lifetime real income and the lifetime consumption equivalents (see Table 5.6) shows that the welfare effects are similar for both models, because the subsidy-driven

Table 5.5: Steady State Comparison of the HF and RF Models

Variable	Percent change with reform	
	Heterogeneous Firms	Representative Firm
	$\sigma^y(15\%)$	$\sigma^y(15\%)$
Real GDP	-29.6	-31.1
Capital stock	-47.8	-49.2
Labor supply	-22.5	-22.6
Intermediate Input	-47.8	-49.1
Measured TFP	6.1	2.3
Theoretical TFP	2.4	0.0
Real income	-0.3	-0.6
Consumption	-23.0	-24.3
Leisure	14.6	15.1

Figure 5.1: Comparison of TFP



distortions in output and labor, and therefore leisure, are about the same.

5.5.6 Transition Dynamics and Growth Accounting

Here we analyze the elimination of a 15 percent output subsidy on the equilibrium transition paths of the model by developing a growth accounting framework based on the model described in sections 5.2–5.4. Our growth accounting is based on the methods developed by Hayashi and Prescott (2002) and used in Kehoe and Prescott (2007). The equilibrium transition paths are treated as data collected from the economy’s national accounts. Real GDP is decomposed into the

Table 5.6: Welfare Comparison

	Percentage change with subsidy elimination	
	Lifetime real income	Lifetime consumption equivalents
HF Model	3.3	9.6
RF Model	3.4	9.7

TFP, capital-output, and labor factors by rewriting (5.35) as

$$RGDP_t = TFP_t^{\frac{1}{1-\alpha}} \left(\frac{\tilde{K}_t}{RGDP_t} \right)^{\frac{\alpha}{1-\alpha}} \tilde{L}_t. \quad (5.44)$$

TFP is scaled up by $1/(1-\alpha)$ and the capital-output ratio is scaled down by $\alpha/(1-\alpha)$, to account for the proportional increase in capital resulting from changes in TFP. Because our model does not feature growth in TFP or total labor hours, the economy is stationary and all variables are constant in the steady state. This exercise is equivalent to performing growth accounting on an economy after detrending real GDP.

When informed of the subsidy removal, production inefficiencies are exacerbated in the short-run because producers take advantage of the remaining subsidized periods by overcapitalizing relative to real value added. Following the reform, productivity increases because producers quickly readjust to the Pareto-optimal scale.

Figure 5.2 graphs the growth accounting implied by (5.44). Because both the labor factor and real GDP decline at roughly the same rate, the short-term productivity decline is explained by the initial increase in the capital-output factor. Following the reform, real GDP declines slowly to its new steady state, while the TFP factor increases by 15.2 percent from its low point of 95.6 (or 10.1 percent above its initial steady state level). This productivity gain is mainly driven by the rapid decline in the capital-output factor and the convergence of the capital-labor ratio (not shown in the graph) to its Pareto-optimal level.

The inefficiencies apparent in these transition paths leading up to the implementation of the reform imply that productivity gains will be less pronounced the shorter the interval between the announcement and the implementation of the reform. However, with fewer inefficiencies, the consumer will be better off in terms of welfare (see Table 5.7).

Figure 5.2: Growth Accounting, Output Subsidy Case

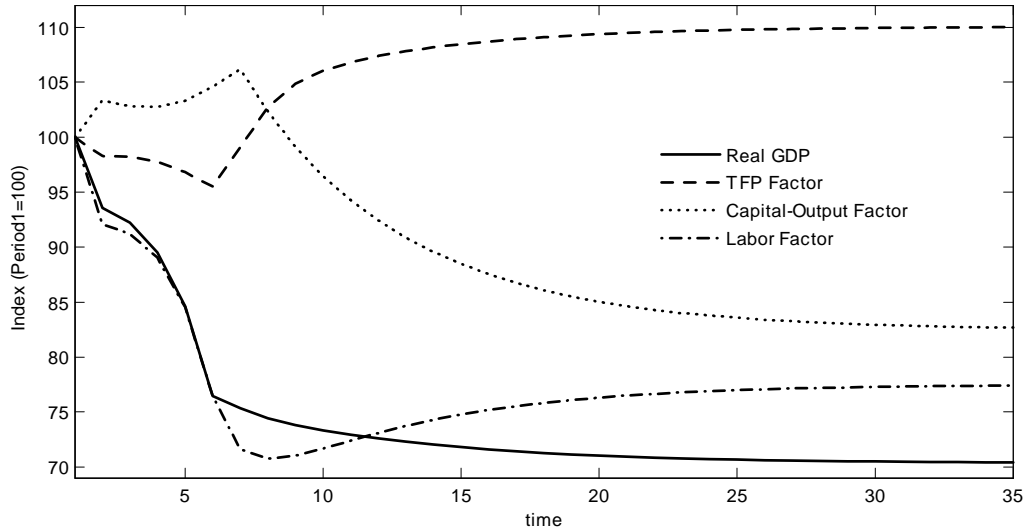


Table 5.7: Comparison for Various Time Lengths Before Reform

Reform	Percentage change with subsidy elimination		
	<i>LRI</i>	<i>LCE</i>	<i>Measured TFP</i>
$t = 1$	3.80	10.70	4.24
$t = 5$	3.30	9.60	6.09
$t = 15$	2.40	6.10	6.12

5.6 Conclusions

We develop a simple dynamic general equilibrium model with firm-level heterogeneity and entry and exit and a calibration method to analyze the effects of operating, output, input, and interest rate subsidies on welfare, real GDP, TFP, ect. We also clearly specify our measurement of these statistics. For the simulation, we compute steady states with and without subsidies. We then compute the equilibrium transition paths between steady states. A caveat to our analysis is that it is less applicable to sectors in which fixed costs of operating are unimportant.

There are five key results from the simulations analysis. First, it is optimal for inefficient firms to operate at lower subsidy levels, in terms of percent of real GDP, the more directly the subsidy impacts profits, and thus the value of the firms. Therefore, the threshold subsidy level as a percent of real GDP for the inefficient firms to operate in order of smallest to largest is operating,

output, and input subsidy. There is not a reasonable level for the interest rate subsidy where the inefficient firms operate. Second, welfare is sensitive to whether the full transition path is taken into account. For the operating, output, and interest rate subsidies, the steady-state comparison shows a decline in real income. However, the lifetime real income and lifetime consumption equivalents show substantial gains over the full transition path. Third, for all four cases, the removal of the subsidy results in a decline in productivity in the short-run, but substantial long-run TFP gains. The removal of a 13.3 percent output subsidy indicates that the reallocation of resource from low- to high-productivity firms accounts for 0.7 percent of the TFP gain, while the adjustment in the scale of the firms augments productivity by 3.2 percent. Fourth, the representative firm model understates productivity gains by a factor of 2.7 relative to the heterogeneous firms model for an output subsidy of 15 percent. Also, an operating subsidy is non-distortionary in a model with a representative firm, and to fully quantify the distortions from this subsidy, we must consider the model with firm heterogeneity. Fifth, productivity effects are smaller while welfare impacts are more pronounced the shorter the interval between the announcement and implementation of the reform.

Given our results, income (decoupled) subsidies, as pursued by the United State and European Union, continue to distort the agriculture sector by causing adverse effects on measured TFP and welfare. In fact, because inefficient firms find it optimal to operate at a lower subsidy level, a decoupled subsidy that is equal to the same percent of real GDP as an output or input subsidy will lead to larger distortions in measured TFP and welfare than those caused by an output or input subsidy. Thus, claiming decoupled subsidies is non-distortionary is not valid, and therefore eliminating all agricultural subsidies is the most efficient policy approach as undertaken by New Zealand.

5.7 Appendix

This appendix has two sections. Section 5.7.1 provides an algorithm for calculating the steady state. Section 5.7.2 presents an algorithm for calculating the transition path between two steady

states. Each involves computing the solution to a system of nonlinear equations using Newton's (or a similar) method. Newton's method requires continuous first derivatives. As a result, we need an approximation of (5.8). We use a standard Heaviside step function:

$$\iota_t(z) = \frac{1}{2} + \frac{1}{\pi} \tan^{-1} \left(\frac{\pi_t(z) + (1/(1+i_{t+1})) \sum_{z'} v_{t+1}(z) q(z, z')}{\varepsilon} \right), \quad (5.45)$$

where ε is small.

5.7.1 Algorithm for Calculating the Steady State

To calculate the steady state, we use the following algorithm. (Where equations are referenced, we are referring to the steady-state versions in which t is eliminated.)

1. Solve for i using (5.4).
2. Solve for r using (5.23).
3. Guess L^s , C , E , and w .
4. Solve for $k(z)$, $l(z)$, and $x(z)$ using the profit-maximization conditions

$$\nu(1 + \sigma^y) z^{1-\nu} F_k(k(z), l(z), x(z))^{\nu-1} = r \quad (5.46)$$

$$\nu(1 + \sigma^y) z^{1-\nu} F_l(k(z), l(z), x(z))^{\nu-1} = w \quad (5.47)$$

$$\nu(1 + \sigma^y) z^{1-\nu} F_x(k(z), l(z), x(z))^{\nu-1} = 1 - \sigma^x. \quad (5.48)$$

5. Calculate $y(z)$ using (5.5).
6. Calculate $\pi(z)$ using (5.6).
7. Use value function iteration to solve for $v(z)$, as given by (5.7).
8. Calculate $\iota(z)$ using (5.45).
9. Solve for $m(z)$ using (5.9).
10. Calculate Y , L^p , K , X , Π , and M using (5.10)–(5.15).

11. Calculate A using (5.19).
12. Calculate T using (5.25).
13. Solve for I using (5.18).
14. If (5.2), (5.3), (5.19), (5.24), and (5.27) hold, stop. If not, go back to step 3.

By Walras's law, (5.26) also holds (approximately).

5.7.2 Algorithm to Calculate the Transition Dynamics

To calculate the equilibrium transition path between two steady states, we use the following algorithm. We assume that the economy is in the initial steady state in period 0 and in the final steady state in period $T + 1$, where T is large. Because the non-negativity constraints may bind, we approximate the no-arbitrage conditions (5.23) and (5.24) by

$$r_{t+1} - \delta + \theta \min\{I_t, 0\}^2 = i_{t+1} \quad (5.49)$$

$$w_t f_e + \theta \min\{E_t, 0\}^2 = \frac{1}{1 + i_{t+1}} \sum_z v_{t+1}(z) g(z), \quad (5.50)$$

where θ is large. We take the values of K_1 , $m_1(z)$, and i_1 from the initial steady state. Any values from periods $t = T + 1, T + 2, \dots$ are taken from the final steady state.

1. Guess $\{L_t^s, C_t, E_t, w_t, r_t\}_{t=1}^T$ and $\{K_t, i_t\}_{t=2}^T$.
2. Solve for $\{k_t(z), l_t(z), x_t(z)\}_{t=1}^T$ using the profit-maximization conditions

$$\nu(1 + \sigma_t^y) z^{1-\nu} F_k(k_t(z), l_t(z), x_t(z))^{\nu-1} = r_t \quad (5.51)$$

$$\nu(1 + \sigma_t^y) z^{1-\nu} F_l(k_t(z), l_t(z), x_t(z))^{\nu-1} = w_t \quad (5.52)$$

$$\nu(1 + \sigma_t^y) z^{1-\nu} F_x(k_t(z), l_t(z), x_t(z))^{\nu-1} = 1 - \sigma_t^x. \quad (5.53)$$

3. Calculate $\{y_t(z)\}_{t=1}^T$ using (5.5).
4. Calculate $\{\pi_t(z)\}_{t=1}^T$ using (5.6).

5. Use backward induction to solve for $\{v_t(z)\}_{t=1}^T$, as given by (5.7).
6. Calculate $\{\iota_t(z)\}_{t=1}^T$ using (5.45).
7. Calculate $\{m_t(z)\}_{t=2}^T$ using (5.9).
8. Calculate $\{Y_t, L_t^p, K_t, X_t, \Pi_t, M_t\}_{t=1}^T$ using (5.10)–(5.15).
9. Calculate $\{T_t\}_{t=1}^T$ using (5.25).
10. If (5.2) holds for $t = 1, 2, \dots, T$, (5.3) holds for $t = 1, 2, \dots, T$, (5.19) holds for $t = 1, 2, \dots, T$, (5.24), and (5.27) hold, stop. If not, go back to step 1.

By Walras's law, (5.26) also holds (approximately).

Bibliography

- Appelbaum, E. (1982). The estimation of the degree of oligopoly power. *Journal of Econometrics* 19(2-3), 287 – 299.
- Arnade, C., D. Pick, and M. Gopinath (1998). Testing oligopoly power in domestic and export markets. *Applied Economics* 30, 753–760.
- Baldwin, R. and P. Krugman (1988). Industrial policy and international competition in wide-bodied jet aircraft. In *Trade policy issues and empirical analysis*, pp. 45–78. University of Chicago Press.
- Bettendorf, L. and F. Verboven (2000). Incomplete transmission of coffee bean prices: Evidence from the netherlands. *European Review of Agricultural Economics* 27(1), 1–16.
- Brander, J. and P. Krugman (1983). A ‘reciprocal dumping’ model of international trade. *Journal of International Economics* 15(3-4), 313 – 321.
- Brander, J. A. (1981). Intra-industry trade in identical commodities. *Journal of International Economics* 11(1), 1–14.
- Brander, J. A. and B. J. Spencer (1985). Export subsidies and international market share rivalry. *Journal of International Economics* 18(1-2), 83 – 100.
- Bresnahan, T. F. (1982). The oligopoly solution concept is identified. *Economics Letters* 10(1-2), 87–92.
- Bresnahan, T. F. (1989). Chapter 17 empirical studies of industries with market power. In R. Schmalensee and R. Willig (Eds.), *Handbook of Industrial Organization*, Volume 2, pp. 1011 – 1057. Elsevier.
- Brock, W. A. (1972). On models of expectations that arise from maximizing behavior of economic agents over time. *Journal of Economic Theory* 5(3), 348 – 376.
- Brown, M. G. (2010). European demand for orange juice. Florida Department of Citrus. Research Paper: 2010-5.
- Brown, M. G., T. H. Spreen, and J.-Y. Lee (2004). Impacts on U.S. prices of reducing orange juice tariffs in major world markets. *Journal of Food Distribution Research* 35(2), 26–33.
- Buera, F., B. Moll, and Y. Shin (2013). Well-intended policies. *Review of Economic Dynamics* 16(1), 216–230.
- Bureau of Labor Statistics (2012). Databases, Tables and Calculators by Subject. <http://www.bls.gov/data>.

- Buschena, D. E. and J. M. Perloff (1991). The creation of dominant firm market power in the coconut oil export market. *American Journal of Agricultural Economics* 73(4), 1000–1008.
- Chu, T. (2003). Exit barriers and productivity stagnation. Manuscript, University of Hawaii.
- Da Rocha, J. and P. Pujolas (2011). Policy distortions and aggregate productivity: The role of idiosyncratic shocks. *The BE Journal of Macroeconomics* 11(1).
- Davis, A., M. Gunderson, M. Brown, and L. House (2008). The effect demographics have on the demand for orange juice. Southern Agricultural Economics Association Annual Meeting, Dallas, TX.
- Dick, A. R. (1993). Strategic trade policy and welfare: The empirical consequences of cross-ownership. *Journal of International Economics* 35, 227–249.
- Dixit, A. and J. Stiglitz (1977). Monopolistic competition and optimum product diversity. *The American Economic Review* 67(3), 297–308.
- Eaton, J. and G. Grossman (1986). Optimal trade and industrial policy under oligopoly. *Quarterly Journal of Economics* 101, 383–406.
- Economic Research Service (2012a). Food Consumption and Nutrient Intakes. <http://www.ers.usda.gov/data/foodconsumption>.
- Economic Research Service (2012b). Fruit and Tree Nut Yearbook. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1377>.
- Environmental Working Group (2011). 2011 farm subsidy database. <http://farm.ewg.org/progdetail.php?fips=00000>.
- Evans, L., A. Grimes, B. Wilkinson, and D. Teece (1996). Economic reform in New Zealand 1984-95: The pursuit of efficiency. *Journal of Economic Literature* 34(4), pp. 1856–1902.
- Fattal, R. N. (2012). Entry, exit and misallocation frictions. Manuscript, International Monetary Fund.
- Femenia, F., A. Gohin, and A. Carpentier (2010). The decoupling of farm programs: Revisiting the wealth effect. *American Journal of Agricultural Economics* 92(3), 836–848.
- Flam, H. and E. Helpman (1987). Industrial policy under monopolistic competition. *Journal of International Economics* 22, 79–102.
- Florida Department of Agriculture and Consumer Services (2012). Orange processors and volume in boxes. Division of Fruit and Vegetable Inspection.
- Florida Department of Citrus (2012). Market research, Nielsen Topline Sales: 4-week period. <http://www.fdocgrower.com/economics/market-research/nielsen-sales-four-week-period/>.
- Food and Agricultural Organization (2011). Faostat. <http://faostat.fao.org/default.aspx>.

- Food and Agricultural Organization (2012). Faostat. <http://faostat.fao.org/default.aspx>.
- Foreign Agricultural Service (2012). Global agricultural information network. <http://gain.fas.usda.gov/Pages/Default.aspx>.
- Gourio, F. and J. Miao (2011). Transitional dynamics of dividend and capital gains tax cuts. *Review of Economic Dynamics* 14(2), 368–383.
- Grossman, G. and D. Rogoff (Eds.) (1995). *Handbook of International Economics, Vol III*. Amsterdam: North-Holland.
- Guner, N., G. Ventura, and X. Yi (2008). Macroeconomic implications of size-dependent policies. *Review of Economic Dynamics* 11(4), 721–744.
- Hart, E. (2004). The effects of Florida's brasil-based processors on the political debate over the U.S. orange juice tariff. The Fletcher School of Law and Diplomacy, Tufts University.
- Hayashi, F. and E. C. Prescott (2002). The 1990s in Japan: A lost decade. *Review of Economic Dynamics* 5(1), 206 – 235.
- Hopenhayn, H. and R. Rogerson (1993). Job turnover and policy evaluation: A general equilibrium analysis. *Journal of Political Economy* 101(5), pp. 915–938.
- Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica* 60(5), pp. 1127–1150.
- Huang, S. and F. Gale (2006). China's rising fruit and vegetable exports challenge U.S. industry. USDA, Economic Research Service, FTA-320-01.
- International Labour Organization (2011). Laborsta internet. <http://laborsta.ilo.org/default.html>.
- International Monetary Fund (2011). World economic and financial surveys, world economic outlook database. <http://www.imf.org/external/pubs/ft/weo/2011/01/weodata/index.aspx>.
- Jovanovic, B. (1982). Selection and the evolution of industry. *Econometrica* 50(3), pp. 649–670.
- Kehoe, T. J. and E. C. Prescott (Eds.) (2007). *Great Depressions of the Twentieth Century*. Research Department, Federal Reserve Bank of Minneapolis.
- Klepper, G. (1990). Entry into the market for large transport aircraft. *European Economic Review* 34, 775–803.
- Krugman, P. and A. Smith (Eds.) (1994). *Empirical Studies of Strategic Trade Policies*. Chicago and London: University of Chicago Press.
- Krugman, P. R. (1979). Increasing returns, monopolistic competition, and international trade. *Journal of International Economics* 9(4), 469 – 479.
- Krugman, P. R. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review* 70(5), 950–959.

- Lancaster, K. (1980). Intra-industry trade under perfect monopolistic competition. *Journal of International Economics* 10(2), 151 – 175.
- LaVigne, A. W. (2003, November). Ftaa keep tariffs on imported orange juice.
- Lavoie, N. (2005). Price discrimination in the context of vertical differentiation: An application to canadian wheat exports. *American Journal of Agricultural Economics* 87(4), 835–854.
- Lucas, Robert E., J. (1978). On the size distribution of business firms. *The Bell Journal of Economics* 9(2), pp. 508–523.
- Lucas, Robert E., J. and E. C. Prescott (1971). Investment under uncertainty. *Econometrica* 39(5), pp. 659–681.
- McCracken, V. A., P. Tansuhaj, A. D. O'Rourke, and K. Walter (1991). Strategies for U.S. apple exporting firms. *Journal of Food Distribution Research* 22(2), 63–75.
- Mendes, D. M. (2011). Gain report: Eu27 citrus annual. <http://gain.fas.usda.gov>.
- National Bureau of Statistics of China (2011). Stastical data. China Statistical Yearbook, <http://www.stats.gov.cn/english/statisticaldata/yearlydata/>.
- Nevo, A. (1998). Identification of the oligopoly solution concept in a differentiated-products industry. *Economic Letters* 59, 391–395.
- Pakes, A. and R. Ericson (1998). Empirical implications of alternative models of firm dynamics. *Journal of Economic Theory* 79(1), 1–45.
- Pick, D. H. and T. A. Park (1991). The competitive structure of u.s. agricultural exports. *American Journal of Agricultural Economics* 73(1), 133–141.
- Porter, R. H. (1983). A study of cartel stability: The joint executive committee, 1880-1886. *The Bell Journal of Economics* 14(2), 301–314.
- Restuccia, D. and R. Rogerson (2008). Policy distortions and aggregate productivity with heterogeneous establishments. *Review of Economic Dynamics* 11(4), 707 – 720.
- Russo, C., R. E. Goodhue, and R. J. Sexton (2011). Agricultural support policies in imperfectly competitive markets: Why market power matters in policy design. *American Journal of Agricultural Economics* 93(5), 1328–1340.
- Sanchez, J. and W. Bugang (2006). China: Fresh diciduous fruits; annual 2006. USDA, Foreign Agricultural Service, GAIN Report Number: CH6078.
- Sexton, R. J., I. Sheldon, S. McCorriston, and H. Wang (2007). Agricultural trade liberalization and economic development: the role of downstream market power. *Agricultural Economics* 36(2), 253–270.
- Sheldon, I. and R. Sperling (2003). Estimating the extent of imperfect competition in the food industry: What have we learned? *Journal of Agricultural Economics* 54(1), 89–108.

- Smith, V. L. (1974). Optimal costly firm entry in general equilibrium. *Journal of Economic Theory* 9(4), 397 – 417.
- Spencer, B. J. and J. A. Brander (2008). strategic Trade Policy. In S. N. Durlauf and L. E. Blume (Eds.), *The New Palgrave Dictionary of Economics*. Basingstoke: Palgrave Macmillan.
- Spreen, T. and W. Fernandes (2000). Consolidation in the Florida citrus processing industry. *Citrus industry* 81(10), 23–24.
- Spreen, T. H., C. Brewster, and M. G. Brown (2003). The Free Trade Area of the Americas and the market for processed orange products. *Journal of Agricultural and Applied Economics* 35(1), 107–126.
- The Economist (2010). The China-ASEAN free-trade agreement: Ajar for business.
- The World Bank (2011). World development indicators database.
<http://data.worldbank.org/data-catalog/world-development-indicators>.
- The World Bank (2012). Trade, production and protection database, 1976-2004.
<http://econ.worldbank.org/programs/trade>.
- U.S. Apple Association (2010). Chinese fresh apple imports.
<http://farm.ewg.org/progdetail.php?fips=00000>.
- U.S. Census Bureau (2011). Foreign Trade Statistics.
<http://www.census.gov/foreign-trade/statistics/index.html>.
- U.S. Census Bureau (2012). Foreign Trade Statistics.
<http://www.census.gov/foreign-trade/statistics/index.html>.
- U.S. International Trade Commission (2006). Certain orange juice from Brazil. Investigation No.731-TA-1089. Publication 3838.
- U.S. International Trade Commission (2010). Apples: Industry and trade summary. USITC Publication ITS-04.
- U.S. International Trade Commission (2011). China's agricultural trade: Competitive conditions and effects on U.S. exports. USITC Publication 4219.
- USDA (2011). Quick stats. National Agricultural Statistics Service, <http://www.nass.usda.gov>.
- Wade, M. A., C. C. Ramos, and E. M. Neves (2001). A comparative analysis of citrus costs and returns, 1980-2000: Florida, USA and Sao Paulo, Brazil. WORLD FOOD AND AGRIBUSINESS SYMPOSIUM.
- Wang, H., Q. Xiang, and T. Reardon (2006). Market power and supply shocks: Evidence from the orange juice market. Staff Paper 2006-02.
- Wheat, D. (2010). China's apple exports face hurdles.
<http://www.capitalpress.com/nation/djw-chinaANALYS-101510-w-Todd-Fryhover-mug>.

- World Trade Organization (2002). WTO negotiations concerning the WTO agreement on 45 subsidies and countervailing measures - proposal by the European communities. November 21, catalogue record TN/RL/W/30.
- World Trade Organization (2011). Tariff Analysis Online.
<http://tariffanalysis.wto.org/default.aspx>.
- World Trade Organization (2012). Tariff Analysis Online.
<http://tariffanalysis.wto.org/default.aspx>.
- Yerger, D. B. (1996). Testing for market power in multi-product industries across multiple export markets. *Southern Economic Journal* 62(4), 938–956.
- Zhan, X., H. Qiu, and Z. Huang (2009). Linking small scale farmers in China with the international markets: A case of apple export chains. *Journal of Food Distribution Research* 12(3), 89–110.