A STRUCTURAL MODEL OF THE INTERNATIONAL COFFEE SECTOR: AN ECONOMETRIC INVESTIGATION

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by

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

A STRUCTURAL MODEL OF THE INTERNATIONAL COFFEE SECTOR:

AN ECONOMETRIC INVESTIGATION

Robert Dale Maltsbarger

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ABSTRACT

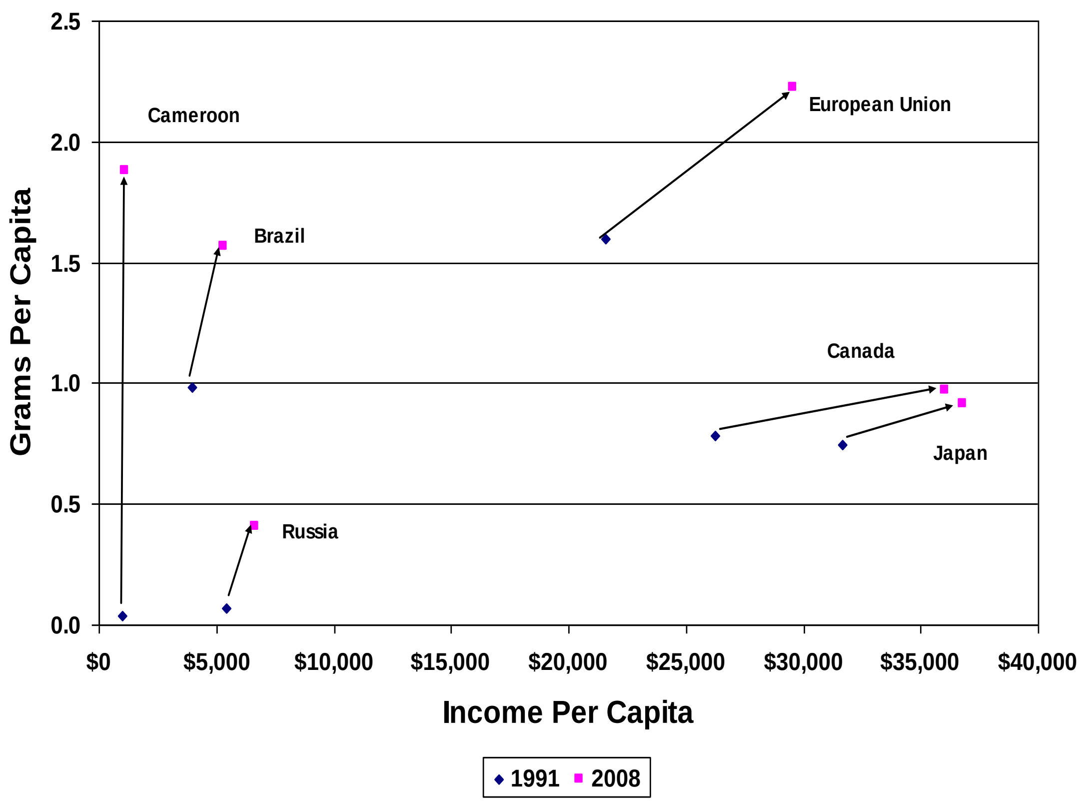
The primary objective of this research was to build an econometric model of the international coffee sector that could be used to simulate alternative scenarios including macroeconomic changes, potential technological advancements, policy changes and in-country growing season impacts. The commodity coverage of the study included green coffee production and consumption of coffee at the combined roasted and soluble level. Specific country coverage included Brazil, Colombia, the European Union, Honduras, India, Indonesia, Japan, Mexico, the United States and Vietnam. An additional twenty-four individual countries and five other regional aggregates were constructed to capture the rest of the world, but were considered exogenous for the scope of this project.

In total, 130 structural equations were estimated. Given structural equations and corresponding identities, the total system represents 196 equations and approximately 450 data observations per year using annual data sets on a crop year basis. Following the estimation process the model was historically simulated from 1995 to 2009 and tested using impact analysis and shocking the model with results compared to a baseline projection. The historical tests and projection simulations were an iterative process. In the final iteration the model performed well and solved to a reasonable solution.

CHAPTER 1 INTRODUCTION

Coffee is a historically interesting and dynamic sector in agriculture. Unlike many other commodities, coffee's role is not so much as a player in fulfilling caloric needs, but instead provides the means to create a beverage that has crossed time and spatial boundaries to help perk up countless individuals to meet the challenges of their daily grind. There are limited analyses available at the scale that compares to the magnitude of this study, which presents a global perspective on underlying structural relationships. With the current void, this thesis seeks to fill the void by developing a comprehensive international econometric model of the coffee sector that will be added into a system of global econometric models developed and maintained by IHS Global Insight for quarterly long-term forecasting of the agricultural sector including shorter-term market analysis.

An important aspect to consider is the effects of global income growth especially in developing, or emerging countries, which make up all the primary exporting countries for coffee. In many developing countries income per capita has or is beginning to reach levels where food and beverage purchases have become consistently more affordable. Having over 80 percent of the world's population in developing and emerging countries allows that even marginal increases in per capita consumption can lead to significant changes in aggregate demand. In order to supply the growth in coffee demand and maintain relative prices over time, production expansion from either expanded area or increased yields become increasingly important. Figure 1-1 below illustrates the Engel curve for the consumption of coffee. The chart displays the change in income per capita from 1991 to 2008 across several countries and displays out Engel's law of declining income elasticity as incomes grow. One point of interest is the high level of responsiveness of per capita green coffee consumption at income levels below $9,000 per capita. According to IHS Global Insight's February 2011 estimates over two-thirds of countries have income levels below $9,000 with over half of those countries estimated to average income per capita growth over 3 percent per year across the next ten years. The Engel curve suggests that this type of income growth will help poise the coffee sector for demand expansion across the next several years.



Source: USDA/FAS PSD 2010 and IHS Global Insight February 2011 estimates.

Figure 1-1 Per capita consumption of coffee and income in 1991 and 2008.

The Problem Statement

An effectively functioning rigorous, methodical, global quantitative model works to assist in the understanding of the dynamics of the coffee sector. It becomes imperative that agricultural industry players as well as policy makers comprehend future impacts of policy decisions on prices, supply and demand at both the global and domestic levels. Some important issues that will need to be addressed by the coffee sector include the current round of the World Trade Organization (WTO) negotiations, the future of trade policies, the shift in emphasis of the International Coffee Organization to a marketing role, developments in yield growth including more productive hybrids and/or genetically modified varieties and the macroeconomic impact of increased per capita income into the future on consumption. Having a well structured and rigorously tested econometric model that is designed to address these and other issues provides an excellent tool for assessing quantitative impacts of differing alternatives.

Much of the existing literature covering econometric analysis of the coffee industry falls into two major categories:

1) Global models with few equations and limited analytical rigor, and
2) Price models that focus on relationships between spot and futures prices among different coffees or a selected country.

The resulting analyses from either of these approaches provide limited insight about the interrelationships of supply, demand and producer prices on the industry as a whole and the underlying relationships across several countries. With the limitations of previous research, policies were not developed with appropriate theoretical specification, adequate country coverage, and a reasonable understanding of the impact on in-country producer prices within the sector. The size of the coffee sector including the large number of developing, exporting countries has been a major hurtle that has not been adequately crossed. With the abundant availability of current software applications and hardware processing speeds the capability to create a transparent large scale model is much more manageable than it was even within that last two decades. It is also significantly easier to maintain, update and run a large scale model on a quarterly basis. This ability has become increasingly important under the current dynamic and volatile commodity price environment in order to incorporate fundamental shifts in supply expectations that are inherent in agricultural commodity production. The magnitude of this model is meant to be similar to other partial equilibrium models maintained by organizations such as the Food and Agricultural Policy Research Institute (FAPRI), the Food Agricultural Organization (FAO) and IHS Global Insight. The primary focus of this thesis is to develop a theoretically consistent and rigorously tested partial equilibrium model of the global coffee sector.

Objectives of the Study

The primary objective of this study is to build a rigorous econometric model of the international coffee sector that can be applied to the simulation of alternative scenarios affecting supply and/or demand from factors such as impacts from technology implementation, macroeconomic developments, policy changes and in-country growing season impacts facing the coffee sector. This research is by design more granular than previous coffee models in that it emphasizes the global interrelationships of supply and demand across multiple countries and its effect on producer prices at the international level. Coverage is expanded from previous models to include multiple individual country breakouts of major consumers as well as producers and agricultural policies, including value-added taxes and trade policies, which are incorporated as policy levers where applicable.

Several steps were necessary to achieve the primary objective of building the econometric model. The first step was a thorough quantification of supply and demand for coffee by country and/or region. Next, the agricultural trade policies for each country were carefully documented. Data were then collected on supply, demand and prices and followed up with evaluations across sources for consistency. A literature review of previous econometric models including other coffee research with a focus on model specifications and resultant elasticities was performed. Based on the background research the theoretical specifications for the econometric model was developed. Since most steps overlapped, this was the result of a concurrent exploratory approach.

Once the theoretical development was complete, the second priority was to specify and estimate the equations for the model. Various estimation techniques were considered with the ordinary least squares method of multiple regression ending as the primary method of estimation discovery. Estimation results were evaluated for consistency within a priori expectations, elasticities from other studies, performance under simulation and generation of impact analysis.

The scope of this study is reflected in the number of countries and corresponding in-country producer prices. In order to help manage the magnitude, the principle producing and consuming countries received the majority of the attention. Country coverage includes: Brazil, Colombia, the European Union, Honduras, India, Indonesia, Japan, Mexico, the United States and Vietnam. An additional twenty-four individual countries and five other regional aggregates were constructed to capture the rest of the world, but are considered exogenous for the scope of this project. In total, 130 structural equations were estimated. Given structural equations and corresponding identities, the total system represents 196 equations and approximately 450 data observations per year, whereas this study is based on annual data sets on a crop year basis.

Organization of the Thesis

The thesis is organized into ten chapters. After review of the problem statement and thesis objectives in Chapter 1, Chapter 2 presents background information on the coffee industry. Starting with a brief history of coffee cultivation and moving next to detail the relevant cultivated coffees and followed by discussing the ecology and the development of coffee from the bean to the cup. Chapter 3 details various governmental policies affecting trade. Chapter 4 reviews the historical data available and alternative sources used to fill in data gaps. In Chapter 5, there is a focused look at the progression of theory in the literature that may be used to construct an international model of the coffee sector including documentation of elasticities found from previous research. Chapter 6 closes the background chapters with a discussion of included theoretical developments underlying select behavioral equations. This chapter presents theoretical structures using specific assumptions in order to develop the supply and demand system applicable to the coffee sector. Next, Chapter 7 builds on the theoretical chapters with structural specification and model closure concerns used in the actual coffee model. The chapter details the basic structural framework and walks through the model closure methods used in each country. Chapter 8 provides results of the estimated equations, their performance statistics and a discussion of estimation issues. Elasticities for each equation are reported as appropriate. Chapter 9 discusses the testing of the model performance and evaluates the magnitude and consistency of the model responses. Elasticities are detailed and were compared among countries and across regions. Impact analysis is then provided for three alternative scenarios for the system. Chapter 10 concludes the thesis with a discussion of the summary and conclusions of the study and provides insight into future improvements.

CHAPTER 2 BACKGROUND ON THE COFFEE INDUSTRY

This chapter provides a brief history of coffee, a breakout of the commercially relevant coffees including some biological and ecological characteristics of coffees as well as some detail about the roasting and making of coffee for the end result as a beverage. With the primary marketed coffees in mind, a brief profile of the growing conditions and differences between the primary cultivars are discussed plus the physical characteristics of coffee are examined.

The Story of Coffee

This section was taken as a direct quotation from "The Story of Coffee" as detailed by the International Coffee Organization (2010).

> The global spread of coffee growing and drinking began in the Horn of Africa, where, according to legend, coffee trees originated in the Ethiopian province of Kaffa. It is recorded that the fruit of the plant, known as coffee cherries, was eaten by slaves taken from present day Sudan into Yemen and Arabia through the great port of its day, Mocha. Coffee was certainly being cultivated in Yemen by the 15th century and probably much earlier. In an attempt to prevent its cultivation elsewhere, the Arabs imposed a ban on the export of fertile coffee beans, a restriction that was eventually circumvented in 1616 by the Dutch, who brought live coffee plants back to the Netherlands to be grown in greenhouses.
>
> Initially, the authorities in Yemen actively encouraged coffee drinking. The first coffeehouses or kaveh kanes opened in Mecca and quickly spread throughout the Arab world, thriving as places where chess was played, gossip was exchanged and singing, dancing and music were enjoyed. Nothing quite like this had existed before: a place where social and business life could be conducted in comfortable surroundings and where - for the price of a cup of coffee - anyone could venture. Perhaps predictably, the Arabian coffeehouse soon became a centre of political activity and was suppressed. Over the next few decades coffee and coffeehouses were banned numerous times but kept reappearing until

eventually an acceptable way out was found when a tax was introduced on both.

By the late 1600's the Dutch were growing coffee at Malabar in India and in 1699 took some plants to Batavia in Java, in what is now Indonesia. Within a few years the Dutch colonies had become the main suppliers of coffee to Europe, where coffee had first been brought by Venetian traders in 1615. This was a period when the two other globally significant hot beverages also appeared in Europe. Hot chocolate was the first, brought by the Spanish from the Americas to Spain in 1528; and tea, which was first sold in Europe in 1610. At first coffee was mainly sold by lemonade vendors and was believed to have medicinal qualities. The first European coffeehouse opened in Venice in 1683, with the most famous, Caffe Florian in Piazza San Marco, opening in 1720. It is still open for business today. The largest insurance market in the world, Lloyd's of London, began life as a coffeehouse. It was started in 1688 by Edward Lloyd, who prepared lists of the ships that his customers had insured.

The first literary reference to coffee being drunk in North America is from 1668 and, soon after, coffee houses were established in New York, Philadelphia, Boston and other towns. The Boston Tea Party Of 1773 was planned in a coffee house, the Green Dragon. Both the New York Stock Exchange and the Bank of New York started in coffeehouses in what is today known as Wall Street.

In 1720 a French naval officer named Gabriel Mathieu de Clieu, while on leave in Paris from his post in Martinique, acquired a coffee tree with the intention of taking it with him on the return voyage. With the plant secured in a glass case on deck to keep it warm and prevent damage from salt water, the journey proved eventful. As recorded in de Clieu's own journal, the ship was threatened by Tunisian pirates. There was a violent storm, during which the plant had to be tied down. A jealous fellow officer tried to sabotage the plant, resulting in a branch being torn off. When the ship was becalmed and drinking water rationed, De Clieu ensured the plant's survival by giving it most of his precious water. Finally, the ship arrived in Martinique and the coffee tree was re-planted at Preebear. It grew, and multiplied, and by 1726 the first harvest was ready. It is recorded that, by 1777, there were between 18 and 19 million coffee trees on Martinique, and the model for a new cash crop that could be grown in the New World was in place.

But it was the Dutch who first started the spread of the coffee plant in Central and South America, where today it reigns supreme as the main continental cash crop. Coffee first arrived in the Dutch colony of Surinam in 1718, to be followed by plantations in French Guyana and the first of many in Brazil in the state of Pará. In 1730 the British introduced coffee to

Jamaica, where today the most famous and expensive coffee in the world is grown in the Blue Mountains.

The 17th and 18th centuries saw the establishment across Brazil of vast sugar plantations or fazendas, owned by the country's elite. As sugar prices weakened in the 1820's, capital and labor migrated to the southeast in response to the expansion of coffee growing in the Paraiba Valley, where it had been introduced in 1774. By the beginning of the 1830's Brazil was the world's largest producer with some 600,000 bags a year, followed by Cuba, Java and Haiti, each with annual production of 350 to 450,000 bags. World production amounted to some 2.5 million bags per year.

The rapid expansion of production in Brazil and Java, among others, caused a significant decline in world prices. These bottomed out in the late 1840's, from which point a strong upward movement occurred, reaching its peak in the 1890's. During this latter period, due mainly to a lack of inland transport and manpower, Brazilian expansion slowed considerably. Meanwhile, the upward movement of prices encouraged the growth of coffee cultivation in other producing regions in the Americas such as Guatemala, Mexico, El Salvador and Colombia.

In Colombia, where coffee had been introduced by the Jesuits as early as 1723, civil strife and the inaccessibility of the best coffee-growing regions had hampered the growth of a coffee industry. Following the "Thousand Days War" of 1899 to 1903, the new peace saw Colombians turn to coffee as their salvation. While larger plantations, or haciendas, dominated the upper Magdalena river regions of Cundinamarca and Tolima, determined peasants staked new claims in the mountainous regions to the west, in Antioquia and Caldas. New railways, relying on coffee for profit, allowed more coffee to be grown and transported. The opening of the Panama Canal in 1914 permitted exports from Colombia's previously unreachable Pacific coast, with the port of Buenaventura assuming increasing importance.

In 1905 Colombia exported five hundred thousand bags of coffee; by 1915 exports had doubled. While Brazil desperately tried to control its overproduction, Colombian coffee became increasingly popular with American and European consumers. In 1914 Brazil supplied three-quarters of U.S. imports with 5.6 million bags, but by 1919 that figure had fallen to 4.3 million, while Colombia's share had risen from 687,000 to 915,000 bags. During the same period Central American exports to the U.S. had risen from 302,000 to 1.2 million bags.

In spite of political turmoil, social upheaval and economic vicissitude, the 20th century saw an essentially continuous rise in demand for coffee. U.S.

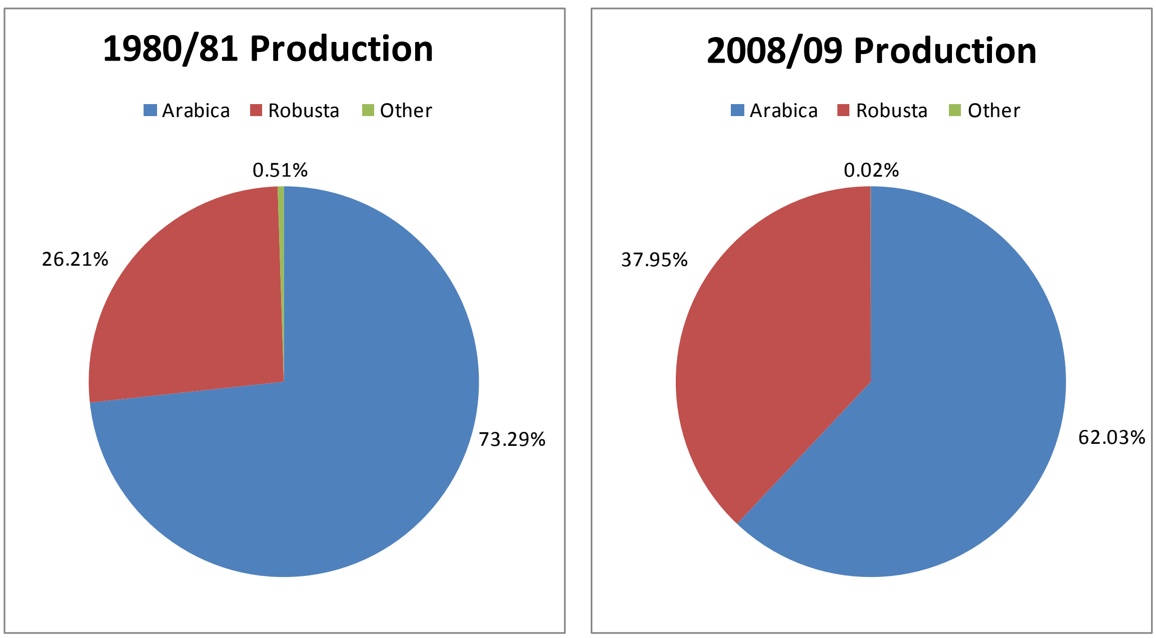
consumption continued to grow reaching a peak in 1946, when annual per capita consumption was 19.8 pounds, twice the figure in 1900. Especially during periods of high global prices, this steadily increasing demand lead to an expansion in production throughout the coffee-growing regions of the world. With the process of decolonization that began in the years following the Second World War, many newly independent nations in Africa, notably Uganda, Kenya, Rwanda and Burundi, found themselves in varying degrees dependent on coffee export revenue.

For US coffee drinkers, the country's wettest city, Seattle, has become synonymous with a new type of café culture, which, from its birth in the 1970s, swept the continent, dramatically improving the general quality of the beverage. This new found 'evangelism' for coffee has spread to the rest of the world, even to countries with great coffee traditions of their own, such as Italy, Germany, and Scandinavia, adding new converts to the pleasures of good coffee. Today it is possible to find good coffee in every major city of the world, from London to Sydney to Tokyo; we are drinking more and, more importantly, better coffee.

The importance of coffee to the world economy cannot be overstated. It is one of the most valuable primary products in world trade, in many years second in value only to oil as a source of foreign exchange to producing countries. Its cultivation, processing, trading, transportation and marketing provide employment for hundreds of millions of people worldwide. Coffee is crucial to the economies and politics of many developing countries; for many of the world's Least Developed Countries, exports of coffee account for more than 50 percent of their foreign exchange earnings. Coffee is a traded commodity on major futures and commodity exchanges, most importantly in London and New York.

Relevant Cultivated Coffees

As coffee cultivation has developed over the centuries the two species that are relevant to commerce are Coffea Arabica and Coffea Canephora (Robusta). These two coffee species including any sub-species are the top two major coffees as categorized by the United States Department of Agriculture (USDA) Production, Supply and Distribution (PSD) reporting system. PSD breaks out coffee production as Arabica production, Robusta production and other coffee production. In recent history Arabica coffees generally make from 60 to 70 percent of global coffee production, while Robusta coffees fill almost all of the rest of global coffee production. Any other commercially produced coffee falls into an other coffee production category, which make up less than one percent of production at the global level. PSD reports that other coffee production has declined historically from 0.51 percent in 1980/81 to 0.02 percent by the 2008/09 crop year as illustrated in Figure 2-1 below representing the insignificance of current commercial coffee production outside of the most common coffee species categories.



Source: USDA/FAS PSD, 2010
Figure 2-1 Percent of production by coffee type

With Arabica and Robusta coffees making up practically all of commercially produced coffee in the world the majority the information provided in this chapter focuses on these two species of coffees.

Coffee Botany

Coffee botany and classification has been studied for centuries and is well published in many sources with Wellman (1961), Coste (1992) and Clarke and Macrae (1985) all covering the history and classifications in great depth, whereas any additional granularity not covered in this study may be found in one of these listed sources or among many others. Even as authors admit that coffee had been studied prior to the 1700's, the original classification of the Coffea genus is attributed to C. Linnaeus around the middle of the 18th century. Coffea belongs to the botanical family Rubiaceae with the majority of genera composed of tropical trees and shrubs that growing in the lower storey of forests. The differing species within Coffea have very diverse appearances and behavior (Coste, 1992) from development to size, to differences in branch characteristics, leaves, flowers, fruits and beans. With the significant amount of variation within Coffea, some species can only be identified by certain specialized botanists (Coste, 1992). The International Coffee Organization (2010) also details that there are difficulties in the classification and even in the designation of plants as a true member of the Coffea genus due to the great amount of variation among plants and seeds. According to the ICO (2010), "all species of Coffea are woody, but they range from small shrubs to large trees over 10 meters tall; the leaves can be yellowish, dark green, bronze or tinged with purple. With this in mind it is not surprising that additional subdivisions took place to narrow the focus of coffee botany to the more relevant commercially produced coffees. Clarke and Macrae (1985) attribute Chevalier with subdividing the Coffea genus into four groups with Eucoffea being the one of interest because this group's first of five subdivisions includes Erythrocoffea, which contains both Arabica and Canephora (Robusta) species.

Arabica

Coffea Arabica is the species known for the longest time and is the most widespread throughout the world (Coste, 1992). The best known of the Arabica varieties are 'Typica' and 'Bourbon' but from these many different strains and cultivars have been developed, such as Caturra (Brazil, Colombia), Mundo Novo (Brazil), Tico (Central America), the dwarf San Ramon and the Jamaican Blue Mountain (ICO, 2010). The species is self fertilizing, or autogamous (Coste, 1992), whereas the average Arabica plant is a large woody bush with dark-green oval leaves (ICO, 2010). A concern of the Arabica species over the years has been its susceptibility to attack by pests and disease with resistance becoming a major goal for breeding programs. In general Arabicas are grown throughout Latin America in Central and East Africa, in India and to a lesser extent in Indonesia (Clark and Macrae, 1985). One uniqueness to Arabica is that it is genetically different to other coffee species in that it has four sets of chromosomes instead of two, whereas its fruits are oval maturing in 7 to 9 months usually containing two flat seeds (ICO, 2010).

Robusta

Robusta is a commonly accepted term for Coffea canephora attributed to the name of a widely grown variety of the species. Coffees of this species are widely grown in Africa and South-East Asia as well as being successfully cultivated in the Espirito Santo region of Brazil, where it is called conillon (Coste, 1992 and CEPEA, 2011). Compared with Arabica coffees, Robusta generally appears to be more vigorous and robust attributable in part to it being less vulnerable to diseases, specifically Hemileia vastatrix called coffee leaf rust (Coste, 1992 and Clarke and Macrae 1985). Robusta can take many shapes, but commonly it is a robust shrub or small tree growing up to 10 meters in height with a shallow root system with fruits that are rounded and take up to 11 months to mature producing oval seeds that are smaller than Arabicas (ICO, 2010). Robusta is cross fertilized, or self-sterile (Wellman, 1961 and Coste, 1992) producing many different varieties in the wild with two main forms being recognized: 1) Robusta – upright forms and 2) Nganda – spreading forms (ICO, 2010).

Comparison of the two most cultivated coffees		
	Arabica	**Robusta**
Date species described	1753	1895
Chromosomes (2n)	44	22
Time from flower to ripe cherry	9 months	10-11 months
Flowering	after rain	irregular
Ripe cherries	fall	stay
Yield (kg beans/ha)	1500-3000	2300-4000
Root system	deep	shallow
Optimum temperature (yearly average)	15-24° C	24-30° C
Optimal rainfall	1500-2000 mm	2000-3000 mm
Optimum altitude	1000-2000 m	0-700 m
Hemileia vastatrix	susceptible	resistant
Koleroga	susceptible	tolerant
Nematodes	susceptible	resistant
Tracheomycosis	resistant	susceptible
Coffee berry disease	susceptible	resistant
Caffeine content of beans	0.8-1.4%	1.7-4.0%
Shape of bean	flat	oval
Typical brew characteristics	acidity	bitterness, full
Body	average 1.2%	average 2.0%
Source: ICO, 2010		

Table 2-1 Comparison of the two most cultivated coffees

Ecology of Coffee

Geographically coffee is commercially grown only between the Tropic of Cancer, latitude of 25 degrees North and Tropic of Capricorn, latitude of 25 degrees South (Sivetz and Desrosier, 1979). The primary reason for this somewhat narrow band is that outside of this range there becomes an increasing opportunity for frost. The possibility of frost also limits coffee production in high altitudes. As was illustrated in Table 2-1 above the differences between Arabica and Robusta coffee increases the environments where coffee can be grown, also contributing to the limited competition for area between the two species as the optimal ecological conditions for each species has little overlap. Generally speaking Robusta coffees thrive in more humid, warmer zones and at lower altitudes than Arabicas (Sivetz and Desrosier, 1979). The ICO reports the ideal average temperatures and rainfall for Arabicas at 15 to 24 degrees Celsius with 1500 to 3000 mm of rain and Robustas at 24 to 30 degrees Celsius with 2000 to 3000 mm of rain (2010). The temperature concern for productivity within each species is different. Arabicas will suffer badly with temperatures above 30 degrees Celsius, whereas Robustas are much less adaptable to lower temperatures and its leaves and fruits do not withstand temperatures below +5 or +6 degrees Celsius, with the plant perishing well before the freezing point is even reached (Coste, 1992).

Coffee can grow in numerous types of soils, but texture and depth will determine the amount of supplementation the plants will need (Coste, 1992). The usual criteria for soil fertility can be expected i.e. the presence of an adequate supply of essential minerals, moisture and drainage (Sivetz and Desrosier, 1979). According to the ICO (2010), “all coffee needs good drainage, but it can grow on soils of different depths, pH and mineral content, given suitable applications of fertilizer." Ultimately, with the variation of cultivars among coffee species profitability will be determined in part by the soil type suited for the most productive variety grown within a specific region and the amount of supplementation that is necessary to support productive yields.

In its natural habitat, coffee can be found in shaded or semi-shaded situations such as clearings, secondary gallery forests and banks of water courses (Coste, 1992). Another interesting point is the effect of wind on coffee productivity. Hot and dry winds can cause leaves and young shoots to wilt retarding growth and reducing productivity (Coste, 1992). Attributable to the concerns with light and wind, wind-breaks and shade trees are sometimes planted, which may be economical in nature such as bananas or rubber trees in order to mimic the natural habitat of coffee (ICO, 2010). This practice is considered more traditional with a trend towards abandoning these practices as selective breeding is producing higher yielding cultivars that are capable of being cultivated intensively without shade thereby shifting land away from less economical wind-break or shade trees (Coste, 1992).

Physical Properties of Coffee

Coffee like all food products contain characteristics related to state, aspect or appearance including weight, volume, size, shape, color, solubility, moisture content, texture, etc. Depending on its stage in development and processing coffee's physical characteristics varies as detailed in Table 2-2 below. Also, size, shape and color are used to grade beans after they have been dried to an even moisture content for storage (ICO, 2010).

Physical Properties of Coffee		**Moisture Content of Coffee**	
Bulk density	**(kg/cu metre)**	**Moisture**	**Percent**
Red cherry	800	Fresh cherry	50
Wet green beans	800	Green bean	12.5
Dry beans or pergamino	400	Roasted coffee	7*
Light roast beans	370	Soluble powder	<4
Dark roast beans	290	*depending on humidity	
Coarse ground coffee	300		
Fine ground coffee	400		
Source: Sivetz and Desrosier, 1979 and ICO, 2010			

Table 2-2 Physical properties of coffee

From the Bean to the Cup

Planting

Propagation, Germination and Productive Life

Coffee species are commonly propagated by either seed or using routine forestry techniques such as cuttings or grafting (Coste, 1992) with the usual commercial practice to raise plants from seeds for Arabicas (Sivetz and Desrosier, 1979), while cuttings are restricted mostly for Robustas (Coste, 1992). When using seeds for propagation fruits are pulped by hand immediately after harvest and the seeds may then be planted immediately due to an absence of a dormancy period or can be dried for later use (Coste, 1992 and

ICO, 2010). In all cases it is recommended that the seeds should be stored in their parchment as this covering provides protection from outside agents, particularly excessive humidity (Coste, 1992). The germination rate if dried for later use declines rapidly as illustrated in Table 2-3. With proper storage dried coffee seeds may be used up to a year, and possibly longer.

Viability of seed from Coffea arabica at different ages

Age of seed in weeks	Percent germination of seed	Number of weeks to germinate after sowing
7	95	10.1
12	96	15.7
16	94	11.6
21	87	16.1
25	60	23.1
29	62	16.3
34	27	16.7
38	40	23.0
43	24	23.3
47	22	26.0
Source: Wellman, 1961		

Table 2-3 Viability of seed from C. Arabica at different ages

Germinating or pre-germinating the coffee seeds have become more common in order to evaluate seedlings or plantlets for vigor and uniformity as well as culling for twisted taproots prior to transplanting (Coste, 1992). One method spreads seeds across a sand bed and covers them with moist burlap bag sacks or straw until radicals emerge, while an alternative method mixes seeds with moist vermiculite or expanded polystyrene and kept in a polythene bag (ICO, 2010). The coffee seedlings whether grown in nursery beds or in polybags are transplanted into the coffee fields once they reach 20 to 40 centimeters.

Once established growing conditions play a significant role in the productive life of a coffee plant. The optimal growing conditions as previously described in the ecology section are largely dependent on coffee being a tropical plant. As frost is a large limiting factor for all coffees, commercially viable production is limited mostly between 25 degrees North and 25 degrees South latitudes. Within this range a number of factors impact productivity primarily based on the species of coffee and the ecology of where it is grown. Generally, coffee raised from seed will not begin flowering for about three years, and will not produce a good crop for four to six years (Ukers, 1922 and Coste, 1992). Coffee plants have a long lifespan, and when properly cultivated may live for 30, 40, 50 years or more with a coffee tree living to 100 years not being unusual (Coste, 1992). The problem is that even though coffee plants may have a long lifespan, they are not generally economically viable past 30 years, except in exceptional cases (Ukers, 1922). Also, dependent on the variety and local ecological conditions as well as farm practices, individual coffee plant's profitability generally falls between 15 to 25 years even under optimal conditions (Coste, 1992).

Harvesting Methods

Essential to producing the best quality of coffee is the timing of the harvest to ensure that the fruit is fully ripe. An indication of ripeness is the when the fruit called the coffee cherry turns a bright cherry-red color (Wellman, 1961). Coffee is primarily harvested by hand due to the fact that many plantations are grown in mountainous areas making the use of mechanical harvesting not possible (ICO, 2010). The primary exception to this rule is in parts of Brazil where relatively flat land and larger coffee field sizes provide more opportunity for mechanical harvests. Hand picking is a labor-intensive process where fruits are separated from the branches singly and collected in containers (Coste, 1992). Individual harvesters' yields are a direct result of their efficiency and the yield per tree. As much as 100 kg of cherries may be picked by an individual in a day, although the amount collected may not exceed 30 to 50 kg depending on harvesting conditions such as sparse fruiting and the timing of the season (Coste, 1992).

Harvesting when done by both machine and by hand is harvested either by strip picking or selective picking. When strip picking the entire crop is harvested at one time with all the cherries being stripped off of the branch (Coste, 1992). Selective picking includes only harvesting the ripe cherries picked individually. With this method pickers must rotate among the trees every 8 to 10 days. Due to the labor intensity of this method of picking it is more costly and used primarily for finer Arabicas (ICO, 2010). Once harvested, the crop is combined and taken to the next step in the process called field processing.

Field Processing

After harvesting coffee is then prepared for market. This step in the process to prepare coffee is called field processing. Field processing ultimately makes the coffee beans hard and dry and frees them from their covering (Wellman, 1961). According to the ICO (2010),

> Coffee beans are the seeds of fruits that resemble cherries, with a red skin (the exocarp) when ripe. Beneath the pulp (the mesocarp), each surrounded by a parchment-like covering (the endocarp), lie

two beans, flat side together. When the fruit is ripe a thin, slimy layer of mucilage surrounds the parchment. Underneath the parchment the beans are covered in another thinner membrane, the silver skin (the seed coat). Each cherry generally contains two coffee beans; if there is only one it assumes a rounder shape and is known as a peaberry. Coffee beans must be removed from the fruit and dried before they can be roasted; this can be done in two ways, known as the dry and the wet methods. When the process is complete the unroasted coffee beans are known as green coffee.

Dry Method

In the dry or natural method, the fruit is dried to about 12 percent moisture in the whole fruit form. Once dry, the outer layers are removed by hulling. This results in the commercial bean being obtained directly (Sivetz and Desrosier, 1979). Although, the dry method is simpler and cheaper, the resultant coffee bean is of poorer quality than the wet method. To assist in the drying process the cherry is left on the tree rather longer than the wet method, and is likely strip picked with foreign matter removed in the field prior to transportation to the drying ground. The drying ground is preferable smooth finished concrete, although a small farmer will often spread his cherries on strips of matting place on bare ground (Clarke and Macrae, 1985). It may take 3 weeks or more to reach the desired 12 percent moisture by this method.

The dry methods is used for about 90 percent of Arabica coffee produced in Brazil, most of the coffee produced in Ethiopia, Haiti and Paraguay, as well as for some Arabicas produced in India and Ecuador (ICO, 2010). Also, although almost all Robustas are processed by the dry method, there are exceptions in areas where the humidity is too high and it rains frequently during the harvest season (ICO, 2010).

Wet Method

In the wet or washed method, after a preliminary washing during which some inferior quality fruit may be separated by flotation, and stones, etc. removed through sinking (Clarke and Macrae, 1985), the ripe fruit is then squeezed in a pulping machine removing most of the outer soft pulp (fibrous fruit flesh), leaving a slippery exposed layer of mucilage (Sivetz and Desrosier, 1979). As the layer of mucilage cannot be readily dispersed with water, it is then removed by one of several various methods leaving the clean parchment layer. One popular method of removing the mucilage is through fermentation where the mucilage is degraded by natural enzymes and aided by yeasts or other bacteria that develop concurrently (Clarke and Macrae, 1985). Following the removal of all of the mucilage the coffee bean is then dried to about 12 percent moisture. Once it reaches the desired moisture content the thin yellowish parchment layer is removed by a hulling machine, and the commercial green coffee is the result (Sivetz and Desrosier, 1979).

The wet method is generally used for Arabica coffees, with the exception of those produced in Brazil and the Arabica producing countries as mentioned above, also the wet method is rarely used for Robustas (ICO, 2010).

The final stages in coffee processing in preparation for the market that are common to both wet and dry processing include additional cleaning, screening, sorting and grading operations, whereas electronic sorting machines may be implemented to remove defective beans that cannot be distinguished by the naked eye.

Processed coffee terminology			
Dry-processed coffee		**Wet-processed coffee**	
Before hulling	**Green coffee**	**After pulping**	**Green coffee**
Dry cherry	Unwashed coffee	Parchment coffee	Washed coffee
	Natural coffee		Plantation coffee
	Cherry coffee		
Source: ICO, 2010			

Table 2-4 Processed coffee terminology

The Roasting Process

The aromatic and flavor qualities of coffee do not become apparent until the green coffee beans have been exposed to high temperatures during pyrolysis, which is commonly called roasting (Coste, 1992). Depending on the degree of roast required green coffee beans will be heated between 185 degrees Celsius and 240 degrees Celsius for 12 to 15 minutes (Coste, 1992). As moisture is lost from the coffee bean an audible pop similar to popcorn occurs indicating that pyrolysis is taking place. During pyrolysis starches are converted into sugar, proteins are broken down (ICO, 2010). Once coffee beans have been roasted in whole bean form they will retain their characteristic flavor and aroma for almost a week in normal atmospheric conditions, and once ground, the coffee loses freshness within 2 to 3 days unless specially treated and packed (Clarke and Macrae, 1985). According to the ICO (2010), “roasting is one part art, one part science and several parts judgment.” As diverse as the coffee, processing and roasting may be, many sources agree that to obtain a good cup of coffee, not only quality coffee is required but also careful preparation (Coste, 1992).

Making Coffee

The challenge of coffee preparation is that no single method can be considered as "the best" way to make coffee. Coffee lovers are akin to wine lovers in that one person's favorite coffee may be poured out and considered as disgusting by another person. Personal preference combined with availability plays a role in choosing not only the type of coffee or roast, but the method of beverage preparation. Coffee preparation is in many cases "both a ritual and a practical necessity" (ICO, 2010). Coffee preparation and drinking varies greatly dependent upon the culture. As coffee has a long history many methods have been derived from both convenience and cup flavor. The ICO provides in depth detail about nine general methods to prepare a cup of coffee including: Arab or Turkish coffee, the filter method, the plunger/cafeteire, the jug, espresso and cappuccino, the Moka-Napoletana, the percolator, soluble (instant) coffee and flavored coffees (2010). These methods combined with numerous roasts, grinds, blends and variations in coffee cultivars provide exponential diversity in cup taste.

Cup Tasting

The market understands that the end result of flavor to the consumer is the ultimate measure of coffee quality. For this reason coffee is assessed at every level of its journey, especially from the point where the coffee is graded in the country of origin and when it is sold in the importing country (ICO, 2010). As part of this process "cupping" or cup tasting techniques are used by "cuppers" or tasters to evaluate coffee flavor and create a coffee profile (coffeeresearch.org, 2011). Cupping helps to evaluate minor differences in coffees across regions and around the world by tasting coffees side-by-side. Using established terminology basic attributes of aroma, flavor, body and acidity are established (ICO, 2010). Describing a sample of coffee may use terms such as "body, strength, rich, poor, acidic or acidity, strong, harsh, neutral, earthy, woody, rank, bitter, sour or sourish, foul, stinker, grassy, fruity, mellow, bitter, musty, greasy or muddy" (Coste, 1992). This process allows coffees to be evaluated for either defective coffee or to create coffee blends (coffeeresearch.org, 2011).

The cupping process as documented by the ICO (2010) is as follows:

> Once the beans have been assessed for their overall visual quality, they are roasted in a small laboratory roaster, immediately ground and infused in boiling water, the temperature of which is carefully controlled. The cupper *noses* the brew to experience its aroma, an integral step in the evaluation of the coffee's quality. After letting the coffee rest for several minutes, the cupper "breaks the crust" by pushing aside the grounds at the top of the cup. Again the coffee is nosed before the tasting begins.
>
> To taste the coffee, the cupper "slurps" a spoonful with a quick inhalation. The objective is to spray the coffee evenly over the cupper's taste buds, and then *weigh* it before spitting it out. Samples from a variety of batches and different beans are tasted daily. Coffees are not only analyzed this way for their inherent characteristics and flaws, but also for the purpose of blending different beans or determining the proper roast. An expert cupper can taste hundreds of samples of coffee a day and still taste the subtle differences between them.

Use of Coffee- Variety Comparison

Generally, Arabica coffee is considered a premium versus Robusta. This is largely attributed to the difference in the cupping of the two species. Robustas have lower cupping characteristics, thereby bringing lower prices on the market as it is widely considered an inferior product to Arabicas. Although, Robusta and Arabica have botanical, ecological and cup variation their uses overlap at the consumer level. This overlap can be seen as in many cases as both species will be used concurrently in the end product. A good deal of Robusta goes to the manufacture of instant, or soluble, coffees. Following this use is the integration of Robustas and Arabicas blended to together to make roasted and ground (R&G) coffees with about 25 percent of the blend being made up by Robustas (Sivetz and Desrosier, 1979). These R&G coffee blends are commercially produced and are indicative of what is offered at the grocer (Ken, 2009). Another aspect of these R&G coffees is that they will also be blended with about another 25 percent lower quality Arabicas likely including unwashed Brazils, which are not considered truly top quality beans (Sivetz and Desrosier, 1979). The justification for blending with Robustas and lower quality Arabicas into commercially packed R&G blends is that the manufacturer maintains profit margin by using lower quality coffees as filler, and the consumer accepts the lower cupping of such blends, because they are an inexpensive and convenient choice for coffee consumption (Ken, 2009). Another use of Robusta is to increase the caffeine content of a blend. For special or higher quality blends such as espressos, Robusta is commonly used to not only add caffeine content but also add a more bold and balanced taste (Ken, 2009). Outside of R&G or espresso blends, Arabicas are used to create exclusive gourmet or specialty blends including only Arabica species, or roasted and sold as whole beans (Coffee, 2011). The heavy use of blending of coffee species at the consumer level lends itself that although the market segregates the price level of the two species, prices intuitively move similar to each other as substitution between species and varieties within a species is common to create the end product.

CHAPTER 3 AGRICULTURE POLICY

This chapter summarizes the agricultural policies affecting coffee production and trade as a whole. Historical data on agricultural policies, especially in developing countries can be extremely difficult to find. The policy parameters are often pieced together over several different sources. Even with the tariff schedules laid out in the World Trade Organization's (WTO) database, countries have often used applied tariffs that were significantly lower than the agreed upon tariff bounds. Using the bound tariffs as the starting point where no other data are present provides a level tariff structure. However, when only a bound tariff is provided other sources were used to find a more reasonable applied tariff schedule. Direct and indirect domestic production subsidies may exist, but the focus of this policy review are on trade policies, which are more transparent. Most policy documentation and context was sourced and distilled from a combination of sources including the International Coffee Organization (ICO), the WTO, the Agricultural Market Access Database (AMAD), USDA Gain reports and articles from either the World Bank or the World Development an international journal.

To provide a good general understanding of the development of international trade policy for the coffee sector across the last fifty years it is necessary to discuss a brief history of the International Coffee Organization (ICO) and the evolution of the International Coffee Agreements (ICA's). The following provides an abstract of points of interest gleaned from a self published history from the ICO website (ICO, 2010). The ICO was established in 1963 at a conference convened by the United Nations in response to fluctuations in prices and supply and demand during the 1930s to the 1960s, which culminated in the enactment of the first ICA that was negotiated in 1962. This agreement was created by a Coffee Study Group, which came together as an extension of previous short-term agreements between producing countries in order to incorporate both exporting and importing nations to stabilize supply and support prices. The first two ICA's of 1962 and 1968 contained provisions for the enactment of a quota system where supplies of coffee in excess of consumer demand were withheld from the market. During both agreements provisions existed that limited production and promoted increased consumption. A problem arose in 1973 causing the quota system to collapse due to changes in supply and demand that caused prices to increase. The 1968 agreement was then extended twice with all economic provisions deleted until a new agreement was enacted in 1976. One of the largest changes for the 1976 ICA was that it allowed for the suspension of quotas if prices were high with a reintroduction if prices became too low. In conjunction with this agreement quotas were resumed in 1980. A fourth ICA entered into effect in 1983. This new agreement included the obligatory import and export quota system, thresholds for quota suspension and reintroduction dependent on price, carry-over stocks counting in each exporting country, a fund for promoting consumption as well as other provisions to coordinate national production policies. In 1989 the agreement was extended until 1991, although its quotas and controls, verification of stocks and production policies provisions were suspended with any activities associated with the Promotion Fund in a wind down mode. Following the 1991 extension the agreement was extended again in 1992 and 1993 as negotiations were not successful in completing an official new ICA. Finally, in 1994 a new ICA was established. With this version of the ICA there was a formalization of the dramatic shift in the influence of the ICO, which effectively took place with the suspension of the quota system in 1989. The 1994 ICA officially moved the ICO from negotiating quotas and controls to more of a source for compiling and disseminating information on the world coffee market also including educational and promotional activities. The changes in the ICO happened as a reflection of the global trend across many agricultural sectors toward more liberalization of markets, which was illustrated by the shift away from protectionism and stock holding to fewer and lower tariffs similar to actions of the time by the WTO. Since the 1994 ICA there have been two more iterations of the agreement with the 2007 ICA being current. Following the suspension of the last active quota system in 1989, the coffee market structure has remained for the most part more open with limited domestic price controls and import tariffs remaining mostly only in application among select exporting countries. The shift of the role of the ICO is illustrated below in Table 3.1.

Role shift of the International Coffee Organization pre and post 1989		
	ICA quota regime (1962-89)	**post ICA quota regime (1989-present)**
Entry barriers to trade	***Domestic trade and export:*** high barriers due to monopoly of marketing or politically set domestic trade quotas	***Domestic trade and export:*** first, decreased entry barriers due to liberalization; later, increased barriers following the strenghthening of international trader operations in producing countries
	International trade: increasing due to consolidation	***International Trade:*** increasing entry barriers in "fair-average-quality" market due to further consolidation and requirements set by roasters through SMI; decreasing in the specialty market due to fragmentation and the growing importance of e-commerce sales
Institutional framework	***Strong:*** international trade regulated by ICA's	***Weak:*** end of ICA; producing country cartels fail to set up effective quota or retention schemes
Source: Ponte 2002		

Table 3-1 Role shift of the ICO pre and post 1989

After the conclusion of the last active quota system that was suspended by the ICO in 1989, the liberalization of the international coffee sector was not automatic. The evolution was staggered dependent on the ability of select countries to transform from an almost thirty year system of price and stock holding controls to a more open market system of trade. Table 3.2 provides an example of the quickness of four of the exporting countries to integrate into a more liberalized trade format. Even though the switch was not automatic the majority of countries were able to shift trade policy into a more liberalized structure as documented below in the early to mid 1990s.

Following the transition to a more open or liberalized international coffee sector, trade policy is now constricting primarily to WTO agreed upon tariff schedules as documented in Table 3.3 with limited domestic support policies driven by less direct programs such as subsidized loan plans or promotional incentives such as branding initiatives. These types of policies are not included in this review as they are much less transparent and are more difficult to quantify into the structural econometric system placing them outside the scope of this study.

Outcome of the coffee sector liberalization					
	Reform Year	Change in the role of the parastal agency	Price control after the reform	Domestic marketing after the reform	Exporting after the reform
Brazil	1990	From price stabilization to industry supervision	None	Liberalized	Liberalized
Columbia	1995	Producer-dominated, reforms limited	Administered prices	Partly done by FNC*	Partly done by FNC*
India	1993	From state trading to industry supervision	None	Liberalized	Liberalized
Mexico	1996	From state trading to industry supervision	None	Liberalized	Liberalized
*Federacion National de Cafeteros de Columbia - producer association contracted by the government handling about half of all coffee sales					
Source: Krivonos, 2004					

Table 3-2 Outcome of the coffee sector liberalization

Trade policy parameters																
		1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Import Tariffs																
Brazil	Percent	.	.	13	13	13	13	13	10	10	10	10	10	10	10	10
Columbia	Percent		10	10	10	10	10	10	10	10	10	10	10	10	10	10
Honduras	Percent	.	.	15	15	15	15	15	15	13.8	13.8	13.8	13.8	13.8	13.8	13.8
India	Percent	.	12	12	12	12	12	12	12	10	10	10	10	10	10	10
Value Added Tax (VAT)	Percent	.	.	.	.	.	.	.	.	4	4	4	4	4	4	4
Indonesia	Percent	.	.	.	5	5	5	5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Mexico	Percent	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Vietnam	Percent	.	.	.	.	.	.	.	20	20	20	20	20	20	20	15
Source: International Coffee Organization, World Trade Organization, Agricultural Market Access Database or United States Department of Agriculture - Gain reports																

Table 3-3 Trade policy parameters

CHAPTER 4 THE DATA

The data that supports this thesis are a crucial element to the results and deserves its own evaluation. This chapter discusses the details of the sources of data and analyzes the data for consistency both within the data from each source and across sources. The chapter is organized around the two primary types of data used: supply and utilization data and price data.

Supply and Utilization Data

The number of and access to sources of supply and utilization have definitively improved since many of the older coffee models created in the 1950s and 1960s. The data are much quicker and easier to access. Many countries publish supply and utilization data with some degree of frequency, although the frequency and granularity of the data are unique to each individual country's preferences, units of measurement and marketing year. Specific to coffee, the International Coffee Organization (ICO) reports supply, demand, producer price and futures price data for most exporting and some importing countries. Other extensive sources of supply and demand data by country and commodity include the FAO and the Production, Supply and Disposition (PSD) of the United States Department of Agriculture (USDA). While all three of these are reasonable sources, a concern arises that depending on their application, each source may suffer from a number of challenges including one or all of the following: a lack of internal consistency, a lack of regular updates, insufficient granularity and/or a lack of consistent format over time. Another consideration of data sources outside of the three listed publications, primarily concerning private data sources is the expense to acquire and receive redistribution rights to proprietary data.

To address the challenges of any data source each of the three primary data sources listed above were evaluated for their frequency, granularity and consistency in order to accumulate the scope of data necessary in order to estimate detailed country equations. In order to provide the necessary data set needed a combination of all three data sources was used. Of the three sources the most consistent and regularly updated free source of global supply and demand information was the USDA's PSD estimates now maintained through the Foreign Agriculture Service. Supply and utilization data are updated biannually (twice a year) for green coffee. The data reported in PSD are based on official estimates from the particular country unless there appears to be significant errors in the country's official statistics. Internally, PSD is a mostly consistent data set with balanced supply and demand across most countries. The weakness provided by using PSD as the primary data source is the lack of granularity of attributes to estimate a complete structural model. PSD does not provide either price data or harvested area numbers for green coffee. Also, consumption data prior to 2004/05 are not reported for a number of countries. To remedy this weakness a combination of other sources was used. The secondary data source to fill in the gaps left by PSD was the International Coffee Organization (ICO). This data source provided necessary supply and utilization series to fill the historical gaps left by PSD as well as evaluate the consistency of the PSD datasets. The ICO updates statistical data on a monthly, quarterly and annual basis dependent upon the specific dataset. The final alternative for supply and utilization data was the FAO. This source was used to provide harvested area numbers not covered by other sources. FAO has a tendency to be the least consistent of the three sources on reporting data. With this in mind the FAO still was the best source for country and time series coverage for the area harvested numbers for coffee.

Price Data

Time series data on commodity prices can be very difficult to find in many countries. A complication can arise as individual countries may have up to four different levels of prices if it is available including port prices, wholesale prices, farm level prices and retail prices. Another consideration is how the relationships between the various prices can be skewed by a country's domestic policy, trade policy and any transportation or storage costs added to or subtracted from the price. Farm level or producer prices were the first priority as they provide the best representation of first level marketing of green coffee by growers. This price level is the most critical for countries who are large producers. Whenever, producer prices were not available port prices received the next priority to detail. Retail prices although available in some cases were not used for this study as retail prices were only provided for select importing countries.

The primary source used for price data series was the International Coffee Organization (ICO). The ICO provided farm level producer prices, which they defined as prices to growers for most exporting countries. As many of the producer prices were reported through calendar year 2009 this provided current data sets to create in-country price transmission equations. One weakness of the data set was that several of the price series were not updated through 2006 or later leaving several of the price series as unusable for this application. In order to remedy this weakness, different sources were located dependent on available current data. In a few instances another source was found and combined and/or compared to the ICO price series in order to create a continuous time series from 1980 through 2009. When a current source could not be found the residual exporting country's price was converted into local real currency including any trade policies associated with the country. The following section breaks out two countries where additional sources were sought and found to fill in gaps left by the ICO for price data.

Brazil

The ICO provides their producer farm level prices on a calendar year basis. In order to integrate those prices into the model a marketing year conversion was used. This methodology worked well in most cases, but since Brazil was the residual exporting country for the world a more granular source for producer prices was sought out. In Brazil an organization called Centro de Estudos Avancados Emeconomia Aplicada – ESALQ/USP (CEPEA) reports a daily Arabica price for delivery at Sao Paulo. This is a cash price for physical lots at the first marketing level. Once the units were converted to the same basis the price series were compared for accuracy. The daily price provided marginally more price variation. This was attributed to more accurate marketing year averages versus the ICO price converted to a marketing year. With the series tracking from 1996 onward the CEPEA price was used for the Brazilian producer price beginning in the 1997/98 marketing year.

Vietnam

For Vietnam the ICO's producer price was only reported through the 2006 calendar year lending itself to limit the price series to the 2005/06 marketing year. As Vietnam is the second largest global exporter of coffee and the number one global exporter of Robusta an incomplete price series to use integrate a price transmission equation was deemed unacceptable. DakLak Trade and Torism is an internet site that is published by the Province of DakLak in Vietnam. DakLak is one of the largest producing coffee provinces in the country and reports daily coffee prices beginning in January 2006. This source was the most granular and only consistent source of price data for in-country prices for Vietnam. With DakLak reporting beginning in the final year of ICO reported prices it was opportune to find the source. When DakLak's price series was compared to the ICO historical series the Thành phố Hồ Chí Minh (TPHCM) price provided the nearest price level. It is possible that the ICO used a TPHCM price as their historical price series, but this could not be verified. With the continuation of the price series a price transmission equation was able to be estimated as presented in Chapter 8.

CHAPTER 5 LITERATURE REVIEW

There has been an abundance of literature and research concerning coffee and the coffee sector. The scope of the literature has addressed various points of interest ranging from price differentiation of different botanical coffee varieties to implications of policy from International Coffee Agreements and including many topics in between. This study organizes the literature review to focus on selected theoretical and empirical studies whose objectives, methods of analysis, specifications, elasticities and/or conclusions may help address the structural behavior of supply, demand, policy and price in the analysis of the international coffee industry.

Theoretical

Statistical Methods

Waugh

In 1943 Frederick Waugh published an article in Journal of the American Statistical Association detailing an analysis of choosing the appropriate dependent variable in regression analysis. Waugh develops his points by critiquing works published by Mordecai Ezekiel. According to Ezekiel's analysis a dependent or resultant variable is estimated from a known, independent or causal variable, and the independent variable should have a direct understood cause followed by an effect on the dependent variable (Ezekiel, 1941). In opposition to this concept Waugh argues that the choice of the dependent variable is determined not by strictly a cause and effect understanding of the variables, but more importantly by the question that is being answered. This means that depending on the theoretical question one is examining a reverse regression may provide further understanding of the variables within the definition of the research question itself. In a follow-up comment section at the end of the article, Ezekiel defends his position that in most cases the reverse regression of the variables would be unsatisfactory and unpractical, and that, "for the practical researcher who expects to use his research as a basis upon which to advise on the probable consequences of actions in the real world, for in that world, people need to know what effects (results) are most likely to follow from given things they may select to do (causes)" (Waugh, 1943, p. 216).

The significance of Waugh and Ezekiel's analysis of the selection of appropriate variables for regression analysis is of utmost importance to this thesis as the underlying individual relationships are the backbone of how equations were specified. The concept of cause and effect was considered in combination with previously defined causal and resultant variables from other studies including their theoretical specifications. The inclusion of other studies and their theoretical specifications allows the opportunity to draw on previous work to develop not only the appropriate variable, but also the appropriate number of causal variables in the equation in order to minimize specification biases, or omitted variable bias that may unwittingly occur otherwise.

Later in 1961 Waugh published another article this time in Econometrica relating to statistical methods concerning the critique of least squares in econometrics. To address the least squares method Waugh analyzes and quotes from the work published by Trygve

Haavelmo in Econometrica from 1943, which developed the concept of least squares for simultaneous equations. According to Waugh (1961), "most competent mathematicians have always granted that the ordinary least squares regression, gives the best unbiased estimates of the expected values of Xo associated with the various stated values of X1, X2, …, Xn, at least so far as a past sample is concerned" (p. 391). To this point Waugh (1961) argues that as long as market structure does not change then, "in the future as well as in the past, the least squares regression will yield the best estimate" (p. 392). Insomuch as the use of least squares regression is argued as a legitimate statistical tool for defining relationships from historical data under that assumption that those relationships will have similar structural relationships for forecasting future results, then this method of regression may be useful for exploring estimates of underlying relationships of causal and resultant data series. Waugh (1961) warns the reader about using higher mathematics to understand economic relationships when those methods "may often introduce much greater errors than those resulting from least squares bias" (p. 394). He further suggests that simple graphical analysis is quick and easy and in combination with simple least squares regressions, "will help anyone get real insights into the meaning of statistical facts…and find out what sort of model is realistic in a particular case" (Waugh, 1961, p. 395).

Wold

In 1956 Herman Wold was published in the Journal of the Royal Statistical Society detailing the ends and means of causal inference from observational data. In this article Wold (1956) details various points about causal relationships. The most applicable section as it pertains to statistical methods is his understanding and development of regression and the least squares principle as it concerns individual causal relationships. Wold (1956) purports that, "when the problem is to estimate a causal relationship…no other estimate (referring to least squares regression) of the relation will give such small residual variance" (p. 43). The primary risk Wold (1956) explains from using least squares on observational data is specification errors caused by the uncontrolled factors that cannot be neutralized by randomization. In order to compensate for these potential specification errors, Wold (1956) suggests using the traditional compromise, "to include as explanatory those variables which, according to experience and a priori theory, are believed to be the main causal factors" (p. 43). This formula for exacting appropriate causal or independent variables into individual relationships is an important step in the process of relating underlying equation specifications for this thesis. Wold (1956) goes on to provide an example and additional explanation borrowed from J. Tinbergen (1939). Tinbergen's example provides the basic structure of a priori theory for causal variables for demand relationships. According to Tinbergen (1939), the demand relation shows how a group of consumers change or adjust their demand according to changes in price and income (Wold, 1956, p. 45). It is important to note that Wold (1956) defines that variables in a simultaneous systems are defined as being either "endogenous", which is defined by the system or "exogenous", which is a fixed variable appearing in the system (p. 45). These definitions are the protocol used to address variables used for this thesis. Also, in a simultaneous system, "the relations are specified as dynamic in which causal relations of individual equations link together as to form a causal chain; that is, on the basis of the past history of the system, its relations enable us to predict the future path of the effect (dependent) variables" (Wold, 1956, p. 45). Wold (1956) later admits that in certain cases the reactions of select relations are rapid and may require instantaneous feed-back models. With such a causal chain system the appropriate statistical treatment, "can be estimated by forming the least squares regression for each relation in the system" (Wold, 1956, p. 46). In a previous paper the author found that in causal chain models that the least squares method with normal and mutually independent residuals ended up being equivalent to the maximum likelihood method making it the appropriate format for estimating causal relations (Bentzel and Wold, 1946). To take the concept of causal chains further it is suggested that the dynamization of an interdependent system with causal relations specified for each of the variables involved for supply and demand while price is dealt with as an equilibrating variable. He explains that an effective interdependent model will then have identities that are introduced as assumptions such as "$d_t = s_t = x_t$" that help to form constraints on the effect variables and provide instantaneous feedbacks into the model (Wold, 1956, p. 47). Wold (1956) explains that such an interdependent system would be of interest for total categories in economic models. In a later paper Strotz and Wold (1960) further define the differences between a recursive model and an equilibrium model, and how in a nonrecursive or equilibrium model bicausality allows for the system to solve where, "$q_d(t)$ is quantity demanded and $q_s(t)$ is quantity supplied," because "$q_d(t) = q_s(t)$" is not an identity, but an equality, which is assumed to hold in fact over the observations" (p. 425). It is a similarly theoretically structured interdependent price equilibrating supply and demand system that is used as the model for the work in this study.

Multiple regression analysis using the ordinary least squares method was used extensively in combination in concert with simple graphical analysis to evaluate statistical significance as well as data fit of individual equations in order to define the causal relations of selected independent variables on select resultant variables. Ordinary least squares regression was used for a number of reasons. The first reason being that as according to Jeffrey Wooldridge in his textbook Introductory Econometrics, "with OLS, we have the ability to derive, unbiasedness, consistency, and other important statistical properties relatively easily" (Wooldridge, 2009, p. 32). Another reason is that the use of ordinary least squares was found as the most commonly used statistical method across the literature as it concerns the coffee sector models as well as other structural models reviewed. Ultimately, due to the simplicity of use as well as the proven track record of ordinary least squares this method of regression analysis became the basis for developing quantifiable relationships between the dependent and independent variables in individual equations in the model for this thesis.

Supply

Nerlove

Marc Nerlove in an article from the Journal of Farm Economics from 1956 provided an introductory framework for addressing acreage elasticities through the concept of a partial adjustment model for agricultural commodities. This concept has been used to assist in the quantification of the response of supply to price. Nerlove's perspective that producers will partially adjust to where their ideal position would be provides an appealing point of view and seems realistic. "In general, more recent prices are a partial result of forces expected to continue to operate in the near future: the more recent the past price, the more it expresses the operation of those forces relevant to expectation" (Nerlove, 1956, p. 499). This basic premise provides a framework that introduced the lagged dependent variable into the supply specification allowing for the ability to derive long range elasticities. An interesting point is that the concept of lagged dependent variables has also been extended into stock behavior as well, which will be discussed later. In this thesis, Nerlove's partial adjustment model was considered in combination with other supply function work that was extended for perennial crops and also specifically for the coffee sector by other authors.

An important consideration when including lagged dependent variables is the potential for the parameter estimate to approach one, which becomes unacceptable when it exceeds one. As parameter estimates become closer to one the behavior of the equation is dwarfed by the lagged dependent variables. The influence of prices become insignificant in affecting the equation and consequently the equation does not catch turning points under simulation. The concern is that as the parameter estimate of the lagged dependent variable nears and exceeds one, the model will not equilibrate and solve to a solution. This is due in part to how the lagged dependent parameter affects the long-run price elasticity. As the long-run price elasticity may be derived as a function of short-run elasticity and the lagged dependent parameter, a lagged dependent parameter estimate over 1 can become explosive as the long-run price elasticity becomes negative.

French and Matthews

In 1971, French and Matthews in an article published in the American Journal of Agricultural Economics structured an approach to modeling the supply response of perennial crops. Using an aggregative model orientation, they attempted to explain the behavior of producers as a group, starting with assumptions including: "producers are faced with similar product and factor prices, similar production functions and attempt to maximize profits…also the behavior of individual producers is conditioned by expectations concerning the behavior of other producers and the probable impact of this behavior on output" (French and Matthews, 1971, p. 479). The authors divided productive area of perennial crops into new area added to production, old area removed from production and the previous year's productive area. As they developed the specification for new area added and area removed, it was noted that price expectations at the time period when new area is planted were quite influential in determining production k periods later when they actually became productive. They applied their theory to asparagus in the United States and estimated the change in area planted as a function of the lagged ratio of asparagus price to wage rates multiplied by lagged area, the k+1 period lag of the ratio of asparagus price to wage rates, the lagged area, the k+1 period of lag of area, a labor adjustment and a dummy variable. It was found that a lack of transparency and/or availability of certain desired time series variables forced substitutable proxies. One key example was where a price ratio, or deflated price, was used as a function for profit. Embedded within this ratio is a wage index that was used as a deflator for price in the place of a true cost of production index. Another key data obstacle that had to be overcome was the lack of time series available detailing area of old asparagus plants. To address this situation old age area became a function of average harvested area during the previous five years with an error term. The use of closely associated variables as substitutes seemed to the authors (French and Matthews, 1971), "to be a fairly common problem in measuring supply response for perennial crops" (p. 488). The modification and extension of Nerlove's partial adjustment framework by French and Matthews when considering variables and potential proxies for the supply response of perennial crops provided insight and perspective during the process of selecting appropriate variables for area equations.

Initially the potential existed that additions and removals of coffee trees may be able to be estimated separately for this thesis, but similar to French and Matthews research there was not enough available data to create an explicit separation of area. In order to overcome the lack of age data on coffee area, in this study, an adaption of the French and Matthews specification was applied and also considered the specifications of Wickens and Greenfield (1973) and Parikh (1979) as described below.

Wickens and Greenfield

In 1973, Wickens and Greenfield developed a framework published in The Review of Economics and Statistics that had similarities to that of French and Matthews (1971), but with a more direct relationship Nerlove's partial adjustment framework with an extension into the coffee sector. The purpose of their research was to fill any gaps left from Nerlove's application to field crops in order to encompass tree crops using the supply of coffee in Brazil to develop their structural model. The authors (Wickens and Greenfield, 1973) found that "a difficulty arises in the case of coffee…usually only area data are obtainable" (p. 434). Due to the data deficiencies Wickens and Greenfield (1973) listed other instances where supply specification of coffee was relegated to price and lagged area such as work done by Klein and Behrman (1970). Using annual data Wickens and Greenfield (1973) found that, "the importance of lags in the supply of tree crops is greater than for field crops" due to time lag of new plants to produce (p. 439). It was concluded that expected net revenue, which is expected price minus expected harvest costs can be proxied by a distributed lag of actual current and past prices. In its simplified form the authors (Wickens and Greenfield, 1973) specified that the change in area is a function of price and lagged area t-1 $\left(\Delta Area = f(P_t, Area_{t-1})\right)$, adding that their specification was ad hoc and that it "need not be a good approximation in all cases" (p. 436).

The example Wickens and Greenfield (1973) created of the area function provides a very simplistic specification to estimate area for coffee. The concern would be that this simple function may not effectively take into consideration the appropriate lagged price response for the slow gestation process of new area for coffee. The authors illustrated that they ran ordinary least squares to test for significance of differing variables, but the focus of the tests were on lagged area and not the distribution and significance of lagged prices. The applicable concept for this thesis is that inclusion of lagged area variables past t-1 were not significant in the supply function.

Parikh

A. Parikh in 1979 published an article in Applied Economics that further developed the relationship of coffee supply with a focus on production response to lagged prices. Parikh also emphasized the importance that lags in the supply function of tree crops is greater than for field crops similar to Wickens and Greenfield (1973). In order to estimate the affect of lagged prices the author estimated the supply equation using a polynomial distributed lag model, where production was a function of distributed lagged prices from P_t to P_{t-9} and lagged yields of y_{t-1} and y_{t-2}. Parikh (1979) found that the estimated mean lag between profitability and output was about 5.5 to 6.5 years for Brazil and 4 to 5 years for Columbia, El Salvador and Guatemala. This time period from 4 to 6.5 years corresponds to the maturation lag time between planting and harvesting for coffee trees.

The significance of Parikh's results for this thesis is not so much in the structure of the polynomial distributed lag model that is used, but of which years Parikh found to be significant as price relates to production. Upon observation of the t-ratios that Parikh provides in the output tables it is interesting to note that not only did a variety of lagged prices in the 4 to 6 year range have significance but also in some countries price in t-1 was also significant. This significance of a combination of lagged prices allows for the consideration of additional specification developments of the area function used as expanded in Chapter 6.

Demand and Consumer Behavior

Brown and Deaton

In 1972 Alan Brown and Angus Deaton published an article in The Economic Journal presented a review of models of consumer behavior. This publication provided diverse perspectives referencing the historic progression of theories of demand and consumer behavior. Brown and Deaton (1972) found that "agricultural commodities were the first to be studied and provided econometricians with some of their most convincing successes" (p. 1147). They argue that, "partial equilibrium analysis based on fitting single equations requires, ideally, a homogeneous commodity with a simple quantity dimension, stable consumer preferences, and relatively large fluctuations or trends in supply which may be independent of the current market price; and these conditions are most nearly met by many agricultural staples" (Brown and Deaton, 1972, p. 1147). Coffee is considered such a commodity, as Brown and Deaton (1972) had found that an early example of demand analysis was in “Benini in 1907 used multiple regression analysis to estimate a demand function for coffee in Italy with the prices of coffee and sugar as arguments” (p. 1147). In order to successively evaluate demand Brown and Deaton (1972) suggested that two classical questions must be addressed, including the deriving of income elasticity and price elasticity (p. 1149). Following their line of thought that large econometric models can be formed for planning and policy formulation (Brown and Deaton, 1972), the coffee model underlying this thesis was built in part for such purposes. The authors go on to purport that, "for many practical purposes it may be sufficient to estimate separately a set of single equations…for example, each equation might express the quantity purchased of each good per head of population as a function of average per capita income, the price of a good relative to some overall price index, and time" (Brown and Deaton, 1972, p. 1150). When using such a methodology a functional form must be chosen for the demand equation. It suggested to using a pragmatic approach in such cases similar to a functional form progressed by Stone (1954), where quantity demanded is a function of time, price and income per capita. The concern with this pragmatic approach is that there are assumptions implicit that although make it more convenient methodologically, ignore topics such as changes income response as income changes or the effects of changes in income distribution as established by Engel (1857) and progressed by others, as well as any concerns that may arise with arguments of aggregation or separability, which may be deemed as significant omissions. Despite the misgivings of any demand model chosen due to its assumptions or any strong a priori notions that are built into the choice of the model, Brown and Deaton (1972), argue that, "some functional form must serve as a basis for estimation" (p. 1152). The authors go on to detail the various explanations and progression of the literature that addresses topics of interest to this thesis including theories of consumer behavior and analysis of household budgets. Demand equations in the coffee model follow Brown and Deaton's (1972) assumption that demand theory follows the, "law of demand, that own-price compensated elasticities of demand are negative or that compensated demand curves slope downward" (p. 1163). Also, when the authors (Brown and Deaton, 1972) address the concern of aggregation, they argue that, "clearly we are not interested in the vagaries of the individual consumer, only in behavior with the disturbing factors averaged out" (p. 1168).

To quote Hicks (1956, p. 55), "the preference hypothesis only acquires a prima facie plausibility when it is applied to a statistical average…to assume that an actual person…who lives around the corner, does in fact act in such a way does not deserve a moment's consideration" (Brown and Deaton, 1972, p. 1168). This assumption uses what Brown and Deaton (1972) refer to as the "oldest and still most common approach", which, "is to ignore the problem of aggregation altogether." (p. 1168). They (Brown and Deaton, 1972) justify this direction by stating that, "All applied work is subject to errors, and errors of aggregation may not significantly add to the errors of measurement and omission which are inevitably present" (p. 1168).

Another important concept of interest is that of separability or homogeneity of commodities. This concept is concerned with how to group or bundle commodities in order to address utility. According to Brown and Deaton (1972), the work of utility trees was established by publications by Gorman (1959) and Strotz (1957 and 1959). Using in part others' concepts of separability, Brown and Deaton (1972) argue that, "the utility function should be strongly or additively separable into branches each of which is homogenous" (p. 1170). This concept applies to the underlying assumption of this study insomuch as coffee is assumed to be included as a homogenous commodity under the umbrella of a larger utility branch, whereas different varieties of coffee, which may be separable on the botanical and technological levels, are assumed homogenous at the production, trade and consumption levels addressed in the model. Brown and Deaton (1972) also point out that as long as select commodities can be grouped according to the needs they satisfy, then their, "discussion has provided little more than justification for what has always been done in practice – some aggregation is always necessary" (p. 1171).

The next topic of interest covered by the authors was an analysis of household budgets, which detailed various literature progressions of the measurement of Engel curves. As noted by Paris and Houthakker (1955), Engel curves with declining income elasticities fit budgetary data better than curves with constant elasticities. According to Brown and Deaton (1972), "the hypothesis of declining income elasticity is consistent with but weaker than the hypothesis of a saturation level of demand" (p. 1173). To clarify the point the authors add explanation of two hypotheses of saturation in the theory. They include absolute and relative saturation. The first hypothesis of absolute saturation is based on the premise that, "for the commodity in question there exists (an average for a group of consumers) a finite level of demand which is not exceeded, either as income increases indefinitely or as prices decrease indefinitely; this hypothesis reflects the fact that the marginal utility of the commodity becomes zero, or turns negative, at a finite level of consumption" (Brown and Deaton, 1972, p. 1174). On the other hand the relative saturation hypothesis is based on the premise that, "consumption tends to a saturation level as income increases at a given price, but the saturation level is itself a function of price…as price falls, the relative saturation level in general increases, but it may or may not tend to an absolute saturation level" (Brown and Deaton, 1972, p. 1174). The authors go on to provide examples of different functions that illustrate types of Engel curves such as linear, lognormal, double logarithmic, semi-logarithmic and logarithmic reciprocal curves for both normal and inferior goods. The progression of Engel curve theory suggests a generalization based on market behavior with the fitting of the appropriate Engel curve function dependent on the definition of the good and which path the income elasticity may take. With these considerations in mind the authors admit that it is evident from the theoretical discussion that it is most unlikely that the theory holds rigorously in application, which is attributable to dynamic elements that may affect the utility function (Brown and Deaton, 1972). Having this understanding in mind, Engel curves, which were considered of interest conceptually were not explicitly incorporated into the demand functions in the coffee model for the purpose of this study. Also, as the projection period of model’s impact analysis is limited to a ten year time horizon, the income level does not change dramatically limiting the necessity for inclusion of an income elasticity adjustment as suggested by the Engel curve.

Brandt, et al

Much literature since Brown and Deaton (1972) concerning demand has addressed the building of aggregate or complete demand system models that satisfy regularity conditions derived for the individual utility maximizing consumer. Although, the mathematical precision and the symmetrical relationships implied by the regularity conditions may be relevant to demand theory, the application of one of these systems into the coffee model is a concern. One example in the literature of a complete demand system is the Almost Ideal Demand System (AIDS) published by Deaton and Muellbauer (1980a), which is purported to satisfy, "the axioms of choice exactly; it aggregates perfectly over consumers without invoking parallel linear Engel curves; it has a functional form which is consistent with household-budget data; it is simple to estimate, largely avoiding the need for non-linear estimation; and it can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters" (p. 312). Having the ability to apply all the restrictions tests to demand theory is compelling. The bottom line is that models that satisfy the regularity conditions with precision do not perform well under simulation (Brandt, et al., 1985). With this understanding in mind despite the popularity of complete demand systems and imposing regularity conditions, they were not applied in this study.

Price Transmission and Trade Policy

Mundlak, Cavallo and Domenech

An article published in association with The World Bank Economic Review in 1990 by the authors Yair Mundlak, Domingo Cavallo and Robert Domenech developed an underlying structural relationship of real domestic prices by incorporating real exchange rates and proxies for the openness of economies. The authors (Mundlak, Cavallo and Domenech, 1990) chose a framework progressed by Dornbusch (1974) defining the structural relationship for price when influenced in a small open economy, or an economy that, "is a price taker in the world market" (p. 56). The price relationship was defined as price of a traded good, P_j, being determined by the world price, P^*_j, and then adjusted by the nominal exchange rate E (expressed in units of domestic currency per unit of foreign currency) and the trade tax, $T_j = (1+t_j)$, which is the proxy used for the openness of the economy, where the tax rate, t_j, is positive for imports and negative for exports (Mundlak, Cavallo and Domenech, 1990, p. 56). Under this structural definition domestic supply and demand of good needs not to be equal, because the gap is closed by trade at the world level, where supply and demand are then equalized through the adjustment of price (Mundlak, Cavallo and Domenech, 1990). In order to develop real prices from the current equation using nominal exchange rates the authors created a function of prices to include the relationship between an import price and a home goods price and an export price and an import price (Mundlak, Cavallo and Domenech, 1990).

The price equation relating a domestic price to the world price including a proxy for the openness of the economy provides a relatively simple price linkage or price transmission relationship between world prices and domestic prices. A problem arises when attempting to apply the deflation equation insomuch that in most cases separate import, export and home good prices are not reported. The price transmission relationship presented therefore provides a good starting point, but a more simplistic proxy will be used to deflate nominal prices in this thesis to real terms as according to specifications detailed in the following article by Tomek (2000).

Tomek

William G. Tomek in an article published in the Agricultural and Resource Economics Review from 2000 reviewed a number of topics as it relates to empirical models of commodity prices. Tomek (2000) argued that in order to observe clear trends in farm prices, time series must be deflated, and the appropriate deflator should be guided by the research objective and theory. He goes on to detail how in analyses for commodities, deflating prices by the consumer price index (CPI) is rather common. He then provides two references from literature where the CPI was used as the appropriate deflator for analysis listing Chavas (1999) and Antonovitz and Green (1990) as relevant examples.

Similar to other commodity analyses a deflator for prices becomes important especially when multiple countries are considered in order to take a common nominal world price and convert it into real local currency units. For this study forecasted CPI's were used as an exogenous deflator for nominal prices. It was used as the proxy for the equation provided by Mundlak, Cavallo and Domenech (2000) to determine real prices, whereas the price data necessary to populate all four series required to develop their real price function were not available.

Stocks

Clark

In 1979 Peter Clark published an article detailing the progression of the accelerator theory. With beginnings from 1917 by J. Clark with a generalized accelerator model was meant to relate investment in fixed capital stocks to changes in output. The basic assumption was that the desired capital stock at any point in time is a constant multiple of output at that time. This concept was later developed to consider the flexibility of the slow reaction of capital investment to output by adding distributed lags into the equation, whereas Clark (1979) referring to research done by Feldstein and Foot (1971) stated that, "if it can be assumed that depreciation is approximately exponential and that the replacement of capital responds linearly to current and lagged output, then gross investment, *I*, can be represented as a distributed lag on output, plus a constant multiplied by the capital stock of the last period" (p. 79). One concern that arises following this extension of the accelerator theory is that, according to Peter Clark, (1979) "the usual theoretical discussion of the flexible accelerator ends as the expectations of future levels of output are assumed either implicitly or explicitly to be static" (p. 79). The problem is that such an assumption is unwarranted at the theoretical and real world levels. To address this problem then investment in capital stocks in time t must be a function of past and future expectations. In the development of the modern accelerator model past levels of output are considered the most important determinates of future output (Clark, P., 1979). Also, in order to incorporate the neoclassical principle that "the optimal combination of factor inputs should be a function of their relative prices" (Clark, P., 1979), this modification of the accelerator model consequently then included a proxy for rents or cost of output (p. 82). This concept allowed for the addition of cost or price into the equation. Generally, the end result of the flexible accelerator model is to measure the change in stocks or inventory holding considering output or production as well as the nature of slow reaction to changes in output including a consideration for the cost or price of the capital stocks.

In order to incorporate the accelerator model and its modifications over time into stock and inventory accumulation and/or holdings in the coffee sector several other studies were also considered to better understand how stock levels of a storable and yet perishable commodity such as coffee may change including the most common reasons for inventory formation such as transaction, precautionary and speculative demand. The studies used in the application to develop the stock equation specification are detailed further in Chapter 6.

Specification

FAPRI

Commodity and policy analysis systems across the Food and Agricultural Policy Research Institute (FAPRI) as well as centers associated with FAPRI such as the Center for Agricultural and Rural Development (CARD) have been well documented over time. The systems used in association with FAPRI (Devadoss, et al., 1989) consist of an, "integrated set of models used to provide quantitative evaluations of national and international agricultural policies, as well as other exogenous factors that affect agriculture" (p. 2). Using a combination of models that cover several commodities provides a diverse understanding of market structure and behavioral relationships across differing crops and livestock types. The models used by FAPRI and associated centers use econometrically estimated models that have been augmented over time by a number of student dissertations in order supplement and expand econometric relationships to overcome any inadequacies that may have been found in existing models. This study considered model documentation for area, yield, production identities, ending stocks, price transmission linkages and domestic consumption as well as world trade relationships across countries from technical reports published by FAPRI and CARD from 1989, 2004 and 2009. Similar to FAPRI's crop models the coffee model underlying this study is a dynamic, nonspatial, partial equilibrium, net trade, econometrically estimated model. Using definitions published by FAPRI (Devadoss, et al., 1989), the model is nonspatial meaning, "it does not identify trade flows between specific regions; the intent is to identify net quantities traded by country or region," and "partial equilibrium because only one commodity is included in a model and resource market outcomes are assumed exogenous." (p. 27). The linkage between countries are designed to reflect simultaneity of the price determination process in the respective commodity market. FAPRI (Devadoss, et al., 1989) employs, "a descriptive econometric approach in their structural specifications, where the functional forms of the equations are generally linear, but identities and other basic relationships that are introduced may result in nonlinearities." (p. 29). These documented specifications were used in part as guidelines for structural relationships and overall model functionality for this study.

Kruse

In his PhD dissertation John R. Kruse (2003) focused on a model for the oilseed sector. He estimated several countries including Canada, Mexico, Brazil, Argentina, the European Union, China, Japan, India, Malaysia and Indonesia as well as constructing an aggregate for the rest of the world excluding the United States. He approached each country by estimating equations for area, yield, a production identity, crush, ending stocks, oil and meal use (including meal share equations), oil and meal ending stocks, an import or export equation when applicable and price transmission linkage equations. He applied policy levers such as import and export tariff barriers by linking port prices to world prices where available to more accurately represent price transmission among the various countries and commodities. The equations included estimates for major oilseed commodities including soybeans, soybean meal, soybean oil, sunflowers, sunflower meal, sunflower oil, rapeseed, rapeseed meal, rapeseed oil and palm oil. The price transmission linkage equation incorporation of trade barriers including value added taxes and import tariffs were of critical interest in fully integrating policy levers for the specification of this study.

Other Studies and Elasticities

This section documents elasticities found from other studies that will be used for comparison with elasticities estimated in this thesis. Table 5-1 presents short-run and long-run supply elasticities from a study by Akiyama and Varangis in 1990 and a study that documented other studies' supply elasticities reviewed by Askari and Cummings in 1977. One concern about the supply elasticities reported by Akiyama and Varangis (1990) is that they are not reported as short-run and long-run elasticities, but as short-term and longer-term elasticities. The authors reported the short-term supply elasticity as the elasticity two years after a price change simulated in their model and the longer-term elasticity as the elasticity at five years after their price change. This makes the short-run and long-run elasticities presented not as relevant for a comparison benchmark. For example the Indian longer-term elasticity is smaller than the short-term elasticity. If these were short-run and long-run elasticities this would be not theoretically accurate, although since the study provides the most extensive list of supply elasticities it is included as an observable reference.

Elasticities of Coffee Area from other Studies			
	Own Price Elasticity		
	Short-run		Long-run
Brazil			
Akiyama & Varangis - 90*	0.030		0.100
Berhman & Klein - 70	0.100		0.110
Colombia			
Akiyama & Varangis - 90*	0.160		0.440
Bacha - 68	0.070		0.450
Latin America (excl. Brazil & Colombia)			
Bacha - 68	0.280		0.520
Honduras			
Akiyama & Varangis - 90*	0.130		0.150
India			
Akiyama & Varangis - 90*	0.190		0.100**
Indonesia			
Akiyama & Varangis - 90*	0.140		0.170
Mexico			
Akiyama & Varangis - 90*	0.020		0.060
*Not Short-run and Long-run elasticities; elasticities for 2 years after price change and 5 years after price change			
**theoretically Long-run elasticity should be higher than Short-run; attributable to authors' ad-hoc elasticity reporting			

Table 5-1 Elasticities of coffee area from other studies

Table 5-2 presents the domestic use own price and income elasticities from various studies. Notice how inelastic demand elasticities are to its own price. One concern of the most extensive source, Akiyama and Varangis (1990) is the reported own-price elasticity for India, which is positive. Although, they report that Indian own-price was significant at the 25 percent significance level or below, my concern would be which price they used in their study for India. Knowing from prior experience that India historically has had a relatively closed economy for select other commodities it is not surprising that the issue may be with the price transmission of the price used in their study. The authors list that their data were based on World Bank data from 1968-86, but they do not list if every country had a domestic price available (Akiyama and Varangis, 1990). Additionally, the income elasticities varied dramatically with select developing countries having smaller income elasticities and select developed countries having elasticities over 1. This runs counter to a priori expectations as generally one may expect developing countries' response to income change to be more impactful than developed countries. One potential explanation for this is that the study done by Akiyama and Varangis (1990) included only data during the market structure of an active quota system. As the last active quota system was suspended in 1989 it will be interesting to observe how income and own-price elasticities may be more or less elastic in a more liberalized coffee sector.

Elasticities of Coffee Demand from other Studies				
		Income		Own-Price
Belgium				
Akiyama & Varangis - 90		0.36		-0.28
Brazil				
Akiyama & Varangis - 90		0.50		-0.09
Colombia				
Akiyama & Varangis - 90		0.41		-0.14
France				
Akiyama & Varangis - 90		0.68		-0.13
Germany				
Akiyama & Varangis - 90		0.98		-0.17
India				
Akiyama & Varangis - 90		0.24		0.08*
Indonesia				
Akiyama & Varangis - 90		0.18		-0.07
Italy				
Akiyama & Varangis - 90		0.92		-0.18
Japan				
Akiyama & Varangis - 90		2.03		-0.31
Mexico				
Akiyama & Varangis - 90		0.35		-0.14
Netherlands				
Akiyama & Varangis - 90		0.89		-0.34
Spain				
Akiyama & Varangis - 90		1.07		-0.07
United Kingdom				
Akiyama & Varangis - 90		1.26		-0.51
United States				
Akiyama & Varangis - 90		0.50		-0.46
Huang - 96		0.81		-0.17
Hughes - 69 (1920-41)		0.33		-0.30
Hughes - 69 (1947-66)		0.29		-0.15
*study defined this elasticity as significant at 25 percent significcance level or below,				
also this was the only price elasticity reported as positive				

Table 5-2 Elasticities of coffee demand from other studies

Finally, Table 5-3 presents the price transmission elasticities listed from a study by Mundlak and Larson (1992). Their price transmission results were based on domestic price data from the Food and Agriculture Organization's (FAO) for 1968-78 as a function of a world price including exchange rates, which were annual averages published by the International Monetary Fund. The world price used was from a calculation incorporating an export-unit value in nominal U.S. dollars, which was derived from a ratio of the total world value of exports for coffee divided by the total world exported quantity. Represented in Table 5-3 are countries the authors listed that are included in this study. Interesting to note is the wide spectrum of R-square and elasticities reported. This lends itself to a potential concern of the ability of a world price to be transmitted to the producer. As Mundlak and Larson's (1992) study included only data during an ICA that included an active quota system it will be interesting to see if elasticities set-up in the price linkage equations will have similar or higher transmission.

Price Transmission Elasticities		
	Elasticity	R^2
Brazil	0.652	0.22
Columbia	0.619	0.95
India	0.142	0.39
Mexico	0.858	0.80

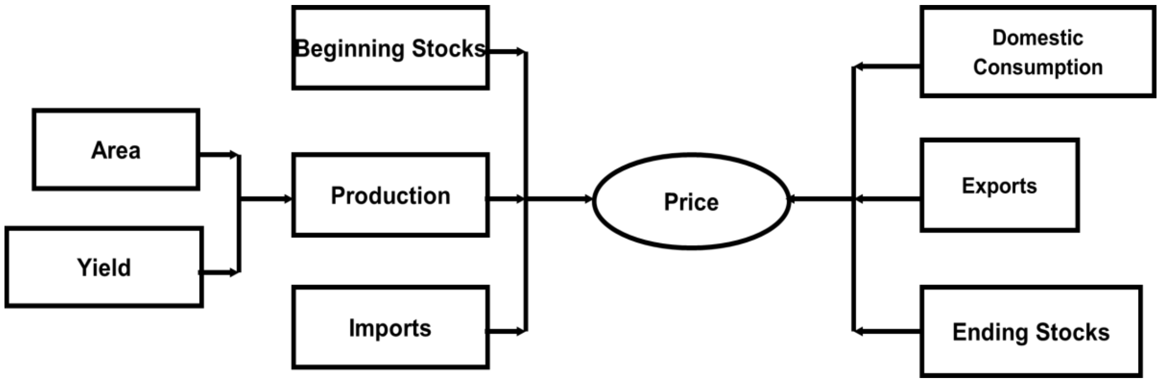
Table 5-3 Price transmission elasticities

CHAPTER 6 THEORETICAL DEVELOPMENT

In this thesis, the objective was to create a rigorous structural econometric model of the world coffee industry adaptable for analysis under various scenario conditions. The completeness of the model is dependent on its structure and specifications. This chapter opens by discussing the structural system, which includes both behavioral equations and the identities that bind them together. The next section addresses the traditional theoretical development underlying the specifications of equations in the system. For this thesis there are two overriding behavioral assumptions of agents in the market. These assumptions are that agents will either attempt to maximize utility and/or profits depending on their position in the value chain. Included in the development of these behavioral assumptions, this chapter also incorporates microeconomic implications of supply and demand into the equation specifications for the agents.

The Structural Model

The structural model of this study follows the traditional manner in which the data on supply and demand are reported. To demonstrate the basic structural model of the crops sector within any given country Figure 6-1 is provided illustrating the flow of supply and demand.



Source: Brown et al., 2009.
Figure 6-1 Basic structural flow diagram for an individual country

Data are reported for each box in the flow diagram. The left side of the diagram represents the supply variables, while the right side illustrates the demand variables. The price variable, which resides in the middle, acts an equilibrator between supply and demand. Each box, or variable, is a part of the model as either an estimated behavioral equation or as an identity. In Figure 6-1, the implied behavioral equations are area, yield, imports, domestic consumption, exports and ending stocks. The implied identities are production, beginning stocks and price. A solution price is then derived from an implied identity when supply equals demand at an iterated, simultaneously generated equilibrium price (Devadoss, et al., 1989).

To expand on Figure 6-1 and make it more specific Figure 6-2 illustrates how price in the coffee model feeds back into harvested area and how beginning stocks are an identity of lagged ending stocks. The flow diagram is similar to Figure 6-1 in that each box corresponds to a reported datum variable. From top to bottom, the supply of coffee in any given country is determined by what is produced in that country as the product of area harvested and yield, plus imports and beginning stocks, which are a function of lagged ending stocks. Price serves as an allocating instrument within the system iterating until supply and demand converge to equilibrium. Total annual demand for coffee includes domestic consumption, exports and to a much lesser extent ending stocks. Domestic consumption is the primary demand driver in importing countries, whereas in the majority of producing countries exports are the driving factor in total demand.

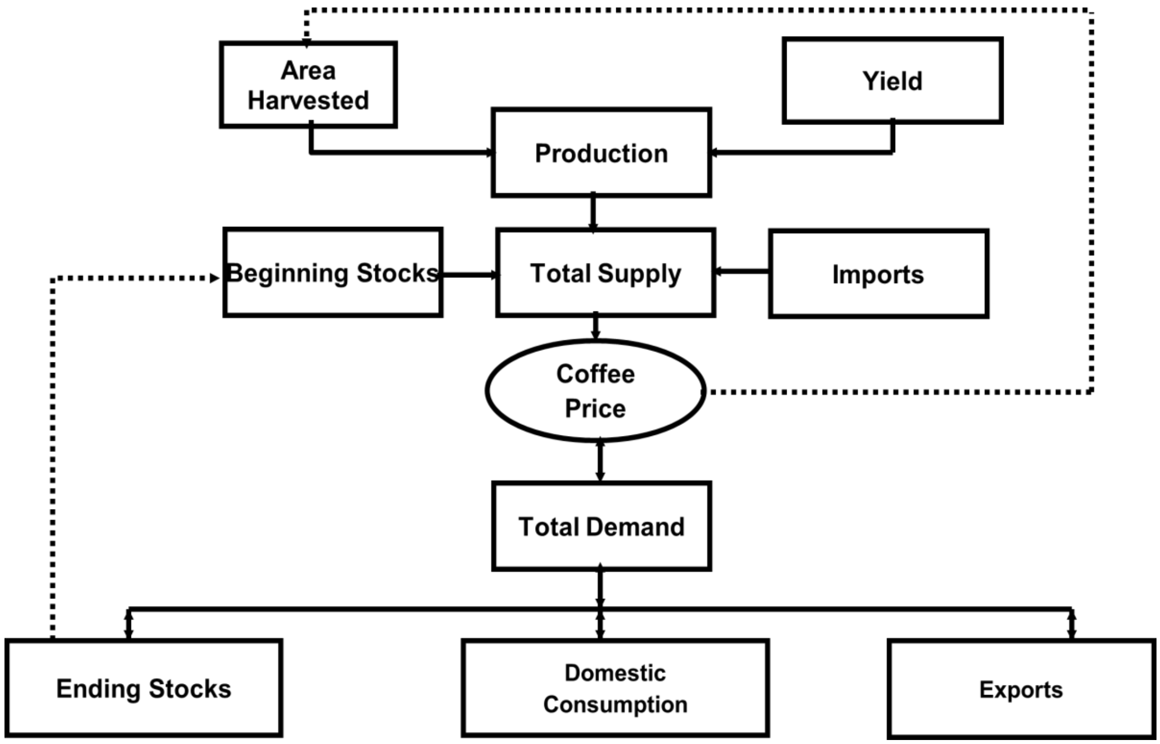
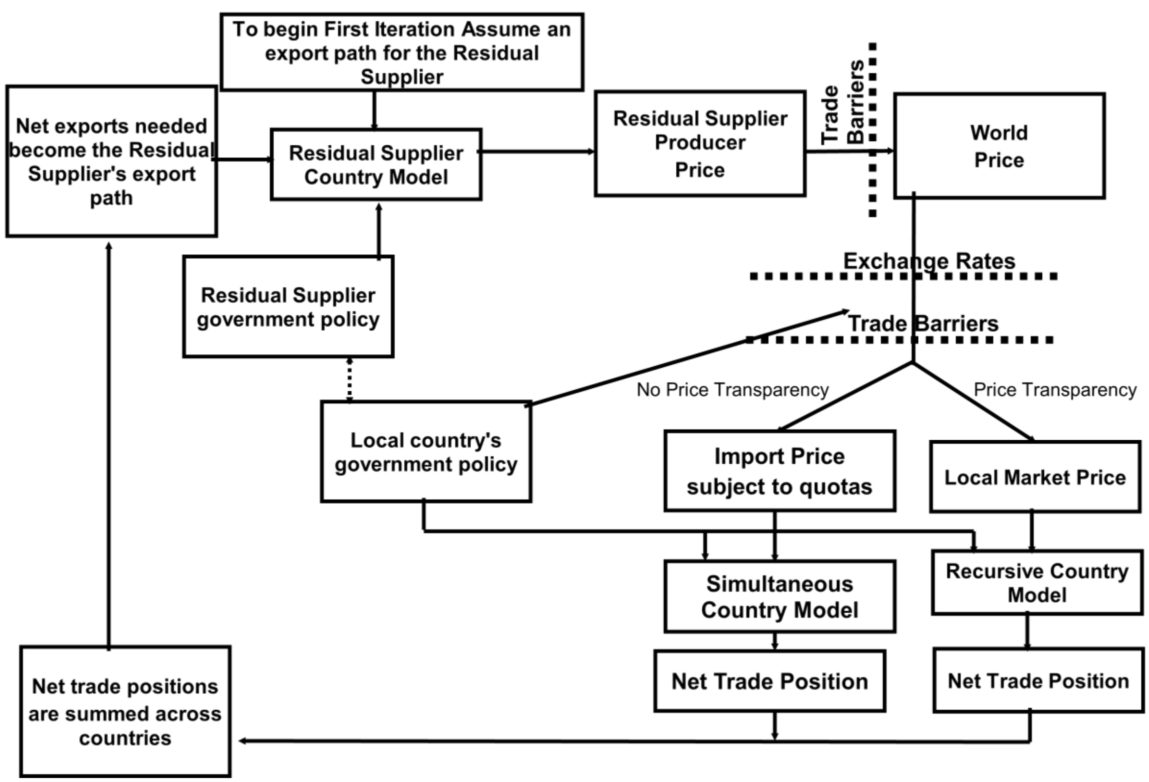


Figure 6-2 Coffee model flow diagram

As previously discussed, model structure is made up of a combination of behavioral equations and identities. For the coffee model beginning stocks, production, and total supply are determined by identities, whereas the remaining variables may be determined by behavioral equations. The only exception would be price, which is derived by an implied identity, also called the "Market Clearing Identity" where the solution is determined when supply equals demand (Brown, et al., 2009).

At this point the structure of the coffee model has been described in terms of a single country. Each country model is tied together through trade. To better understand solution process for the system it is simplest to think of each country by its net trade position. Select countries are net exporters, while others are the opposite as net importers. The largest net exporter is chosen as the residual supplier for the rest of the world so the errors in projecting trade do not result in trade path problems if a small country is used (Kruse, 2003). Also, the world price is solved for within the residual supplying country, so that it is preferred if there are little or no policy adjustments affecting the price transmission to the other countries. Figure 6-3 shows how the models are linked across countries. Beginning at the top-center of Figure 6-3 with the residual supplying country model, the model diagram starts with an assumption about the level of exports from this country where demand and supply are equilibrated through the farm price. The farm price is then translated into a world price through inclusion of any export barriers the residual country may have. This world price is then translated using exchange rates and import barriers to the local market price. As long as the country has reasonably open trade without any effective quotas or binding tariff rate quotas, the domestic price can be determined from the world price. Using this price, the supply and demands are solved in the country with the residual falling out as net trade. The net position of the country may be positive or negative depending on whether the country is a net exporter or net importer. Another possibility arises if a country has a fixed import quota or binding tariff rate quota that does not allow for internal prices to equilibrate with the world price. Normally, a country under these types of trade barriers do not export, and with imports given at the quota level, domestic prices will ration demand to be equal with domestic supply (Kruse, 2003). This may result in countries which have fixed import quotas or binding tariff rate quotas to have significantly differing price paths from the world price. Relatively closed economies under these types of trade regimes may still have effects on world prices by what is purchased through their quotas (Kruse, 2003).

Once a net trade position for a given country is reached, the net positions across all countries are summed to form a new net export position for the residual supplier. This new position equilibrates a new farm price for the residual supplier. The new farm price for the residual supplier may then be translated again to all the countries, starting the iterative process again. These iterations continue until the model solves converging to where supplies equal demand worldwide.



Source: Kruse, 2003
Figure 6-3 Structural linkages across countries

The overriding net result of the world trade balance is that the necessity to estimate both import and export equations is eliminated. The world price equilibrium dictates the net trade balance for each country. Although, the addition of a spatial model that estimates trade by source and destination could potentially be created based on historic shares, the net trade by country would remain the same. A concurrent spatial model is outside the scope of this study. Also, it is important to recognize that only the net trade position is given. If any given country has a significant amount of both imports and exports, it is necessary to estimate one or the other.

Theoretical Development Underlying Specification of the Behavioral Equations

The first part of this section includes specifications that may be implicit or derived from the behavioral assumption of profit maximization. The behavioral equations associated with supply are included in this section. The second part is designed around the specification that uses the theoretical development of the behavioral assumption of utility maximization, which includes consumer demand. The final part of this section presents the theoretical development of stock holding behavior.

Producer Supply

The operating behavioral assumption that determines the specification of agents described as producers or farmers is one of profit maximization. To simplify the derivation, generally profit maximizing agents are assumed to operate under conditions of pure competition, have perfect knowledge of all prices and costs and are able to adjust to the desired output in response to changing economic conditions.

Using the traditional development of Henderson and Quandt (1980, p. 98-101), the objective function for profit maximization in matrix notation (Kruse, 2003, p. 94) is:

$$Max\Pi = P'Q - i'XW$$

Subject to $F(q_1, \dots, q_s, x_1, x_n) = 0$

Where:

> Q is a vector of s outputs produced, $(q_1,\dots,q_s)$,
> P is a vector of s output prices, $(p_1,\dots,p_s)$,
> X is a (s x n) matrix of input quantities,
> W is a vector of n input prices, $(w_1,\dots,w_n)$,
> i is a vector of s 1's and
> F is the vector of production functions for each s output and each n input in generalized form.

Assuming a continuous twice-differentiable objective function and a production function that is strictly convex for some optimal level of output, the following Langrangian can be formed:

$$L = P'Q' - i'XW + \lambda(F(q_1, \dots, q_s, x_1, \dots, x_n))$$

the First Order Conditions imply

the following (s+n+1) equations in (s+n+1) unknowns:

$$\frac{\partial L}{\partial q_i} = p_i + \lambda F_{qi}(q_1, \dots, q_s, x_1, x_n) for\ i = 1\ to\ s,$$

$$\frac{\partial L}{\partial x_j} = -w_i + \lambda F_{xj}(q_1, \dots, q_s, x_1, x_n) for\ j = 1\ to\ n\ and$$

$$\frac{\partial L}{\partial \lambda} = F(q_1, \dots, q_s, x_1, x_n)$$

Simultaneous solution of these (s+n+1) equations yield the following long-run unconditional demand equation:

$$x_n^* = x_n^*(w_1, \dots, w_n, p_1, \dots, p_s) \quad (6.1)$$

Whereas optimal supply, q_s*, is a function of the optimal input quantities x_n* (equation 6.1).

Therefore, by substitution:

$$q_s^* = q_q^*(w_1, \dots, w_n, p_1, \dots, p_s) \quad (6.2)$$

Attributable to biological gestation lag in the production process, at the time the production decision is made farmers do not know the final price of their output. Consequently, producers must formulate an expected price. The assumption used throughout this study is that farmers have naïve price expectations (Ezekiel, 1938). This means that area is determined not by prices in the current year, but by expectations based on the previous year prices (Bahrenian, et al., 1986). In projecting results over a ten year time horizon alternative price expectations offer little or no additional information (Kruse, 2003). Thus, lagged prices are used in the formulation of supply specifications (Brown, et al., 2009).

An additional problem with supply equations is that it assumes that the firm can fully respond to price changes, which may not be realistic. Hindrances such as constraints on assets, price uncertainty, transaction costs, etc., likely limit a producer's ability to fully adjust in the short run. To account for these potential dynamics, the partial adjustment model developed by Nerlove (1956) was used as a beginning point.

Nerlove's (1956, p.502-503) model is given by the following notation (Kruse, 2003, p. 98-99):

$$(q_t - q_{(t-1)}) = \gamma(q_t^* - q_{(t-1)}), \tag{6.3}$$

where

q_t is the actual supply in year t,
$q_{(t-1)}$ is the actual supply in the previous year,
q_t* is the desired level of supply and
γ is the coefficient of adjustment (0≤γ≤1).

Note that the closer γ is to 1, the more able the producer is to reach the desired level of production.

Solving equation 6.3 for q_t yields

$$q_t = \gamma q_t^* + (1 - \gamma) q_{(t-1)}. \tag{6.4}$$

Now suppose the desired level of output is given by

$$q_t^* = b_0 + b_1 r_1 + b_2 r_2, \tag{6.5}$$

where

r_1 is the ratio of the lagged own price to an index of input prices and
r_2 is the ratio of a lagged substitute price to an index of input prices

Substituting equation 6.5 into equation 6.4 yields the following equation:

$$q_t = \gamma(b_0 + b_1 r_1 + b_2 r_2) + (1 - \gamma) q_{(t-1)}. \tag{6.6}$$

Thus the net result of employing a partial adjustment process is the addition of the lagged dependent variable to the specification.

To further expand on Nerlove's (1956) partial adjustment framework in order to incorporate the influences of perennial crops other approaches developed by French and Matthews (1971), Wickens and Greenfield (1973) and Parikh (1979) were considered. The approach is intended to be an intuitive development based on neoclassical microeconomic theory blended with the agronomic factors affecting the perennial nature of coffee.

It is important to understand the data limitations associated with coffee area. Since most exporting producers are grown outside the United States, specific data on the number of new hectares planted and the number of old hectares removed are not available for all countries. Also, as discussed in Chapter 2, coffee has a long productive life, and unfortunately data on the age distribution of coffee trees are not available (Wickens and Greenfield, 1973). Barring these data limitations, coffee area harvested may be determined by the following identity:

$$CFEAHA = CFEAHA_{t-1} + CFEAAD + CFEARM \tag{6.7}$$

where the variables are defined as

CFEAHA:	Coffee area harvested,
CFEAHA_{t-1}:	Coffee area harvested in the previous year,
CFEAAD:	Coffee productive area added and
CFEARM:	Coffee area removed.

The estimation of coffee area in its simplest form is the estimation of area added and area removed (French and Matthews, 1971). Productive area added in any given year is determined by planting that occurred in prior years. For coffee there is a considerable lag between planting and the first crop (Ukers, 1922 and Coste, 1992). As discussed in

Chapter 2, coffee trees can take from 3 to 6 years before the first crop is realized. Consequently, area added to producing area in the current year is based on plantings 3 to 6 years in the past. The decision to plant is then based on profit expectations that will not begin to be realized for at least 3 to 6 years. This is only the beginning of profit potential because of two considerations. First, coffee trees may not reach full productive potential for 6 plus years. Also, coffee trees may remain productive for 30 years depending on proper pruning and disease treatment and prevention, potentially stretching the expected profit stream out into three decades (Ukers, 1922).

To incorporate the long profit stream the formulation of the behavioral postulate for planted area of coffee must consider the net present value of future returns (Wickens and Greenfield, 1973). Therefore, the behavior postulate becomes the maximization of the net present value of all future returns. Due to the time dimension involved, the theoretical development becomes more complicated. For simplicity, the theoretical development does not consider competing crops. The maximization of the net present value of returns is the combination of the profit maximization postulate with a multi-period production function allowing for the inclusion of price and interest rate expectations (Henderson and Quandt, 1980). The notation (Kruse, 2003, p.100-101) of the objective function is given by:

$$Max\ NPV^e = \sum_{t=k}^{n} \frac{p_t^e q_t^e - \sum_{i=1}^{s} w_{it}^e x_{it}}{(1+i^e)^{(t-1)}}\ \ subject\ to\ F(q_t, x_{1t}, \dots, x_{st}) = 0\ \forall\ t = k\ to\ n,$$

where the superscript denotes the expectation operator and the variables defined as

NPV:	Net present value,
p_t^e:	Price in year t,
q_t^e:	Quantity produced in year t,
w_{it}:	Price of input i in year t,
x_{it}:	Quantity of input i in year t and
i^e:	Expected average annualized interest rate over the t year period.

Assuming a continuous twice-differentiable objective function and a production function that is strictly convex for some optimal level of output, the following Langrangian can be formed:

$$L = \sum_{t=k}^{n} \frac{p_t^e q_t^e - \sum_{i=1}^{s} w_{it}^e x_{it}}{(1+i^e)^{(t-1)}} + \sum_{t=k}^{n} \lambda_t F(q_t, x_{1t}, \ldots, x_{st}).$$

The first order conditions imply the following n-k(s+2) equations in n-k(s+2) unknowns:

$$\frac{\partial L}{\partial q_t} = \frac{p_t + \lambda_t F_{qt}(q_t, x_{1t}, \ldots, x_{st})}{(1+i^e)^{(t-1)}} = 0 \; for \; t = k \; to \; n,$$

$$\frac{\partial L}{\partial x_{it}} = \frac{-w_{it}^e + \lambda_t F_{xit}(q_t, x_{1t}, \ldots, x_{st})}{(1+i^e)^{(t-1)}} = 0 \; for \; i = 1 \; to \; s \; and \; t = k \; to \; n \; and$$

$$\frac{\partial L}{\partial \lambda_t} = F(q_t, x_{1t}, \ldots, x_{st}) = 0 \; for \; t = k \; to \; n.$$

Simultaneous solution of these n(s+2) equations yields the following unconditional input demand equations:

$$x_{it}^* = x_{it}^*(w_{1k}^e, \ldots, w_{sk}^e, w_{1(k+1)}^e, \ldots w_{s(k+1)}^e, \ldots, w_{1t}^e, \ldots w_{st}^e, p_{k+1}^e, \ldots p_t^e, i^e).$$

Again noting the optimal supply, q_t^*, is a function of the optimal input quantities x_{it}^*, by substitution,

$$q_t^* = q_t^* (w_{1k}^e, \ldots, w_{sk}^e, w_{1(k+1)}^e, \ldots w_{s(k+1)}^e, \ldots, w_{1t}^e, \ldots w_{st}^e, p_{k+1}^e, \ldots p_t^e, i^e).$$

It is unrealistic to believe a producer to have specific profit expectations for each and every year over a potential 30 year time span, but it is likely that planting decisions are motivated by expectations reliant on previous price expectations and formulated at the time of the planting decision. Econometric theory suggests that a price expectation can be formulated using various weighting schema, such as geometric or polynomial distributed lags for past prices (Kruse, 2003). Although, it is difficult to assign a lag structure with true precision that provides for exact approximation of the price expectations formation. This is partially attributable to a production process where a perennial coffee tree may yield more cherries or beans each year until it reaches 9 to 15 years of age when its maximum productivity is reached and then declines for the remainder of its producing life (Coste, 1992). Consequently, several price lags might be necessary in the equation structure during the estimation process in order to allow the regression to capture the weights and then review those weights to observe if they follow along with a priori expectations (Parikh, 1979). Since a producer is expected to have only one price expectation based on prior experiences, the expected annualized average interest rate should be captured in the price expectation and is so forth dropped from the specification (Kruse, 2003). The proposed specification for the coffee area planted is then:

$$CFEAPA_t = f\left(\frac{CFEPFM_{t-1}}{CPINC}, \frac{CFEPFM_{t-2}}{CPINC}, \frac{CFEPFM_{t-3}}{CPINC}, \ldots, \frac{CFEPFM_{t-v}}{CPINC}, \right), \qquad (6.8)$$

where the variables are defined as

CFEAPA:	Coffee area planted,
CFEPFM:	Coffee farm price,
CPINC:	CPI deflator and
v:	Last historical year influencing price expectations.

The specification for tree removals is also derived from maximizing the net present value of expected net returns, excepting that the tree is usually older so the net present value is based on a shorter period of years. With coffee trees the removals often do not occur until the tree is over 30 years old (Ukers, 1922). Consequently, the specification for the removals is essentially the same as that for additions except that expected net present values covers a shorter period with no delay in results. The specification is then

$$CFEARM_t = f\left(\frac{CFEPFM_{t-1}}{CPINC}, \frac{CFEPFM_{t-2}}{CPINC}, \frac{CFEPFM_{t-3}}{CPINC}, \ldots, \frac{CFEPFM_{t-r}}{CPINC}, \right), \qquad (6.9)$$

where the variables are defined as

CFEARM:	Coffee area removed,
CFEPFM:	Coffee farm price,
CPINC:	CPI deflator and
r:	Last historical year influencing price expectations.

Assuming that it takes a minimum of three plus years for a coffee tree to begin producing, the identity from 6.7 becomes

$$CFEAHA = CFEAHA_{t-1} + CFEAPA_{t-3} + CFEARM \qquad (6.10)$$

Combining specifications from 6.8 and 6.9 into the identity given in equation 6.10 and noting that data on area planted and removals do not exist, the following ad hoc specification is implied:

$$CFEAHA_t = f\left(\frac{CFEPFM_{t-1}}{CPINC}, \ldots, \frac{CFEPFM_{t-3}}{CPINC}, \ldots, \frac{CFEPFM_{t-v}}{CPINC}, CFEAHA_{t-1}\right). \qquad (6.11)$$

The third year lag is displayed to emphasize that it is the most recent possible year of prices experienced when a coffee tree depending on the variety would have to be planted to enter production in time t. Therefore, the parameter estimate on the third year lag has the potential to be more significant than other lagged prices.

The theoretical derivation of yields follows exactly the same derivations of the area equation (Kruse, 2003). Referring to equation 6.2 and adding weather as a proxy for fixed water input, the specification of the yield equation is:

$$CFEYHA = f\left(\frac{CFEPFM}{CPINC}, \frac{CHMPFM}{CPINC}, \frac{FRTPFM}{CPINC}, \frac{LBRPFM}{CPINC}, \frac{FULPFM}{CPINC}, Weather\right).$$

where variables are defined as

CFEYHA:	Coffee yield per hectare,
CFEPFM:	Coffee farm price,
CHMPFM:	Chemicals price,
FRTPFM:	Fertilizer price,
LBRPFM:	Labor or wage price,
FULPFM:	Fuel and/or electricity (energy) price,
CPINC:	CPI deflator and
Weather:	Proxy for fixed water input.

Problems with this specification arise by two practicalities. The first is that international data on input prices in inconsistent and not effectively available for the construction of a complete time series. The second is attributable to the amount of technological advancement over the past three decades, which tends to have impacts that overwhelm the price effects. To more effectively include both impacts from technology and weather as well as recognize the limitations of the data, it becomes necessary to develop an alternative specification. From observing available data it is obvious that impacts from weather are both moderate and severe dependent on the year and country. To capture these impacts a historical trend is used in combination with four indicator variables as a proxy for annual weather effects resulting in a specification (Brown et al., 2009) that is:

$$Yield = f(TREND, CFEGW1, CFEGW2, CFEBW1, CFEBW2), \qquad (6.12)$$

where the variables are defined as

TREND:	Technology trend,
CFEGW1:	Indicator variable, proxy for a moderately favorable weather year,
CFEGW2:	Indicator variable, proxy for a very favorable weather year,
CFEBW1:	Indicator variable, proxy for a less unfavorable weather year,
CFEBW2:	Indicator variable, proxy for a very unfavorable weather year.

Consumer Demand

For coffee the most important estimated behavioral demand equation is domestic consumption, which includes the combined demand for roasted coffee and soluble processed coffee. The theoretical development of the specification for this equation proceeds from the assumption of the behavioral postulate of utility maximization, whereas a "rational consumer" desires to purchase a combination, or bundle of goods from which he derives the highest level of satisfaction, but is limited by his available income (Henderson and Quandt, 1980). In matrix notation (Kruse, 2003) this behavioral postulate is expressed as:

$$Max\ U(x) subject\ to\ p'x = m,$$

where the variables are defined as

U(x):	Utility of a given bundle x,
p:	Vector of prices corresponding to each good, x_i, in bundle x,
x:	Vector of quantities of goods and
m:	Available income.

Assuming a continuous twice-differentiable objective function and well behaved indifference curves that are strictly convex, the following Langrangian can be formed:

$$L(x,\lambda) = \mathrm{U(x)} - \lambda[\mathrm{p'x} - \mathrm{m}].$$

The first order conditions are

$$\frac{\partial L}{\partial x_i} = U_i(x) - \lambda p_i = 0 \; for \; i = 1 \; to \; n \; and$$

$$\frac{\partial L}{\partial \lambda} = -[p'x - m] = 0.$$

Simultaneous solution of these (n+1) equations yields consumer demand equations of the following form:

$$x_n^* = x_n^*(p_1, \ldots, p_n, m). \qquad (6.13)$$

There is a considerable amount of literature on estimating demand systems that impose regularity conditions applicable at the individual consumer level to aggregate consumption (Stone, 1954; Deaton and Muellbauer, 1980a; Varian, 1983). A problem is that almost all of the demand systems produce cross price elasticities with signs contrary to a priori expectations and simulate poorly (Brandt, et al., 1985). This conclusion was not found to be inconsistent with the developers of the famous Almost Ideal Demand System (AIDS). After application of the AIDS model in various commodity settings, Deaton and Muellbauer (1980b) concluded by stating, “modeling detailed commodity demands is best done within a single equation context”.

An interesting point to note for the specification used in for domestic consumption is that it is solved using the farm price. This places the primary demand equation at the farm level, whereas the demand equation in a more pure form at the farm price level would be a derived demand from a retail level. This study does not detail the retail price level, therefore the domestic consumption specification is an imposed retail specification at the farm price level. Consequently, this equation would be construed as a hybrid specification, whereas additional refinement at the retail price level may be generated in future iterations of research.

When applying equation 6.13 the specification for domestic consumption of coffee is

$$\frac{CFEUDC}{NNATT} = f\left(\frac{CFEPFM}{CPINC}, \frac{GDRNC}{NNATT}, TREND\right), \qquad (6.14)$$

where the variables are defined as

CFEUDC:	Total coffee consumed domestically,
NNATT:	Population,
CFEPFM:	Coffee farm price,
CPINC:	CPI deflator,
GDRNC:	Real GDP and
TREND:	Taste/preference trend.

Upon applying this specification, elasticities for price or income in select countries when estimated did not follow a priori expectations, which affected consumption significantly. Imposing elasticities from cross sectional studies was an appealing approach, but such studies do not exist for every country. As a result a combination of methods were applied to achieve a functional system of equations including ordinary least squares multiple regression with graphical analysis, elasticities from cross sectional studies and imposing synthetic elasticities using best fit root mean square error analysis when other means were expended.

Stock Holding

Coffee is a perishable yet storable commodity, and stock holdings have become an increasingly less significant portion of coffee production since the early 1990's when the last active quota system was suspended in 1989 under the International Coffee Agreement. Despite the decreasing trend in coffee stock holdings, inventory accumulation remains an important aspect in understanding the behavior of agents in the coffee sector. The process of inventory formation can vary depending on what level in the value chain the inventories are held, whether by the producer, consumer or speculator (Labys, 1973). The common motives for inventory accumulation include precautionary, speculative and transaction demand.

The advancement of the basic accelerator theory into the modified flexible accelerator allows for the inclusion of all three common motives for stock holding. Transaction demand was encompassed in the basic accelerator model as empirically tested by Abramovitz (1951), which postulated that inventories varied at a constant with output or production such as:

$$S_t = (\beta) QP_t, \ \ 0 < \beta < 1, \qquad (6.15)$$

where the variables are defined as

S_t:	Stocks,
QP_t:	Quantity produced and
β:	Constant.

The primary criticism of the basic accelerator model is that its rigidity failed to incorporate the minimum lags between changes in output to changes in stock levels (Goodwin, 1947). The modification of the basic accelerator model by Goodwin (1947) to incorporate the stickiness or lag of adjusting inventories to the desired level assisted to establish the “flexible accelerator model” which assumes that agents will only partially be able to adjust to a new desired level of inventory. Goodwin (1948) assumed that the inability of agents to respond fully to the new desired level of inventory could be attributed to transaction costs associated with changing the level of stocks and problems associated with the heterogeneous nature of stock where items may have infrequent intervals at which they can be ordered. This modification of the basic accelerator model 6.14 to include desired stocks as a function of output where stocks in any one period may be adjusted by only a fraction δ of the desired level S_t* is reflected in the equation:

$$\Delta S_t = S_t - S_{t-1} = \delta(S_t^* - S_{t-1}) = \delta\alpha_0 + \delta\beta_1 QP_t - \delta S_{t-1} \qquad (6.16)$$

While adding S_{t-1} to both sides of this equation yields the theoretical flexible inventory formation relationship

$$S_t = \delta\alpha_0 + \delta\beta_1 QP_t + (1 - \delta)S_{t-1} \qquad (6.17)$$

The basic accelerator theory and the flexible accelerator both encompass elements of transaction and precautionary motives for holding stocks. This still leaves the theory deficient of speculative motives for inventory accumulation. An additional modification to the flexible accelerator theory by Lovell (1961) attempted to incorporate the speculative reaction of agents holding stocks to future price movements. He progressed that agents would attempt to adjust the level of inventory holding in anticipation of price changes P_t* given as:

$$P_t^* = \left(\frac{P_t - P_{t-1}}{P_t}\right) \qquad (6.18)$$

If following Goodwin (1947), actual stocks are assumed to result from only a partial adjustment and including a residual e_t to capture any variables omitted from the analysis then combining 6.17 and 6.18 would result in the equation:

$$S_t = \delta\alpha_0 + \delta\beta_1 QP_t + \delta\beta_2 \left(\frac{P_t - P_{t-1}}{P_t}\right) + (1 - \delta)S_{t-1} + e_t \qquad (6.19)$$

Another modification to the modified flexible accelerator to integrate the speculative demand motive was to replace the expected price variable with a futures price (Labys, 1975). The challenge of this substitution in projecting the equation is that futures prices would preferably need to be endogenous into the model (Labys, 1975), which would add another layer of complexity, whereas underlying variables that affect futures prices outside of fundamental supply and demand variables may also need to be projected to capture differences between the futures prices and cash prices. One difference includes adjustments in the futures market that center upon speculative and hedging activity. An example given by Labys (1975) included net long commitments versus net short commitments, where it was admitted that these data are not consistently available in all markets. The addition of expected price whether using a partial adjustment framework as suggested by Lovell (1961) or a futures price as suggested by Labys (1975) is compelling. In both cases problems arise in that additional complexity in the independent variables decreases the transparency and intuitive understanding of which variables or parts of the variable has a significant cause and effect relationship to the dependent variable. To simplify and yet still incorporate all three common motives of inventory accumulation and stock holding behavior of precautionary, transaction and speculative demand an ad hoc modification of the modified flexible accelerator is used to yield the following specification:

$$CFECOT = f\left(\frac{CFEPFM}{CPINC}, CFESPR, CFESPR_{t+1}, CFECOT_{t-1}\right) \quad (6.20)$$

where the variables are defined as

CFECOT: Coffee ending stocks,
CFEPFM: Coffee farm price,

CPINC: CPI deflator and
CFESPR: Coffee production.

Whereas coffee production in t+1 is substituted for future price expectations insomuch that the production function uses only lag prices allowing the model to still have a convergent fluctuation and solve to equilibrium. With this specification one could either allow the equation to estimate the parameters without restriction or impose a specific synthetic relationship among the parameter estimates.

The theoretical development described in this chapter provides general specifications applicable to the key equations in the coffee model. These specifications were developed in the absence of government policies that affect both prices and trade variables. The next chapter re-emphasizes the model structure progressed here and also adds definition of model closure conditions used in the estimation of the coffee sector. Policy implications for specification will be discussed in Chapter 8.

CHAPTER 7 MODEL STRUCTURE, MODEL CLOSURE, AND ESTIMATION TECHNIQUE

Following the specifications progressed in Chapter 6, this chapter is developed to present structure for how the equations are interrelated, discuss how each country model is closed as well as how the global system is closed, and briefly further the estimation technique previously discussed in Chapter 5 used to estimate the equations.

Model Structure

A system of structural equations is defined by the set of equations that correspond to the relevant grouping of either supply or demand. For the coffee sector, the equations below represent the relevant structural framework.

Beginning Stocks = Ending Stocks$_{t-1}$

Production = Harvested Area * Yield

Total Supply = Beginning Stocks + Production + Imports

Total Demand = Domestic Consumption + Exports + Ending Stocks

This structural format forms the basis of the relationships among the equations for the coffee sector within any given country. Since these equations form the identities common to coffee, they are not presented by country for each crop in the estimation results reported in Chapters 8 and 9.

Model Closure

The previous structural format does not address the issue of relationships among countries. As presented in Chapter 6, if trade among countries is permitted, then prices among countries should be related. By choosing one country as the residual supplier, where the price is equilibrated, the price from this country may then be linked to every other trading country using a price linkage equation including relevant trade barriers such as tariffs, taxes and exchange rates where applicable. Table 7-1, illustrates how the relationship among countries are modeled in this thesis. The table does not strictly represent the entire historical trade relationship, but only from the last ten to twenty years due to the last active quota International Coffee Agreement expiring in 1989. The table therefore represents how the relationships are modeled for the purpose of simulating the model into the future and deriving impact analysis.

Coffee Model Closure	
Brazil	Residual Supplier
Columbia	Price Linkage
European Union	Price Linkage
Honduras	Price Linkage
India	Price Linkage
Indonesia	Price Linkage
Japan	Price Linkage
Mexico	Price Linkage
United States	Price Linkage
Vietnam	Price Linkage

Table 7-1 Model closure

For the residual supplier country price is determined by equating total supply and demand, whereas total demand includes net export demand that results from the aggregation of net trade paths from all the other countries. Chapter 8 further details the price linkage equations used in the country models.

Estimation Techniques

Estimation of the specifications developed in Chapter 6 have been performed using ordinary least squares multiple regression analysis in the estimation software, Simetar©, which is an add-in to Excel© that was developed by professors associated with the Agricultural and Food Policy Center in the Department of Agricultural Economics at Texas A&M University. When considering the simultaneous nature of the structural system, the opportunity to incorporate other estimation techniques such as two-stage or three-stage least squares may have been an option. The concern arises that with limited data observations of 30 or less depending on the country that even though the application of two-stage or three-stage least squares is possible, the choice of instruments could be made so that results were nearly identical to ordinary least squares. The potential to impact the outcome of the other estimation techniques also increases the opportunity for unproductive application.

The principal objective of this thesis as addressed in Chapter 1 is to produce a rigorous global econometric model of the coffee sector for the purpose of simulation including the opportunity for policy analysis. Consequently, emphasis has been placed on the signs of parameter estimates and the derived elasticities from the estimated equations instead of strict adherence to statistical regression diagnostics. In select instances synthetic equations were established by imposing elasticities when the statistical estimation produced results that conflicted with a priori expectations. Also in a few specific equations indicator variables were used to dummy out the effects of one or more observations that significantly change the equation elasticities from a priori expectations. Whenever possible, equations were estimated statistically.

Following the estimation process, the equations were simulated historically by country and for the whole international coffee model. The results are discussed in Chapter 9. Both static and dynamic historic simulations were performed over the 1995 to 2009 period. The simulation performance helped to provide useful insight into areas of weakness in the model.

CHAPTER 8 ESTIMATION RESULTS FOR EQUATIONS

This chapter summarizes the results of estimating the structural equations for each country as applicable. The development of the estimated equations in this chapter is organized by country and then by type of equation within the country.

A standardized mnemonic coding system was used to shorten the variable names and make the equations easier to compare across countries. When possible, the equation report format has been standardized to help the reader make comparisons among equations. One important deviation from other more traditional reporting of equation results is the listing of p-values instead of t-values. This is due to a component of arbitrariness associated with the classical approach of using t-values, attributable to the significance level preferred, which is dependent on the researcher and the application (Wooldridge, 2009). Whereas, the "p-value is the probability of observing the *t* statistic as extreme as we did *if the null hypothesis is true*" (Wooldridge, 2009, p. 133), thus P-values nicely summarize the strength or weakness of the empirical evidence against the null hypothesis. This makes p-values a nice alternative to determine the statistical significance of a parameter estimate.

In the next section of this chapter the final iteration in the estimation of the principal coffee equations is detailed. Alternative specifications and system structures were applied in earlier estimations. For example, the supply equations of area and yield were re-estimated multiple times as better specifications were discovered.

It should also be noted that some equations were re-estimated upon results of simulation. In select instances, equations were modified with indicator variables to develop elasticities that create better model simulation results as well as incorporate a priori expectations.

Brazil

Area Harvested

Coffee area harvested in Brazil was estimated as a function of the deflated price of coffee in t-1 and the deflated average price of t-4 and t-5 and lag area. The average price of t-4 and t-5 represents the gestation time for coffee plants to mature as the time lag from planting to harvesting is a minimum of 3 to 6 years. This lagged price was found as significant in Brazil, and as the largest exporter of coffee, the average price of t-4 and t-5 was applied in all area harvested equations in the system. The parameter signs for 8.1.1 were consistent with a priori expectations and the R-square and Durbin Watson were reasonable. Lag area elasticity was deemed too high under simulation and was consequently imposed.

Equation 8.1.1. Coffee area harvested in Brazil, CFEAHABR					
Estimation Period: 1985-2009					
	Parameter Estimate		p-value		Elasticity
Intercept	191232.22		0.211		
(CFEPARBR*XRNUSBR/CPINCBR)t-1	38403.785		0.003		0.044
(CFEAHABR)t-1	0.768		0.000		0.773*
(CFEPARBR*XRNUSBR/CPINCBR)avg.t-4,t-5	89547.408		0.000		0.103
Performance Statistics					
R-square= 0.938	D.W.=	1.848		RMSE=	85556
*imposed elasticity = .579				RMSE%**=	5.6
**RMSE% = after any elasticities were imposed					

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price, US dollars per 60kg bag.
XRUNUSBR	Exchange rate into Brazilian local currency from US dollars.
CPINCBR	CPI deflator in Brazil, index.
CFEAHABR	Coffee area harvested in Brazil, hectares.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.1.2. Coffee yield in Brazil, CFEYHABR					
Estimation Period: 1988-2009					
	Parameter Estimate		p-value		Elasticity
Intercept	0.003		0.012		
YEAR	0.001		0.000		0.791
CFEGW1BR	0.001		0.001		0.012
CFEGW2BR	0.004		0.001		0.055
CFEBW1BR	-0.001		0.001		-0.004
CFEBW2BR	-0.003		0.001		-0.026
Performance Statistics					
R-square= 0.940	D.W.=	2.471		RMSE=	0.001
**RMSE% = after any elasticities were imposed				RMSE%**=	6.7

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1BR	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2BR	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1BR	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2BR	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in Brazil was estimated as a function of deflated coffee price and per capita income. The own price elasticity was within a priori expectations, although the income elasticity was deemed too high during simulation and was imposed. The R-square was acceptable, but the Durbin-Watson was low indicating autocorrelation problems prior to the imposing the income elasticity variable.

Equation 8.1.3. Coffee domestic consumption per capita in Brazil, CFEUDCBR/NNATTBR						
Estimation Period: 1994-09						
		Parameter Estimate		p-value		Elasticity
Intercept		-21.487		0.144		
CFEPARBR*XRNUSBR/CPINCBR		-4.712		0.039		-0.152
GDRNCBR/NNATTBR		2.711E+12		0.000		1.427*
Performance Statistics						
R-square= 0.913		D.W.=	0.658		RMSE=	3.386
*imposed elasticity = .214					RMSE%**=	10.5
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
XRUNUSBR	Exchange rate into Brazilian local currency from US dollars.
CPINCBR	CPI deflator, Brazil, index.
GDRNCBR	Real GDP in Brazil, billion Brazilian local currency.
NNATTBR	Population in Brazil, million people.

Ending Stocks

Ending stocks in Brazil was estimated as a function of deflated own price, production, production in t+1 and lag stocks. The R-square was reasonable with the Durbin-Watson falling marginally lower than preferred, but still within the acceptable range. The equation was found to respond very poorly under simulation and the only elasticity that was not imposed was the own price.

Equation 8.1.4. Coffee ending stocks in Brazil, CFECOTBR						
Estimation Period: 1980-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		7241.736		0.123		
(CFEPARBR*XRNUSBR/CPINCBR)		-295.173		0.461		-0.062
CFESPRBR		0.300		0.000		0.756*
(CFESPRBR)t+1		-4.040		0.000		-1.042*
(CFECOTBR)t-1		0.767		0.000		0.777*
Performance Statistics						
R-square= 0.849		D.W.=	1.582		RMSE=	2491
*imposed elasticity = .232; -.639; .587					RMSE%**=	33.5
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
XRUNUSBR	Exchange rate into Brazilian local currency from US dollars.
CPINCBR	CPI deflator, Brazil, index.
CFESPRBR	Coffee production in Brazil, thousand 60kg bags.
CFECOTBR	Coffee ending stocks in Brazil, thousand 60kg bags.

Market Clearing Price

As the largest exporter of coffee and having a fairly direct price transmission, Brazil was chosen as the residual supplier for the coffee sector. Therefore, the world price was determined within Brazil based on the import demands for the rest of the world. The farm price of coffee was solved for within the Brazilian model based on the next export path resulting from other country demands. Equation 8.1.5 reflects the market clearing identity which was used to determine price in the simultaneous solution.

Equation 8.1.5. Coffee farm price in Brazil, CFEPARBR
Market Clearing Identity

LAG(CFECOTBR)+CFESPRBR=CFEUDCBR+CFECOTBR+CFEUXTBR

Variable Name	Definition
CFECOTBR	Coffee ending stocks in Brazil, thousand 60kg bags.
CFESPRBR	Coffee production in Brazil, thousand 60kg bags.
CFEUDCBR	Coffee domestic consumption in Brazil, thousand 60kg bags.
CFEUXTBR	Coffee net exports in Brazil, thousand 60kg bags.

Colombia

Area Harvested

Coffee area harvested in Colombia was estimated as a function of lag deflated price of coffee in t-1 and the lag deflated average price of t-4 and t-5 and lag area. The parameter signs for 8.2.1 were consistent with a priori expectations and the R-square and Durbin Watson were reasonable, although the lag area elasticity was deemed too high under simulation and was consequently imposed.

Equation 8.2.1. Coffee area harvested in Colombia, CFEAHACO						
Estimation Period: 1990-2008						
	Parameter Estimate			p-value		Elasticity
Intercept		91743.825		0.350		
(CFEPARCO*XRNUSCO/CPINCCO)t-1		6.028		0.851		0.021
(CFEAHACO)t-1		0.802		0.001		0.814*
(CFEPARCO*XRNUSCO/CPINCCO)avg.t-4,t-5		13.963		0.565		0.054
Performance Statistics						
R-square= 0.809		D.W.=	1.874		RMSE=	52530
*imposed elasticity = .569					RMSE%**=	6.5
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARCO	Coffee Arabica farm price in Colombia, US dollars per 60kg bag.
XRUNUSCO	Exchange rate into Colombian local currency from US dollars.
CPINCCO	CPI deflator in Colombia, index.
CFEAHACO	Coffee area harvested in Colombia, hectares.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.2.2. Coffee yield in Colombia, CFEYHACO						
Estimation Period: 1988-2009						
	Parameter Estimate			p-value		Elasticity
Intercept		0.014		1.94E-13		
YEAR		1.113E-05		0.723		0.015
CFEGW1CO		0.001		0.061		0.025
CFEGW2CO		0.003		0.000		0.032
CFEBW1CO		-0.002		0.068		-0.006
CFEBW2CO		-0.003		0.000		-0.034
Performance Statistics						
R-square= 0.857		D.W.=	2.133		RMSE=	0.001
**RMSE% = after any elasticities were imposed					RMSE%**=	5.7

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1CO	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2CO	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1CO	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2CO	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in Colombia was estimated as a function of deflated coffee price, per capita income and a trend. The original estimation did not provide the correct sign. To overcome this problem an income elasticity of .410 was incorporated from Akiyama & Varangis (1990). Once the variable was removed and re-estimated the own-price elasticity provided the correct sign as well producing a good R-square and the Durbin-Watson was reasonable. The trend elasticity was deemed too high under simulation and was imposed.

Equation 8.2.3. Coffee domestic consumption per capita in Colombia, CFEUDCCO/NNATTCO						
Estimation Period: 1998-2008						
		Parameter Estimate		p-value		Elasticity
Intercept		68.184		0.000		
CFEPARCO*XRNUSCO/CPINCCO		-0.003		0.178		-0.367
GDRNCCO/NNATTCO		.0018***				0.410***
TREND		-1.587		0.000		-1.729*
Performance Statistics						
R-square= 0.896		D.W.=	2.646		RMSE=	2.264
*imposed elasticity = -.659					RMSE%**=	9.3
**RMSE% = after any elasticities were imposed						
***imposed using elasticity from another study						

Variable Name	Definition
CFEPARCO	Coffee Arabica farm price in Colombia, US dollars per 60kg bag.
XRUNUSCO	Exchange rate into Colombian local currency from US dollars.
CPINCCO	CPI deflator, Brazil, index.

TREND Indicator variable equal to 1 in 1980, 2 in 1981, etc.

Coffee Farm Price

Colombia's coffee farm price was simply estimated as a function of the Brazilian coffee farm price. All prices in this system were reported in U.S. dollars simplifying the price linkage equations to a direct price relationship as exchange differences are implicit in the reported prices. Trade barriers such as import tariffs and value added taxes were excluded in the price linkage equation as statistical performance declined in every case that estimation results were compared across attempts to estimate price transmission with and without the trade barriers. The parameter sign and elasticity for Colombia were above 1, indicating more variation in the Colombian farm price compared to the Brazilian farm price. Not surprisingly there was some autocorrelation in the error terms, but for this type of equation it was ignored.

Equation 8.2.4. Coffee farm price in Colombia, CFEPARCO						
Estimation Period: 1989-2007						
		Parameter Estimate		p-value		Elasticity
Intercept		-18.639		0.239		
CFEPARBR		1.102		0.000		1.185
Performance Statistics						
R-square= 0.795		D.W.=	0.656		RMSE=	18.209
**RMSE% = after any elasticities were imposed					RMSE%**=	20.9

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.

Net Trade Identity

The Colombian coffee model was linked to the world price through the price linkage equation allowing net exports to be determined as the difference between supply and demand. Equation 8.2.5 documents the market clearing identity for the Colombian coffee sector. The net trade position of Colombia was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.2.5. Coffee net exports in Colombia, CFEUXTCO
Identity

CFEUXTCO=LAG(CFECOTCO)+CFESPRCO-CFEUDCCO-CFECOTCO

Variable Name	Definition
CFECOTCO	Coffee ending stocks in Colombia, thousand 60kg bags.
CFESPRCO	Coffee production in Colombia, thousand 60kg bags.
CFEUDCCO	Coffee domestic consumption in Colombia, thousand 60kg bags.

European Union

Domestic Consumption

Domestic consumption per capita in the European Union was estimated as a function of deflated coffee price and per capita income. The original estimation did not provide the correct sign. To overcome this problem a weighted average own price elasticity of -.143 was incorporated from reported elasticities for European countries by Akiyama & Varangis (1990). Once the variable was removed and re-estimated the income elasticity provided the correct sign, although the R-square was poor and the Durbin-Watson was low indicating potential problems with autocorrelation. Considering the issue of estimating this equation prior to using a borrowed elasticity, the parameter sign and elasticity was accepted as a starting point. The income elasticity was deemed too high under simulation and was modestly reduced and imposed.

Equation 8.3.1. Coffee domestic consumption per capita in the European Union, CFEUDCEU/NNATTEU						
Estimation Period: 1980-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		72.375		0.000		
CFEPARBR*XRNUSEU/CPINCEU		-0.157***				-0.143***
GDRNCEU/NNATTEU		333.348		0.001		0.449*
Performance Statistics						
R-square= 0.312		D.W.=	0.701		RMSE=	10.314
*imposed elasticity = .407					RMSE%**=	9.5
**RMSE% = after any elasticities were imposed						
***imposed using elasticity from another study						

Variable Name	Definition
GDRNCEU	Real GDP in the European Union, billion EU currency.
NNATTEU	Population in the European Union, million people.

Net Trade Identity

The European Union coffee model was linked to the world price by using the Brazilian farm price and exchange rated into the country. As the European Union had no reported green coffee production, no producer price was available. In future research a retail price may be linked to the world price, but for this study the residual world price for the model was adjusted to real local currency units and used as a proxy for the European Union's price. Since, the European Union had no trade barriers to green coffee, the world price was not impacted by an import tariff, and was able to be exchanged rated directly into local currency units and deflated for the behavioral equations. Net exports for the European Union were determined as the difference between supply and demand. Equation 8.3.2 documents the market clearing identity for the coffee sector. The net trade position of the European Union was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.3.2. Coffee net imports in the European Union, CFESMTEU

Identity

CFESMTEU= CFEUDCEU+CFECOTEU-LAG(CFECOTEU)-CFESPREU

Variable Name	Definition
CFECOTEU	Coffee ending stocks in the European Union, thousand 60kg bags.
CFESPREU	Coffee production in the European Union, thousand 60kg bags.
CFEUDCEU	Coffee domestic consumption in the European Union, thousand 60kg bags.

Honduras

Area Harvested

Coffee area harvested in Honduras was estimated as a function of lag deflated price of coffee in t-1 and the lag deflated average price of t-4 and t-5, lag area and a trend. The parameter signs for 8.4.1 were consistent with a priori expectations and the R-square and Durbin Watson were reasonable. The trend elasticity was deemed too high under simulation and was consequently imposed. One concern for this equation was the insignificance in the lag deflated average price of t-4 and t-5 variable. It is possible that selection of different lag price structure would be better, or the removal of the second lag price may be necessary in future research to obtain better statistical significance and simulation performance.

Equation 8.4.1. Coffee area harvested in Honduras, CFEAHAHO					
Estimation Period: 1985-2008					
	Parameter Estimate		p-value		Elasticity
Intercept	50444.075		0.019		
(CFEPARHO*XRNUSHO/CPINCHO)t-1	376.488		0.260		0.046
(CFEAHAHO)t-1	0.271		0.309		0.264
(CFEPARHO*XRNUSHO/CPINCHO)avg.t-4,t-5	3.100		0.992		0.0003
TREND	4422.872		0.017		0.417*
Performance Statistics					
R-square= 0.955	D.W.=	1.938		RMSE=	9922
*imposed elasticity = .004				RMSE%**=	17.2
**RMSE% = after any elasticities were imposed					

Variable Name	Definition
CFEPARHO	Coffee Arabica farm price in Honduras, US dollars per 60kg bag.
XRUNUSHO	Exchange rate into Honduran local currency from US dollars.
CPINCHO	CPI deflator in Honduras, index.
CFEAHAHO	Coffee area harvested in Honduras, hectares.
TREND	Indicator variable equal to 1 in 1980, 2 in 1981, etc.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.4.2. Coffee yield in Honduras, CFEYHAHO						
Estimation Period: 1980-2009						
	Parameter Estimate			p-value		Elasticity
Intercept		0.011		0.000		
YEAR		0.0001		0.000		0.144
CFEGW1HO		0.001		0.000		0.024
CFEGW2HO		0.003		0.000		0.013
CFEBW1HO		-0.002		0.000		-0.012
CFEBW2HO		-0.003		0.000		-0.015
Performance Statistics						
R-square= 0.928		D.W.=	1.726		RMSE=	0.001
**RMSE% = after any elasticities were imposed					RMSE%**=	3.6

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1CO	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2CO	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1CO	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2CO	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in Honduras was estimated as a function of deflated coffee price, per capita income, a dummy variable in 2001 and a shift variable for 2002 and forward. The own price elasticity was within a priori expectations, although income elasticity was deemed too high under simulation and was consequently imposed. The R-square indicates that the equation performance was below average, and the Durbin-Watson was low as well drawing concern about autocorrelation. However, the parameter signs met a priori expectations and once the income elasticity was imposed the equation performed reasonably under simulation.

Equation 8.4.3. Coffee domestic consumption per capita in Honduras, CFEUDCHO/NNATTHO						
Estimation Period: 1980-2009						
	Parameter Estimate			p-value		Elasticity
Intercept		27.278		0.150		
CFEPARHO*XRNUSHO/CPINCHO		-0.090		0.522		-0.054
GDRNCHO/NNATTHO		0.914		0.419		.420*
DUMMY01		17.779		0.004		0.016
SHIFT 02		-14.788		0.005		-0.104
Performance Statistics						
R-square= 0.662		D.W.=	1.043		RMSE=	4.935
*imposed elasticity = .071					RMSE%**=	12.9
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARHO	Coffee Arabica farm price in Honduras, US dollars per 60kg bag.
XRUNUSHO	Exchange rate into Honduran local currency from US dollars.
CPINCHO	CPI deflator, Honduras, index.
GDRNCHO	Real GDP in Honduras, billion Honduran local currency.
NNATTHO	Population in Honduras, million people.
DUMMY 01	Indicator variable equal to 1 in 2001, 0 otherwise.
SHIFT 02	Indicator variable equal to 1 from 2002 forward, 0 otherwise.

Coffee Farm Price

The Honduras coffee farm price was simply estimated as a function of the Brazilian coffee farm price. The R-square indicated that the equation fit fairly well and the parameter sign was correct as well as statistically significant. With this type of equation a low Durbin-Watson was ignored similar to before. The price transmission elasticity was below 1 indicating that Honduras farm prices move at a lower level than the Brazilian farm price, which may be attributed to how the farmgate price was reported to the ICO by the member nation. Another potential reason was that an elasticity below 1 represents some possible rigidity in the local markets, which suggest that the full impact of a world price was not transmitted to the local markets.

Equation 8.4.4. Coffee farm price in Honduras, CFEPARHO						
Estimation Period: 1989-2006						
	Parameter Estimate			p-value		Elasticity
Intercept		21.087		0.044		
CFEPARBR		0.674		0.000		0.759
Performance Statistics						
R-square= 0.774		D.W.=	0.924		RMSE=	14.705
**RMSE% = after any elasticities were imposed					RMSE%**=	15.3

Variable Name — Definition

CFEPARBR — Coffee Arabica farm price in Brazil, US dollars per 60kg bag.

Net Trade Identity

The Honduras coffee model was linked to the world price through the price linkage equation allowing net exports to be determined as the difference between supply and demand. Equation 8.4.5 documents the market clearing identity for the Honduran coffee sector. The net trade position of Honduras was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.4.5. Coffee net exports in Honduras, CFEUXTHO
Identity

CFEUXTHO=LAG(CFECOTHO)+CFESPRHO-CFEUDCHO-CFECOTHO

Variable Name	Definition
CFECOTHO	Coffee ending stocks in Honduras, thousand 60kg bags.
CFESPRHO	Coffee production in Honduras, thousand 60kg bags.
CFEUDCHO	Coffee domestic consumption in Honduras, thousand 60kg bags.

India

Area Harvested

Coffee area harvested in India was estimated as a function of lag deflated price of coffee in t-1, the lag deflated average price of t-4 and t-5 and lag area. The parameter signs for 8.5.1 were consistent with a priori expectations and the R-square is reasonable, although the Durbin Watson was high drawing potential concerns about negative autocorrelation. However, with the high R-square and statistically significant variables the equation ran well under simulation and did not need any further adjustment.

Equation 8.5.1. Coffee area harvested in India, CFEAHAIN					
Estimation Period: 2000-2008					
	Parameter Estimate		p-value		Elasticity
Intercept	13955.633		0.016		
(CFEPRBIN*XRNUSIN/CPINCIN)t-1	515.594		0.062		0.046
(CFEAHAIN)t-1	0.516		0.006		0.505
(CFEPRBIN*XRNUSIN/CPINCIN)avg.t-4,t-5	214.994		0.281		0.022
Performance Statistics					
R-square= 0.912	D.W.=	3.013		RMSE=	4290
**RMSE% = after any elasticities were imposed				RMSE%**=	1.3

Variable Name	Definition
CFEPRBIN	Coffee Robusta farm price in India, US dollars per 60kg bag.
XRUNUSIN	Exchange rate into Indian local currency from US dollars.
CPINCIN	CPI deflator in India, index.
CFEAHAIN	Coffee area harvested in India, hectares.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.5.2. Coffee yield in India, CFEYHAIN						
Estimation Period: 1980-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		0.011		0.000		
YEAR		9.2121E-05		0.000		0.109
CFEGW1IN		0.002		0.014		0.004
CFEGW2IN		0.003		0.000		0.062
CFEBW1IN		-0.001		0.000		-0.014
CFEBW2IN		-0.003		0.000		-0.033
Performance Statistics						
R-square= 0.952		D.W.=	1.733		RMSE=	0.001
**RMSE% = after any elasticities were imposed					RMSE%**=	4.0

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1IN	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2IN	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1IN	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2IN	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in India was estimated as a function of deflated coffee price, per capita income and a trend. The signs of the parameters and own price elasticity was within a priori expectations helping to produce a reasonable R-square and Durbin-Watson, and although the income elasticity at the mean was lower than the own price elasticity, this was not the case for the shorter, near-term elasticity. The equation responded reasonably under simulation and was not modified.

Equation 8.5.3. Coffee domestic consumption per capita in India, CFEUDCIN/NNATTIN						
Estimation Period: 1984-1999						
	Parameter Estimate			p-value		Elasticity
Intercept		1.969		0.016		
CFEPRBIN*XRNUSIN/CPINCIN		-0.007		0.083		-0.249
GDRNCIN/NNATTIN		0.009		0.914		0.124
TREND		-0.056		0.222		-0.669
Performance Statistics						
R-square= 0.849		D.W.=	2.269		RMSE=	0.119
**RMSE% = after any elasticities were imposed					RMSE%**=	9.6

Variable Name	Definition
CFEPRBIN	Coffee Robusta farm price in India, US dollars per 60kg bag.
XRUNUSIN	Exchange rate into Indian local currency from US dollars.
CPINCIN	CPI deflator, India, index.
GDRNCIN	Real GDP in India, billion Indian local currency.
NNATTIN	Population in India, million people.
TREND	Indicator variable equal to 1 in 1980, 2 in 1981, etc.

Coffee Farm Price

Indian coffee farm price was simply estimated as a function of the Brazilian coffee farm price. The price transmission elasticity was below 1 indicating that the Indian farm price remains at a lower level versus the Brazilian farm price. This was partially attributable to the lead coffee price being a Robusta price in India as opposed an Arabica price from Brazil, whereas Robusta prices typically trade at a lower level than Arabica.

Equation 8.5.4. Coffee farm price in India, CFEPRBIN						
Estimation Period: 19						
	Parameter Estimate			p-value		Elasticity
Intercept		31.676		0.113		
CFEPARBR		0.704		0.001		0.704
Performance Statistics						
R-square= 0.567		D.W.=	0.474		RMSE=	24.921
**RMSE% = after any elasticities were imposed					RMSE%**=	14.9

Variable Name Definition

CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.

Net Trade Identity

The Indian coffee model was linked to the world price through the price linkage equation allowing net exports to be determined as the difference between supply and demand. Equation 8.5.5 documents the market clearing identity for the Indian coffee sector. The net trade position of India was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.5.5. Coffee net exports in India, CFEUXTIN
Identity

CFEUXTIN=LAG(CFECOTIN)+CFESPRIN-CFEUDCIN-CFECOTIN

Variable Name	Definition
CFECOTIN	Coffee ending stocks in India, thousand 60kg bags.
CFESPRIN	Coffee production in India, thousand 60kg bags.
CFEUDCIN	Coffee domestic consumption in India, thousand 60kg bags.

Indonesia

Area Harvested

The Indonesian equations use the Brazilian price as the own prices variable converted into deflated, local currency units, because the producer price from the ICO had not been reported since 2005, and no other sources were found. Coffee area harvested in Indonesia was estimated as a function of lag deflated price of coffee in t-1, the lag deflated average price of t-4 and t-5 and lag area. The parameter signs for 8.6.1 were consistent with a priori expectations and the R-square and the Durbin-Watson were reasonable. The lag area elasticity was deemed too high under simulation and was consequently imposed.

Equation 8.6.1. Coffee area harvested in Indonesia, CFEAHAID						
Estimation Period: 1983-2008						
		Parameter Estimate		p-value		Elasticity
Intercept		74927.997		0.007		
(CFEPARBR*(1-CFEGITID)*XRNUSID/CPINCID)t-1		0.685		0.501		0.008
(CFEAHAID)t-1		0.906		0.000		.887*
(CFEPARBR*XRNUSID/CPINCID)avg.t-4,t-5		1.261		0.246		0.013
Performance Statistics						
R-square= 0.978		D.W.=	2.800		RMSE=	21211
*imposed elasticity = .265					RMSE%**=	11.2
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
CFEGITID	Green coffee ad valorem import tax, Indonesia, percent.
XRUNUSID	Exchange rate into Indonesian local currency from US dollars.
CPINCID	CPI deflator in Indonesia, index.
CFEAHAID	Coffee area harvested in Indonesia, hectares.

Yield

A simple linear trend was fitted to the yield equation, following two studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts. Two studentized residuals were chosen instead of four due to the smaller variation in historical yields minimizing the residual thresholds.

Equation 8.6.2. Coffee yield in Indonesia, CFEYHAID						
Estimation Period: 1995-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		0.007		0.015		
YEAR		2.2021E-05		0.831		0.071
CFEGW1ID		0.0003		0.814		0.006
CFEBW1ID		-0.001		0.151		-0.094
Performance Statistics						
R-square= 0.235		D.W.=	0.565		RMSE=	0.002
**RMSE% = after any elasticities were imposed					RMSE%**=	5.8

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1ID	Indicator variable equal to 1 when standard exceeds .001 deviations.
CFEBW1ID	Indicator variable equal to 1 when standard error exceeds -.001 deviations.

Domestic Consumption

Domestic consumption per capita in Indonesia was estimated as a function of deflated coffee price, per capita income and a trend. The signs of the parameters and own price elasticity was within a priori expectations. The R-square and Durbin-Watson were both low drawing concern about poor price transmission of the Brazilian price. The Brazilian price was adjusted for the import tariff and exchange rate as well as being deflated, but ended without statistical significance. Without an Indonesian producer price that was able to be linked due to lack of current historical data the price elasticity was accepted, since the parameter sign was correct and the elasticity was similar with other countries. The income elasticity was deemed too high under simulation and was consequently imposed.

Equation 8.6.3. Coffee domestic consumption per capita in Indonesia, CFEUDCID/NNATTID						
Estimation Period: 1991-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		0.273		0.860		
CFEPARBR*(1+CFEGITID)*XRNUSID/CPINCID		-3.171E-05		0.502		-0.041
GDRNCID/NNATTID		2.318		0.000		1.858*
TREND		-0.416		0.000		-0.853
Performance Statistics						
R-square= 0.471		D.W.=	0.670		RMSE=	0.983
*imposed elasticity = .620					RMSE%**=	13.5
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
CFEGITID	Green coffee ad valorem import tax, Indonesia, percent.
XRUNUSID	Exchange rate into Indonesian local currency from US dollars.
CPINCID	CPI deflator, Indonesia, index.
GDRNCID	Real GDP in Indonesia, billion Indonesian local currency.
NNATTID	Population in Indonesia, million people.
TREND	Indicator variable equal to 1 in 1980, 2 in 1981, etc.

Net Trade Identity

The Indonesian coffee model uses the Brazilian price incorporating the import tariff and was exchange rated into the country allowing net exports to be determined as the difference between supply and demand. The ICO only provides producer prices for Indonesia through 2005. Without more current prices available from the ICO, and no other local in-country prices observed from other sources, the residual world price was used including all necessary adjustments for trade barriers and exchange rates to put the Brazilian price in local currency units for the behavioral equations. Equation 8.6.4 documents the market clearing identity for the Indonesian coffee sector. The net trade position of Indonesia was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.6.4. Coffee net exports in Indonesia, CFEUXTID
Identity

CFEUXTID=LAG(CFECOTID)+CFESPRID-CFEUDCID-CFECOTID

Variable Name	Definition
CFECOTID	Coffee ending stocks in Indonesia, thousand 60kg bags.
CFESPRID	Coffee production in Indonesia, thousand 60kg bags.
CFEUDCID	Coffee domestic consumption in Indonesia, thousand 60kg bags.

Japan

Domestic Consumption

Domestic consumption per capita in Japan was estimated as a function of the Brazilian deflated coffee price converted to local currency units and per capita income. The Brazilian price as the equilibrated world price in the system was used as the own price in Japan as no producer price is available from the ICO for Japan, since Japan does not produce coffee at a large enough scale to be reported. The own price and income elasticities had the correct signs, although the income elasticity was deemed to be too high under simulation and was imposed at a lower level. The R-square was lower than preferred, while the Durbin-Watson was reasonable.

Equation 8.7.1. Coffee domestic consumption per capita in Japan, CFEUDCJP/NNATTJP						
Estimation Period: 1992-2007						
		Parameter Estimate		p-value		Elasticity
Intercept		-24.903		0.074		
CFEPARBR*XRNUSJP/CPINCJP		-0.022		0.150		-0.052
GDRNCJP/NNATTJP		19.608		0.000		1.542*
Performance Statistics						
R-square= 0.746		D.W.=	2.242		RMSE=	2.384
*imposed elasticity = .385					RMSE%**=	6.9
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
XRUNUSJP	Exchange rate into Japanese local currency from US dollars.
CPINCJP	CPI deflator, Japan, index.
GDRNCJP	Real GDP in Japan, billion Japanese local currency.
NNATTJP	Population in Japan, million people.

Ending Stocks

Ending stocks in Japan was estimated as a function of own price and lag stocks. The R-square was reasonable with the Durbin-Watson falling marginally lower than preferred. The lag stocks variable was deemed too high under simulation and was imposed.

Equation 8.7.2. Coffee ending stocks in Japan, CFECOTJP						
Estimation Period: 1980-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		340.260		0.018		
CFEPARBR*XRNUSJP/CPINCJP		-1.034		0.040		-0.105
(CFECOTJP)t-1		0.888		0.000		.865*
Performance Statistics						
R-square= 0.916		D.W.=	1.818		RMSE=	155.037
*imposed elasticity = .648					RMSE%**=	13.1
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
XRUNUSJP	Exchange rate into Japanese local currency from US dollars.
CPINCJP	CPI deflator, Japan, index.
CFECOTJP	Coffee ending stocks in Japan, thousand 60kg bags.

Net Trade Identity

The Japanese coffee model was linked to the world price by using the Brazilian farm price exchange rated into the country. Japan had no trade barriers, so the world price was not impacted, and was able to be exchanged rated into local currency units and then deflated directly for the behavioral equations. Net exports were determined as the difference between supply and demand. Equation 8.7.3 documents the market clearing identity for Japan's coffee sector. The net trade position of Japan was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.7.2. Coffee net imports in Japan, CFESMTJP
Identity

CFESMTJP= CFEUDCJP+CFECOTJP-LAG(CFECOTJP)-CFESPRJP

Variable Name	Definition
CFECOTJP	Coffee ending stocks in Japan, thousand 60kg bags.
CFESPRJP	Coffee production in Japan, thousand 60kg bags.
CFEUDCJP	Coffee domestic consumption in Japan, thousand 60kg bags.

Mexico

Area Harvested

Coffee area harvested in Mexico was estimated as a function of lag deflated price of coffee in t-1, the lag deflated average price of t-4 and t-5 and lag area. The parameter signs for 8.8.1 are consistent with a priori expectations and although the Durbin-Watson was reasonable the R-square illustrates that the equation only fits at a fair level. The elasticities were within a priori expectations and the equation response under simulation was acceptable without additional modification.

Equation 8.8.1. Coffee area harvested in Mexico, CFEAHAMX					
Estimation Period: 2001-2007					
	Parameter Estimate		p-value		Elasticity
Intercept	494938.780		0.171		
(CFEPARMX*XRNUSMX/CPINCMX)t-1	4864.020		0.211		0.080
(CFEAHAMX)t-1	0.229		0.545		0.226
(CFEPARMX*XRNUSMX/CPINCMX)avg.t-4,t-5	2038.228		0.437		0.037
Performance Statistics					
R-square= 0.614	D.W.=	1.969		RMSE=	14149
**RMSE% = after any elasticities were imposed				RMSE%**=	1.6

Variable Name	Definition
CFEPARMX	Coffee Arabica farm price in Mexico, US dollars per 60kg bag.
XRUNUSMX	Exchange rate into Mexican local currency from US dollars.
CPINCMX	CPI deflator in Mexico, index.
CFEAHAMX	Coffee area harvested in Mexico, hectares.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.8.2. Coffee yield in Mexico, CFEYHAMX					
Estimation Period: 1980-2009					
	Parameter Estimate		p-value		Elasticity
Intercept	0.009		0.000		
YEAR	1.9773E-05		0.000		0.090
CFEGW1MX	0.001		0.000		0.007
CFEGW2MX	0.002		0.000		0.009
CFEBW1MX	-0.001		0.000		-0.021
CFEBW2MX	-0.002		0.000		-0.008
Performance Statistics					
R-square= 0.930	D.W.=	1.701		RMSE=	0.0003
**RMSE% = after any elasticities were imposed				RMSE%**=	8.6

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1CO	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2CO	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1CO	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2CO	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in Mexico was estimated as a function of deflated coffee price, per capita income, a dummy variable in 1996 through 2002. The own price elasticity was within a priori expectations helping to produce an acceptable R-square, although the income elasticity was deemed too high under simulation and was imposed. The Durbin-Watson was modestly low indicating potential autocorrelation among the variables.

Equation 8.8.3. Coffee domestic consumption per capita in Mexcio, CFEUDCMX/NNATTMX						
Estimation Period: 1990-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		11.147		0.067		
CFEPARMX*XRNUSMX/CPINCMX		-0.136		0.041		-0.166
GDRNCMX/NNATTMX		0.104		0.133		0.541*
DUMMY 96-02		-6.787		0.000		-0.169
Performance Statistics						
R-square= 0.858		D.W.=	1.421		RMSE=	1.546
*imposed elasticity = .294					RMSE%**=	10.1
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARMX	Coffee Arabica farm price in Mexico, US dollars per 60kg bag.
XRUNUSMX	Exchange rate into Mexican local currency from US dollars.
CPINCMX	CPI deflator, Mexico, index.
GDRNCMX	Real GDP in Mexico, billion Mexican local currency.

NNATTMX	Population in Mexico, million people.
DUMMY 96-02	Indicator variable equal to 1 in 1996 through 2002, 0 otherwise.

Coffee Farm Price

The Mexican coffee farm price was simply estimated as a function of the Brazilian coffee farm price. The parameter estimate was .810 indicating the Mexican farm price runs at about 80 percent of the Brazilian price when both were reported on a U.S. dollar basis.

Equation 8.8.4. Coffee farm price in Mexico, CFEPRBMX						
Estimation Period: 1989-2007						
		Parameter Estimate		p-value		Elasticity
Intercept		43.023		0.025		
CFEPARBR		0.810		0.000		0.655
Performance Statistics						
R-square= 0.593		D.W.=	0.793		RMSE=	26.972
**RMSE% = after any elasticities were imposed					RMSE%**=	20.7

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.

Net Trade Identity

The Mexican coffee model was linked to the world price through the price linkage equation allowing net exports to be determined as the difference between supply and demand. Equation 8.8.5 documents the market clearing identity for the Mexican coffee sector. The net trade position of Mexico was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.8.5. Coffee net exports in Mexico, CFEUXTMX
Identity

CFEUXTMX=LAG(CFECOTMX)+CFESPRMX-CFEUDCMX-CFECOTMX

Variable Name	Definition
CFECOTMX	Coffee ending stocks in Mexico, thousand 60kg bags.
CFESPRMX	Coffee production in Mexico, thousand 60kg bags.
CFEUDCMX	Coffee domestic consumption in Mexico, thousand 60kg bags.

United States

Area Harvested

Coffee area harvested in the United States (US) was estimated as a function of lag deflated price of coffee in t-1, the lag deflated average price of t-4 and t-5 and lag area. The parameter signs for 8.9.1 were consistent with a priori expectations and the R-square and the Durbin-Watson were reasonable. The elasticities were within a priori expectations and the equation response under simulation was acceptable without additional modification.

Equation 8.9.1. Coffee area harvested in the United States, CFEAHAUS						
Estimation Period: 1992-2007						
	Parameter Estimate			p-value		Elasticity
Intercept		701.156		0.003		
(CFEPARBR/CPINCUS)t-1		81.771		0.246		0.042
(CFEAHAUS)t-1		0.675		0.000		0.650
(CFEPARBR/CPINCUS)avg.t-4,t-5		12.915		0.860		0.007
Performance Statistics						
R-square= 0.864		D.W.=	2.010		RMSE=	132.669
**RMSE% = after any elasticities were imposed					RMSE%**=	5.4

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
CPINCUS	CPI deflator in the United States, index.
CFEAHAUS	Coffee area harvested in the United States, hectares.

Yield

A simple linear trend was fitted to the yield equation, following three studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts. Negative residuals did not meet the same thresholds as the positive residuals leaving the negative weather impacts to be accounted for by one indicator variable.

Equation 8.9.2. Coffee yield in the United States, CFEYHAUS						
Estimation Period: 1998-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		0.073		0.000		
YEAR		-0.001		0.084		-0.278
CFEGW1US		0.007		0.124		0.055
CFEGW2US		0.015		0.008		0.080
CFEBW1US		-0.010		0.067		-0.013
Performance Statistics						
R-square= 0.926		D.W.=	2.681		RMSE=	0.0003
**RMSE% = after any elasticities were imposed					RMSE%**=	4.4

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1US	Indicator variable equal to 1 when standard error lies between .002 and .01 deviations.
CFEGW2US	Indicator variable equal to 1 when standard error exceeds .01 deviations.
CFEBW1US	Indicator variable equal to 1 when standard error exceeds -.001 deviations.

Domestic Consumption

Domestic consumption per capita in the United States was estimated as a function of deflated coffee price, per capita income, and a dummy variable in 2002. The own price elasticity was within a priori expectations. The R-square was marginally acceptable, but the income elasticity was deemed too high under simulation and was imposed. The Durbin-Watson was low indicating potential autocorrelation among the variables.

Equation 8.9.3. Coffee domestic consumption per capita in the United States, CFEUDCUS/NNATTUS						
Estimation Period: 1994-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		56.259		0.014		
CFEPARBR/CPINCUS		-1.952		0.518		-0.032
GDRNCUS/NNATTUS		0.567		0.205		0.301*
DUMMY 02		-20.581		0.001		-0.017
Performance Statistics						
R-square= 0.701		D.W.=	0.754		RMSE=	3.86
*imposed elasticity = .105					RMSE%**=	4.7
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPARBR	Coffee Arabica farm price in Brazil, US dollars per 60kg bag.
CPINCUS	CPI deflator, United States, index.
GDRNCUS	Real GDP in the United States, billion US dollars.
NNATTUS	Population in the United States, million people.
DUMMY 02	Indicator variable equal to 1 in 2002, 0 otherwise.

Net Trade Identity

The producer price provided by the USDA, statistical service (2010) had very poor statistical performance, and was disregarded as the US has very small coffee production, which may be attributable for the poor estimation results when attempting a price linkage equation with the Brazilian producer price. Consequently, the United States coffee model was linked to the world price using the Brazilian farm price, which was already in US dollars. The Brazilian price was then deflated and directly used in the behavioral equations. Since, the United States has no trade barriers for coffee, the world price had no additional modifications. Net exports were determined as the difference between supply and demand. Equation 8.9.4 documents the market clearing identity for the

United States' coffee sector. The net trade position of the United States was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.9.4. Coffee net imports in the United States, CFESMTUS
Identity

CFESMTUS= CFEUDCUS+CFECOTUS-LAG(CFECOTUS)-CFESPRUS

Variable Name	Definition
CFECOTUS	Coffee ending stocks in the United States, thousand 60kg bags.
CFESPRUS	Coffee production in the United States, thousand 60kg bags.
CFEUDCUS	Coffee domestic consumption in the United States, thousand 60kg bags.

Vietnam

Area Harvested

Coffee area harvested in Vietnam was estimated as a function of lag deflated price of coffee in t-1 and the lag deflated average price of t-4 and t-5, lag area and a shift indicator variable. The parameter signs for 8.10.1 were consistent with a priori expectations and the R-square was good. The Durbin-Watson was lower than preferred, but still within the acceptable range illustrating there was some possible autocorrelation. The elasticities were within a priori expectations and the equation response under simulation was acceptable without additional modification.

Equation 8.10.1. Coffee area harvested in Vietnam, CFEAHAVN				
Estimation Period: 1985-2008				
	Parameter Estimate	p-value		Elasticity
Intercept	-44024.086	0.343		
(CFEPRBVN*XRNUSVN/CPINCVN)t-1	2.380	0.276		0.114
(CFEAHAVN)t-1	0.680	0.000		0.620
(CFEPRBVN*XRNUSVN/CPINCVN)avg.t-4,t-	4.236	0.063		0.195
SHIFT 00	164153.843	0.008		0.249
Performance Statistics				
R-square= 0.968	D.W.=	1.502	RMSE=	40207
**RMSE% = after any elasticities were imposed			RMSE%**=	14.3

Variable Name	Definition
CFEPRBVN	Coffee Robusta farm price in Vietnam, US dollars per 60kg bag.
XRUNUSVN	Exchange rate into Vietnam local currency from US dollars.
CPINCVN	CPI deflator in Vietnam, index.
CFEAHAVN	Coffee area harvested in Vietnam, hectares.
SHIFT 00	Indicator variable equal to 1 in 2000 and forward, 0 otherwise.

Yield

A simple linear trend was fitted to the yield equation, following four studentized residuals were reviewed for each observation with residuals meeting thresholds above and below the trend fitting for weather impact indicators on yield in a given year. The regression was rerun with the indicator variables including trend yield to estimate trend and weather impacts.

Equation 8.10.2. Coffee yield in Vietnam, CFEYHAVN						
Estimation Period: 1984-2009						
		Parameter Estimate		p-value		Elasticity
Intercept		0.022		0.000		
YEAR		0.0003		0.000		0.214
CFEGW1VN		0.002		0.383		0.007
CFEGW2VN		0.007		0.000		0.094
CFEBW1VN		-0.001		0.635		-0.002
CFEBW2VN		-0.004		0.029		-0.035
Performance Statistics						
R-square= 0.861		D.W.=	2.730		RMSE=	0.0003
**RMSE% = after any elasticities were imposed					RMSE%**=	7.5

Variable Name	Definition
YEAR	Indicator variable equal to 1980 in 1980, 1981 in 1981, etc.
CFEGW1VN	Indicator variable equal to 1 when standard error lies between .001 and .002 deviations.
CFEGW2VN	Indicator variable equal to 1 when standard error exceeds .002 deviations.
CFEBW1VN	Indicator variable equal to 1 when standard error lies between -.001 and -.002 deviations.
CFEBW2VN	Indicator variable equal to 1 when standard error exceeds -.002 deviations.

Domestic Consumption

Domestic consumption per capita in Vietnam was estimated as a function of deflated coffee price and per capita income. The signs of the parameters and the own price elasticity was within a priori expectations. The R-square was good, although the Durbin-Watson was low drawing concerns about autocorrelation. The income elasticity was high relative to the own price elasticity, and was deemed too high under simulation and consequently was imposed. With Vietnam being the second largest exporter of coffee in the world and the nature of per capita income growth of the developing nation, it became imperative that the income elasticity was moderated in order to run realistic projections of consumption growth. At this time the performance under simulation with the reduced synthetic income elasticity still produces a significant impact on the model, but per capita consumption growth is reasonable when comparing to recent historical growth within the country, therefore the equation was not further modified at this time.

Equation 8.10.3. Coffee domestic consumption per capita in Vietnam, CFEUDCVN/NNATTVN						
Estimation Period: 1988-2007						
		Parameter Estimate		p-value		Elasticity
Intercept		-1.582		0.058		
CFEPRBVN*XRNUSVN/CPINCVN		-5.0174E-05		0.128		-0.132
GDRNCVN/NNATTVN		2.041		0.000		1.472*
Performance Statistics						
R-square= 0.939		D.W.=	1.112		RMSE=	0.652
*imposed elasticity = .774					RMSE%**=	19.1
**RMSE% = after any elasticities were imposed						

Variable Name	Definition
CFEPRBVN	Coffee Robusta farm price in Vietnam, US dollars per 60kg bag.
XRUNUSVN	Exchange rate into Vietnamese local currency from US dollars.
CPINCVN	CPI deflator, Vietnam, index.
GDRNCVN	Real GDP in Vietnam, billion Indonesian local currency.
NNATTVN	Population in Vietnam, million people.
TREND	Indicator variable equal to 1 in 1980, 2 in 1981, etc.

Coffee Farm Price

The Vietnamese coffee farm price was simply estimated as a function of the Brazilian coffee farm price. The parameter estimate was .863 indicating that the Vietnam price rides almost 14 percent lower than the Brazilian farm price. This lower price level in Vietnam is likely attributable to Robusta coffee being the primary coffee produced and exported from the country, whereas Robusta is considered a lower quality product its price normally runs at a discount to Arabica. The price transmission elasticity was on the high side, and may need to be imposed closer to 1 in future iterations as projection accuracy is measured in a real world application.

Equation 8.10.4. Coffee farm price in Vietnam, CFEPRBVN						
Estimation Period: 1992-2007						
	Parameter Estimate			p-value		Elasticity
Intercept		-20.271		0.150		
CFEPARBR		0.863		0.000		1.382
DUMMY 96, 97		-42.697		0.012		-0.080
Performance Statistics						
R-square= 0.785	D.W.=	0.990			RMSE=	15.791
**RMSE% = after any elasticities were imposed					RMSE%**=	19.8

Variable Name   Definition
CFEPARBR   Coffee Arabica farm price in Brazil, US dollars per 60kg bag.

Net Trade Identity

The Vietnam coffee model was linked to the world price through the price linkage equation allowing net exports to be determined as the difference between supply and demand. Equation 8.10.5 documents the market clearing identity for Vietnam's coffee sector. The net trade position of Vietnam was added in with the net trade positions of the other countries to ultimately provide the Brazilian export path.

Equation 8.10.5. Coffee net exports in Vietnam, CFEUXTVN
Identity

CFEUXTVN=LAG(CFECOTVN)+CFESPRVN-CFEUDCVN-CFECOTVN

Variable Name	Definition
CFECOTVN	Coffee ending stocks in Vietnam, thousand 60kg bags.
CFESPRVN	Coffee production in Vietnam, thousand 60kg bags.
CFEUDCVN	Coffee domestic consumption in Vietnam, thousand 60kg bags.

Elasticity Summary

In the final iteration all of the equations in this section had correct parameter signs that agree with a priori expectations. There were two exceptions where the parameter estimates did not initially provide correct parameter signs, but in those two cases elasticities were used from other studies to ensure that the signs met a priori expectations. Generally, the area equations estimated appropriate own price elasticities, although some of the lag area elasticities were imposed at lower levels so that the equation would respond better under simulation. The total domestic consumption elasticities are fairly inelastic with respect to coffee prices, although in some instances the income elasticities in several equations were quite high and consequently also were imposed so that the equations responded better under simulation.

Comparison of Area Elasticities				
		Own Price Elasticity		
		Short-run		Long-run
Brazil				
Maltsbarger - 11		0.094		0.223
Akiyama & Varangis - 90*		0.030		0.100
Berhman & Klein - 70		0.100		0.110
Colombia				
Maltsbarger - 11		0.074		0.172
Akiyama & Varangis - 90*		0.160		0.440
Bacha - 68		0.070		0.450
Latin America (excl. Brazil & Colombia)				
Bacha - 68		0.280		0.520
Honduras				
Maltsbarger - 11		0.046		0.064
Akiyama & Varangis - 90*		0.130		0.150
India				
Maltsbarger - 11		0.064		0.132
Akiyama & Varangis - 90*		0.190		0.100**
Indonesia				
Maltsbarger - 11		0.021		0.029
Akiyama & Varangis - 90*		0.140		0.170
Mexico				
Maltsbarger - 11		0.111		0.144
Akiyama & Varangis - 90*		0.020		0.060
United States				
Maltsbarger - 11		0.049		0.151
Vietnam				
Maltsbarger - 11		0.113		0.353
*Not Short-run and Long-run elasticities; spot elasticities for 2 years after price change and 5 years after price change				
**theoretically Long-run elasticity should be higher than Short-run; attributable to authors' ad-hoc elasticity reporting				

Table 8-1 Comparison of area elasticities

Comparison of Demand Elasticities				
		Income		Own-Price
Brazil				
Maltsbarger - 11		0.204*		-0.152
Akiyama & Varangis - 90		0.500		-0.090
Colombia				
Maltsbarger - 11				-0.367
Akiyama & Varangis - 90		0.410		-0.140
European Union				
Maltsbarger - 11		0.396*		
Akiyama & Varangis - 90				
Belgium		0.360		-0.280
France		0.680		-0.130
Germany		0.980		-0.170
Italy		0.920		-0.180
Netherlands		0.890		-0.340
Spain		1.070		-0.070
United Kingdom		1.260		-0.510
Honduras				
Maltsbarger - 11		0.071*		-0.054
India				
Maltsbarger - 11		0.124		-0.249
Akiyama & Varangis - 90		0.240		0.080
Indonesia				
Maltsbarger - 11		0.855*		-0.041
Akiyama & Varangis - 90		0.180		-0.070
Japan				
Maltsbarger - 11		0.382*		-0.052
Akiyama & Varangis - 90		2.030		-0.310
Mexico				
Maltsbarger - 11		0.265*		-0.166
Akiyama & Varangis - 90		0.350		-0.140
United States				
Maltsbarger - 11		0.110*		-0.032
Akiyama & Varangis - 90		0.500		-0.460
Huang - 96		0.810		-0.170
Hughes - 69 (1920-41)		0.330		-0.300
Hughes - 69 (1947-66)		0.290		-0.150
Vietnam				
Maltsbarger - 11		0.774*		-0.132
*synthetically imposed elasticities				

Table 8-2 Comparison of demand elasticities

Comparison of Price Linkage Elasticities		
	Elasticity	R^2
Colombia		
Maltsbarger - 11	1.185	0.795
Mundlak & Larson - 92	0.619	0.950
Honduras		
Maltsbarger - 11	0.759	0.774
India		
Maltsbarger - 11	0.704	0.567
Mundlak & Larson - 92	0.142	0.390
Mexico		
Maltsbarger - 11	0.655	0.593
Mundlak & Larson - 92	0.858	0.800
Vietnam		
Maltsbarger - 11	1.382	0.785

Table 8-3 Comparison of price linkage elasticities

Ending Stocks Elasticities	
	Own-price Elasticity
Brazil	
Maltsbarger - 11	-0.062
Japan	
Maltsbarger - 11	-0.105

Table 8-4 Ending stocks elasticities

CHAPTER 9 SIMULATION RESULTS AND IMPACT ANALYSIS

Performance of the International Coffee Model

The international coffee model was simulated statically and dynamically over the 1995 to 2009 period. The simulation period was restricted by the shortest data estimation period across all the equations in the system. The Mexican area equation limited the starting point, because of the average four and five year lag combined with macroeconomic data that did not start until 1995. The upper range of the historic simulation stopped in 2009 attributable to 2010 not being completed as history in the data set at the time of simulation tests. In addition, the international coffee model was historically simulated without the rest of the world being solved. The other countries and other regional aggregates were considered exogenous to the scope of this study. Additional estimating and testing has and will continue outside of the scope of this study in order to obtain an even more complete coffee sector picture, but will not be discussed in association with this thesis.

Table 9-1 presents the root mean square errors for the critical equations. Almost all the percent errors increased under the dynamic simulation. This is partially attributable to the lagged dependent variables feeding through the structure of the model. Kruse (2003) in his dissertation defers to comments from Adams (1994) that, "ideally root mean square errors should be less than 10 percent, and preferably less than 20 percent" (p. 365). This ideal helps to illustrate acceptable levels for error in equations under historic simulation.

Some of the errors across this model are larger than the ideal and the preference levels. The larger errors suggest potential areas that may need further improvement. The largest root mean square error percentage was found in the price linkage equations, the equilibrated price and the ending stocks equation for Brazil. As the price linkage equations hold a direct relationship to the equilibrated price, the concern arises that in future iterations of the historical simulation it may be necessary to test the system including the other 24 country breakouts and the 5 other regional aggregates. It is distinctly possible that without the rest of the world turned on for the historic simulation that this pushed the price and underlying supply and demand variables in the top 10 countries to soak up any additional responsiveness for the other 20-25 percent of the world. Another consideration is that with the additional errors from the other countries' equations pushed into the simulation that the end root mean square error results would have been worse. In either case the focus of future iterations of tests will include additional focus on the parameter estimates and elasticities of the price linkage equations as none of the price linkage elasticities had been imposed for the historic simulations. When considering the ending stocks equation for Brazil it is important to note that stock holding in the coffee sector has declined historically, whereas the average of global ending stocks in the last three years was less than 13% of production. Ultimately, the higher root mean square error percent for Brazil's ending stocks was ignored, because it has a minor impact on the rest of the system.

Many equations in the model performed reasonably well, receiving a percent of root mean square error less than 20 percent and some less than 10 percent, especially when observing the results from the 2005-2009 fit period. The price inelasticity of the domestic consumption of coffee shows up in generally higher error percentages versus the area equations. Many of the current root mean square error percents are much lower than when the first iteration of simulation took place. As overpowering variables were adjusted and synthetically imposed additional iterations of historic simulation and projections became more reasonable. Synthetic elasticities were imposed through a combined iterative process using simulation, impact analysis, projections and adjusting elasticities to minimize the root mean square error percent for fit. Table 9-1 illustrates the most recent iteration of historical simulation with graphs of the simulated equations presented in Appendix A.

Static and dynamic simulation results - Historic Simulation Period 1995-2009												
	1995-2009 Results						2005-2009 Results					
	Static Estimate**		Static Simulation		Dynamic Simulation		Static Estimate**		Static Simulation		Dynamic Simulation	
	RMS Error	RMS % Error	RMS Error	RMS % Error	RMS Error	RMS % Error	RMS Error	RMS % Error	RMS Error	RMS % Error	RMS Error	RMS % Error
Brazil												
CFEPARBR*			66.2	59.4	46.8	42.0			52.5	40.0	51.1	38.9
CFEAHABR	96386.4	4.4	96386.4	4.4	139564.3	6.3	51225.8	2.3	51225.8	2.3	91762.1	4.1
CFEUDCBR	12.1	15.2	8.8	11.4	9.8	12.4	2.8	3.1	4.0	4.4	4.7	5.2
CFECOTBR	3918.2	39.0	4138.1	41.2	5695.3	56.7	2113.2	36.6	2051.3	35.5	2414.1	41.1
Colombia												
CFEAHACO	41057.9	5.3	41057.9	5.3	79201.6	10.3	33646.7	4.4	33646.7	4.4	44022.3	5.7
CFEUDCCO	4.5	13.6	10.0	30.2	8.2	24.8	1.8	6.7	4.5	17.1	4.2	15.9
CFEPARCO	27.7	20.6	80.0	64.9	60.9	49.4	14.8	10.0	74.0	43.9	74.0	43.9
European Union												
CFEUDCCO	11.4	9.7	5.6	4.7	7.1	6.1	3.6	2.7	6.5	4.9	7.2	5.5
Honduras												
CFEAHAHO	21249.6	9.7	21249.6	9.7	28345.4	13.0	6723.2	2.8	6723.2	2.8	6298.0	2.7
CFEUDCHO	3.6	9.7	3.7	10.2	3.6	9.8	5.8	19.9	6.1	20.9	5.9	20.4
CFEPARHO	17.1	17.1	47.3	49.0	37.3	38.6	13.3	12.4	32.9	28.4	34.8	30.0
India												
CFEAHAIN	41475.1	13.4	41475.1	13.4	56539.6	18.3	3587.0	1.0	3587.0	1.0	12484.1	3.7
CFEUDCIN	0.7	60.8	0.5	48.5	0.6	51.6	0.1	9.9	0.1	10.6	0.2	15.0
CFEPRBIN	19.3	25.5	51.1	67.7	39.9	52.9	10.3	13.8	32.5	31.2	34.9	33.5
Indonesia												
CFEAHAID	58057.9	6.3	58057.9	6.3	78913.2	8.6	4730.2	0.5	4730.2	0.5	12452.5	1.3
CFEUDCID	1.3	16.5	1.1	14.5	1.2	15.2	0.3	4.3	0.5	6.2	0.5	7.2
Japan												
CFEUDCJP	3.9	7.5	3.6	6.8	3.7	7.1	1.1	2.1	2.0	3.7	1.6	3.0
CFECOTJP	204.4	11.5	218.6	12.3	333.8	18.8	109.7	5.2	126.6	6.0	241.7	11.4
Mexico												
CFEAHAMX	77144.9	10.5	77144.9	10.5	108312.4	14.7	7314.9	1.0	7314.9	1.0	17087.4	2.2
CFEUDCMX	1.5	10.7	1.8	12.7	1.5	10.7	0.8	4.5	0.9	5.2	0.8	4.4
CFEPARMX	29.2	23.4	55.1	44.1	41.2	33.0	29.3	21.7	51.4	38.0	20.2	14.9
United States												
CFEAHAUS	101.0	4.1	101.0	4.1	188.6	7.7	43.2	1.7	43.2	1.7	102.0	4.0
CFEUDCUS	5.9	7.8	5.8	7.6	5.8	7.7	0.9	1.1	1.5	1.9	1.3	1.7
Vietnam												
CFEAHAVN	41361.2	10.4	41361.2	10.4	82549.1	20.8	4226.2	0.8	4226.2	0.8	94337.1	18.3
CFEUDCVN	0.4	6.8	0.4	5.9	0.4	6.4	0.4	4.3	0.4	5.5	0.4	6.0
CFEPRBVN	13.8	21.3	60.0	93.6	43.4	67.3	16.4	18.4	47.4	52.9	47.9	53.6
*Equilibrated Price		**Equation Estimate after any elasticities were imposed										

Table 9-1 Static and dynamic historic 1995-2009 simulation results

Impact Analysis

A very useful tool in the process of econometric model development is the implementation of impact analysis derived within the system of equations. The effects of impact analysis can provide the user insights into the functionality of the model as well as the specific reaction from exogenous shocks. These two purposes used in combination can add insight into model performance versus a priori expectations.

Calculation of Impact Analysis

In a simultaneous system of equations it is very unlikely to conceive from any individual equation the total effect of an exogenous shock (Kruse, 2003). To do so it would be necessary to run the shock through each equation in the system to then find a final result. Optimally, it would be better to combine all the equations into a reduced form equation with an endogenous variable of interest being a function of either exogenous or lagged endogenous variables in order that the quantities are known within the context of the model (Kruse, 2003). For a structural econometric model such as the underlying international coffee model, it is conceptually possible to create a single reduced form equation for each endogenous variable if the functional form is mathematically manageable (Brown et al., 2009). The set of reduced form equations may then be used to derive a multiplier. This multiplier or shock variable is derived by taking a partial derivative of each of the reduced form equations with respect to the exogenous variable and the short run impact in respect to the change in the exogenous variable. In order to derive a longer-run multiplier more steps are required. For any reduced form equations that are a function of exogenous and lagged endogenous variables, one must eliminate the lagged endogenous variables through a progression of substitutions (Kmenta, 2000). In the process of substitutions a potential geometric pattern may emerge, which in a stable system converges to a limit as the number of lags approaches infinity (Thomas and Finney, 1984). For this to work the system must ultimately be stable. A system may be defined as stable if the average values of endogenous variables settle to a constant level when the endogenous variables in the system are held constant. Consequently, a lagged dependent variable with a parameter estimate greater than one should not be included (Kruse, 2003).

The math behind the actual process of solving for reduced form equations can be rather intractable. This becomes more evident as the total number of equations in the model expands. The process of deriving a multiplier or impact variable when using a software package such as Excel© can be accomplished is a much simpler fashion by using the equations as previously produced in the system without concern for reduced forms and shocking the system by changing exogenous variables. This is executed by choosing exogenous variables of interest and choosing an appropriate level to shock each exogenous variable. A sustained shock in the exogenous variable of interest is then simulated throughout the entire system simultaneously to evaluate the effects in the model on the endogenous variables not only in the year of the shock, but also the effects of the shock in future years.

During impact analysis simulations of the international coffee model, the rest of the world was again left exogenous to the system. Since the percent of the rest of the world is less than 30 percent of production and consumption, the focus of this research was to consider on the most impactful countries in the sector. Therefore, the results should be considered with this in mind. In addition, applying shocks during the projection period of 2010 through 2021 required equilibrating a baseline for comparison. Projections for the baseline and impact projections both used the most recent iteration of parameter estimates and solved to a solution for each year from 2010 out to and including 2021. Also, all macroeconomic exogenous variables leveraged IHS Global Insight's forecast data (2010) for the projection period.

Three of the shocks are included for this analysis. The first is a technological shock, whereas a 10 percent sustained increase in yield for Brazil is simulated illustrating an example of technological advance in the world's largest exporting country. The second shock is macroeconomic in nature, and the third shock impacts trade policy. The second shock is a sustained 10 percent increase in global income, while the third shock is a sustained 50 percent decline in global import tariff rates for green coffee.

Table 9-2 presents the impact of a 10 percent sustained increase in Brazil's yield. As expected the shock had a large negative impact on prices as Brazil is the world's largest exporter. For the most part the bump in production moved prices as a percentage significantly more than domestic consumption illustrating the price inelastic nature of coffee demand. Generally, the more developed countries domestic consumption changes were lower than the developing countries. The exception to this rule is the United States, which had a higher impact than many of the developing countries. This response suggests that the United States may need further review.

Table 9-3 presents the impact of a 10 percent sustained increase in global income. Generally, one might expect total domestic consumption to increase across most or all countries as income increases. This was not the case for the income shock to the model. The income effect of on the system did increase global consumption as expected, but when observing individual countries it can be seen that there were winners and losers from the shock as the income elasticity varies across countries. An example of how this can happen is illustrated in Figure 9-1 below where the actual quantity of domestic consumption can be positive or negative with a shift in income even as total demand increases, attributable to the change in price and the magnitude of the income elasticity.

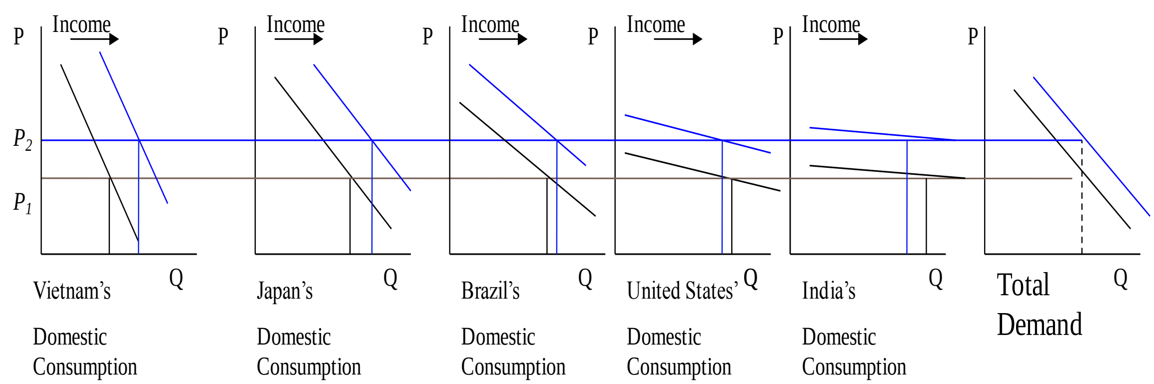


Figure 9-1 Impact example on countries with different income elasticities

For example in the system Vietnam has a high income elasticity relative to most other countries in the model and shows a distinct increase in total domestic consumption from the income shock, whereas only select countries such as Brazil, Colombia and Japan see any positive change to domestic consumption during the projection period. A response where some countries see positive domestic consumption change and other see a negative change is not surprising and was even expected. The concern arises though, that even with reduced and therefore synthetically imposed income elasticity for Vietnam, that there may need to be continued evaluation of the relative magnitude of Vietnam's income elasticity versus other countries as its income effect overpowered the system where many other countries' price effect was larger than their income effect from the shock.

Table 9-4 presents the impact of a 50 percent sustained decline in global tariff rates. As the coffee sector became more liberalized in the early to mid-1990's much of industry has relatively small or no import tariffs as illustrated in Chapter 3, so to view any impact on the model this shock had to be larger and measure the impact at a much more granular level. With the exception of the first year, the decrease in tariffs drove production to increase marginally higher than consumption pushing the world price lower. As production has a lag incorporating price changes in t-1, the increases in the United States and the European Union helped to drive up price in the first year and consequently most other countries saw declines in consumption until production could begin to affect the system in 2011/12. With the very marginal impacts of cutting the tariff rates had on the model, a different more elaborate scenario may be more relevant to the sector in a future iteration such as attempting to replicate a quota or buffer stock system similar one that was in place prior to 1989 when the last active quota system was suspended by the ICO.

In all shocks there is an obvious lagged effect on price. For the first two shocks the model adjusts to have the smallest price difference to the baseline in the fifth year after the beginning of the shock, whereas the third shock shows a four year cycle. All three developments are representative of how the model incorporates shock impacts of price into the area equation attributable to the variable of price(average of t-4, t-5), therefore catching the first turning point of price in about four to five years. Additionally, it can be observed that the model again shifts in another five years for the first two shocks and four years for the third shock following the initial narrowing of variation to the baseline projection. For the first two shocks at about the tenth year there is a peak in the variation from the baseline projection representing a potential cyclical nature of model response. With the slow gestation process for coffee trees from planting to production it is intuitive that there should be a cyclical response from shocks that affect price. This interesting observation of the potential cyclical response of the model draws interest into additional impact analysis incorporating longer timeframes in order to observe if this response will continue similar to what the output tables show, converge to an even linear trend or respond with greater oscillation.

Impact of a 10% sustained increase in Yield in Brazil on Price, Production and Domestic Consumption versus Baseline Projection												
	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22
Green Coffee Price	-21.9%	-18.0%	-15.7%	-14.9%	-9.9%	-7.5%	-7.7%	-8.2%	-9.5%	-11.1%	-11.8%	-10.3%
Domestic Consumption												
Brazil	2.5%	1.7%	1.5%	1.5%	1.0%	0.7%	0.8%	0.8%	0.9%	1.0%	1.1%	1.0%
Colombia	7.8%	5.6%	5.2%	5.1%	3.4%	2.6%	2.7%	2.8%	3.1%	3.6%	3.8%	3.3%
European Union	1.7%	1.2%	1.1%	1.1%	0.8%	0.6%	0.7%	0.7%	0.9%	1.0%	1.1%	1.0%
Honduras	3.4%	2.4%	2.2%	2.1%	1.4%	1.1%	1.2%	1.2%	1.4%	1.5%	1.6%	1.4%
India	8.8%	6.3%	5.7%	5.7%	3.9%	3.1%	3.3%	3.5%	4.1%	4.7%	5.1%	4.5%
Indonesia	5.3%	3.7%	3.3%	3.3%	2.3%	1.9%	2.0%	2.2%	2.6%	3.1%	3.5%	3.2%
Japan	1.1%	0.8%	0.7%	0.7%	0.4%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%
Mexico	3.0%	2.2%	2.0%	2.0%	1.4%	1.1%	1.2%	1.3%	1.5%	1.8%	2.0%	1.8%
United States	5.5%	3.8%	3.4%	3.4%	2.3%	1.8%	1.9%	2.1%	2.4%	2.8%	3.0%	2.7%
Vietnam	1.6%	1.2%	1.0%	0.9%	0.6%	0.4%	0.4%	0.5%	0.5%	0.6%	0.6%	0.5%
World Total												
Domestic Consumption	2.8%	2.0%	1.8%	1.7%	1.1%	0.9%	0.9%	0.9%	1.1%	1.2%	1.3%	1.2%
Production	3.4%	2.4%	2.1%	2.1%	1.3%	1.0%	1.0%	1.1%	1.3%	1.5%	1.5%	1.6%

Table 9-2 Impact of a 10% sustained increase in yield in Brazil on price, production and domestic consumption versus baseline projection

Impact of a 10% sustained increase in Income on Price, Production and Domestic Consumption versus Baseline Projection												
		10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22
Green Coffee Price	20.0%	16.7%	15.0%	14.3%	10.0%	7.9%	8.1%	8.4%	9.6%	10.9%	11.0%	9.6%
Domestic Consumption												
Brazil	-0.1%	0.6%	0.8%	1.0%	1.5%	1.8%	1.8%	1.9%	1.9%	1.8%	1.9%	2.1%
Colombia	-2.3%	-0.4%	0.2%	0.5%	2.2%	3.2%	3.4%	3.6%	3.6%	3.5%	3.8%	4.6%
European Union	-1.5%	-1.1%	-1.0%	-1.1%	-0.8%	-0.6%	-0.7%	-0.7%	-0.9%	-1.0%	-1.1%	-1.0%
Honduras	-3.1%	-2.3%	-2.1%	-2.1%	-1.5%	-1.2%	-1.2%	-1.2%	-1.4%	-1.5%	-1.5%	-1.3%
India	-8.0%	-5.8%	-5.5%	-5.5%	-4.0%	-3.3%	-3.4%	-3.6%	-4.1%	-4.7%	-4.7%	-4.2%
Indonesia	-4.8%	-3.5%	-3.2%	-3.2%	-2.4%	-2.0%	-2.1%	-2.3%	-2.6%	-3.1%	-3.2%	-2.9%
Japan	-0.3%	0.0%	0.1%	0.1%	0.3%	0.4%	0.4%	0.4%	0.4%	0.3%	0.4%	0.4%
Mexico	-2.8%	-2.1%	-1.9%	-1.9%	-1.4%	-1.2%	-1.2%	-1.3%	-1.5%	-1.8%	-1.9%	-1.7%
United States	-5.0%	-3.6%	-3.3%	-3.3%	-2.3%	-1.9%	-2.0%	-2.1%	-2.4%	-2.8%	-2.8%	-2.5%
Vietnam	6.4%	6.9%	7.1%	7.3%	7.7%	7.9%	8.0%	8.1%	8.1%	8.1%	8.2%	8.3%
World Total												
Domestic Consumption	0.1%	0.8%	1.0%	1.1%	1.7%	2.0%	2.0%	2.0%	2.0%	1.9%	1.8%	1.8%
Production	0.0%	0.9%	1.2%	1.3%	2.0%	2.3%	2.4%	2.4%	2.3%	2.1%	2.1%	2.1%

Table 9-3 Impact of a 10% sustained increase in income on price, production and domestic consumption versus baseline projection

Impact of a 50% sustained decline in Tariff Rates on Price, Production and Domestic Consumption versus Baseline Forecast												
	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22
Green Coffee Price	0.17%	-0.14%	-0.14%	-0.13%	-0.17%	-0.13%	-0.09%	-0.08%	-0.06%	-0.07%	-0.08%	-0.09%
Domestic Consumption												
Brazil	-0.02%	0.01%	0.01%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Colombia	-0.06%	0.04%	0.05%	0.05%	0.06%	0.04%	0.03%	0.03%	0.02%	0.02%	0.02%	0.03%
European Union	0.40%	0.38%	0.39%	0.41%	0.43%	0.46%	0.48%	0.49%	0.50%	0.51%	0.53%	0.55%
Honduras	-0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
India	-0.07%	0.05%	0.05%	0.05%	0.07%	0.05%	0.04%	0.03%	0.03%	0.03%	0.03%	0.04%
Indonesia	-0.04%	0.03%	0.03%	0.03%	0.04%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%
Japan	-0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mexico	0.81%	0.77%	0.80%	0.84%	0.87%	0.91%	0.94%	0.96%	0.99%	1.01%	1.03%	1.06%
United States	1.77%	1.57%	1.62%	1.68%	1.73%	1.79%	1.83%	1.85%	1.85%	1.86%	1.87%	1.90%
Vietnam	-0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
World Total												
Domestic Consumption	0.01%	0.04%	0.04%	0.04%	0.04%	0.04%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%
Production	0.00%	0.04%	0.04%	0.04%	0.05%	0.04%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%

Table 9-4 Impact of a 50% sustained decline in global tariff rates on price, production and domestic consumption versus baseline projection

CHAPTER 10 SUMMARY AND CONCLUSIONS

The primary objective of this study was to build an econometric model of the international coffee sector that could be applied to the simulation of alternative scenarios affecting supply or demand including factors such as impacts from technology implementation, macroeconomic developments, policy changes and in-country growing season impacts facing the coffee sector. Specific country coverage included Brazil, Colombia, the European Union, Honduras, India, Indonesia, Japan, Mexico, the United States and Vietnam. An additional twenty-four individual countries and five other regional aggregates were constructed to capture the rest of the world, but were considered exogenous for the scope of this project.

The majority of attention was placed on the development of equations that were considered critical within the sector. For the supply side this included focus primarily on the area equation, and on the demand side the focus was primarily on the domestic consumption equation. Also, the price linkage or price transmission equations gained much initial analysis prior to extensive estimation of the other behavioral equations.

These three equations' structural relationships comprised the largest impacts within each country model. With production being an identity of area multiplied by yield, and yield being comprised mostly as a function of a trend, the largest part of supply variation was dependent on how the behavioral relationships in the area equations were structured. Following the progression of the literature review the development of the area equation was an end result of much previous research. Once the appropriate causal variables were decided upon and incorporated into the area harvested equation the development of supply side of the country models became more reasonable. For the domestic consumption equations the original concern was not as much focused on which causal variables were to be used, as consumer theory more consistently uses similar independent variables and proxies for those variables, but more concern was with the appropriate elasticities in the structural relationship. Almost every final domestic consumption elasticity was the product of the iterative process of estimation, comparison to other studies, graphical analysis, evaluations for fit including root mean square error percent, historical simulations and projection shock analysis, while incorporating additional re-estimation within the various steps. The final equation, which was truly the initial focus of estimation were the price linkage equations. As one of the simplest behavioral equations in the model, the focus of the estimation of this equation was on the appropriateness of the estimated elasticities. In most of the countries where recent producer price data were available the direct relationship between the Brazilian producer price (solved as the world residual price) and the in-country producer price was reasonable. As other studies outside of the coffee sector normally have had the price transmission elasticity mostly near one, the larger variation in the elasticity from one in the coffee sector was disconcerting, but other research evaluating coffee's price transmission showed similar findings. The price linkage equation was imperative to the model as an in-country price linked to the Brazilian producer price, and was used whenever available to assist in capturing individual country policy or market structure variation that is not transparent from available data sources.

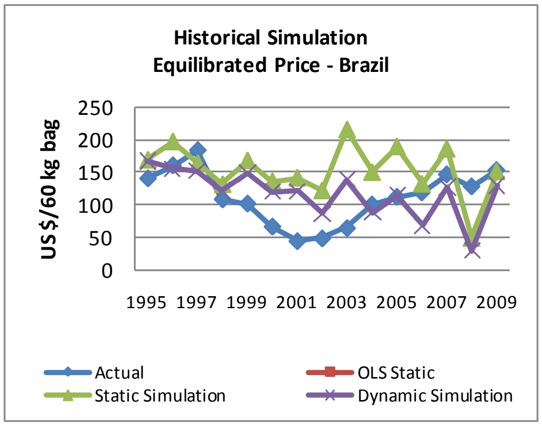
An interesting note in this study is that additional elasticity adjustment outside of estimation and re-estimation, dependent on fit analysis, became necessary to three variables. The primary variable was the income elasticity in the domestic consumption equation. In many cases the income elasticity was deemed too high under simulation and had to be synthetically reduced and imposed. The second variable was the lagged area variable in the area harvested equation. This variable had similar problems under simulation and was consequently in select cases reduced and synthetically imposed. The only other variable that was imposed, which was included in a select few equations was a trend variable. In each case where a variable was synthetically imposed it was the last step in the iterative estimation process, and incorporated simple graphical analysis and error fit analysis to find a reasonable elasticity level falling within a priori expectations.

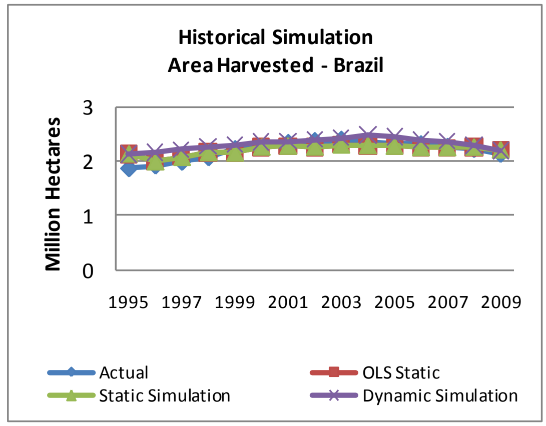
In total, 130 structural equations were estimated. Given structural equations and corresponding identities, the total system represents 196 equations and approximately 450 data observations per year using annual data sets on a crop year basis. Following the estimation process the model was historically simulated from 1995 to 2009 and tested using impact analysis and shocking the model with results compared to a baseline projection. The historical tests and projection simulations were an iterative process. In the final iteration the model performed well and solved to a reasonable solution.

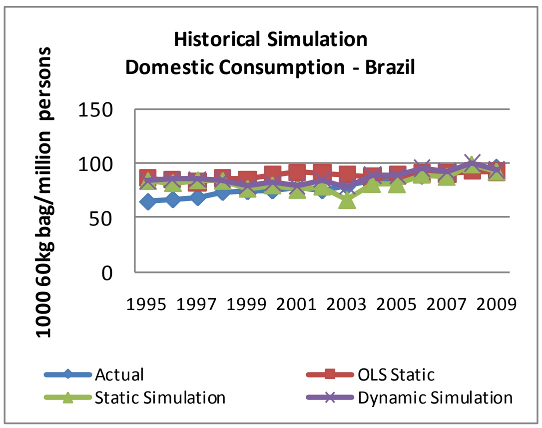
The price inelasticity of coffee consumption in combination with the slow gestation lag for coffee trees from planting to productivity provided a challenge, and although projections were reasonable, the current stage in the model development is only the beginning of the research process. As new or more reliable in-country sources for data are found for price, trade or domestic and trade policies there will continue to be additional iterations in the estimation process to capture more accurate structural relationships. Indubitably there will also be newer and different methodologies found to evaluate these structural relationships, and as these approaches are found this may provide the opportunity to better understand the underlying relationships that make up the international coffee sector.

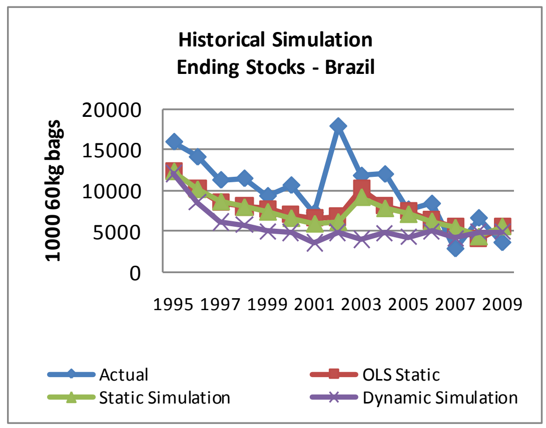
APPENDIX A

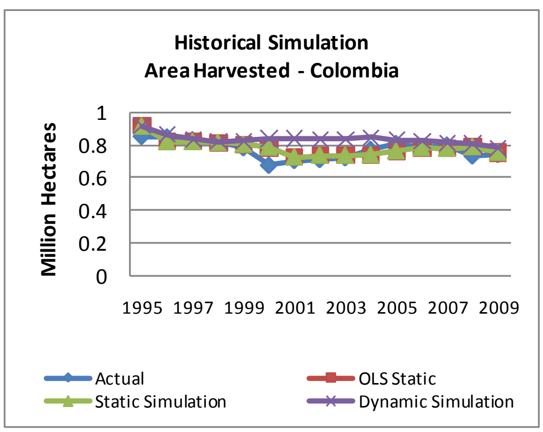
Simulation Graphs

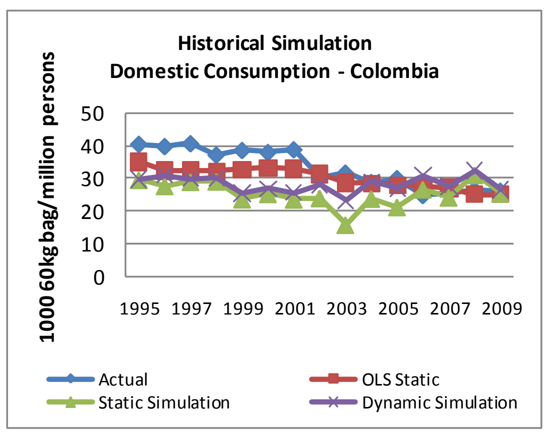


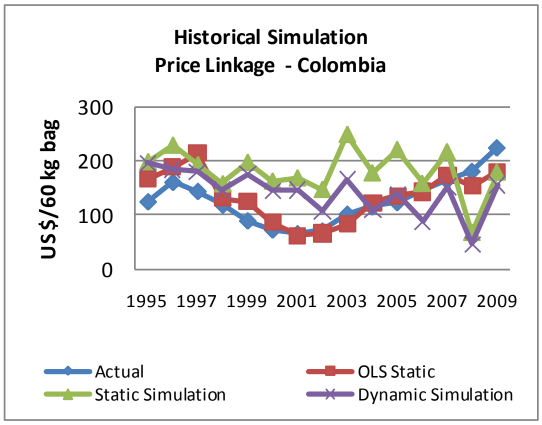


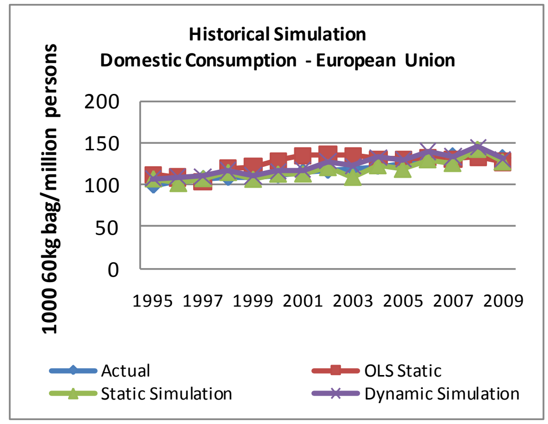


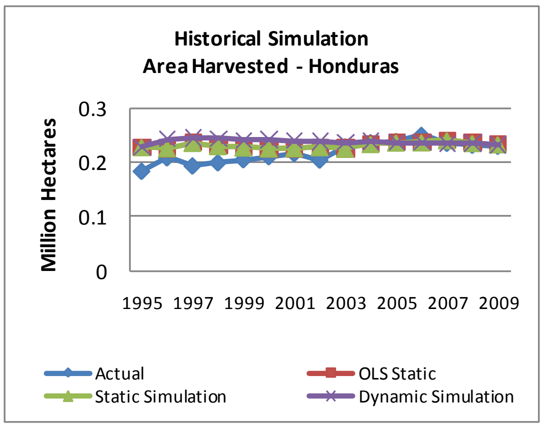


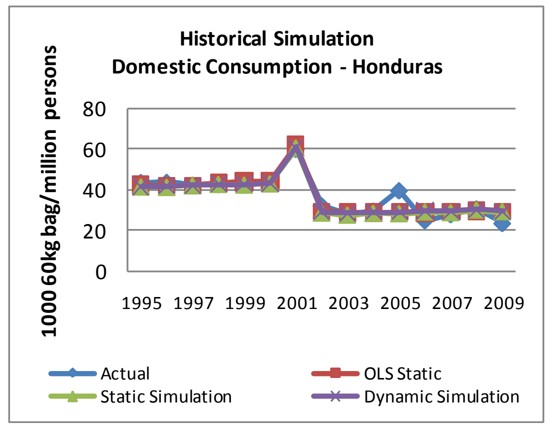


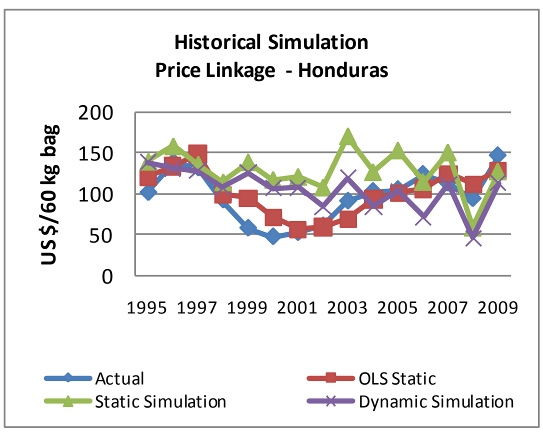


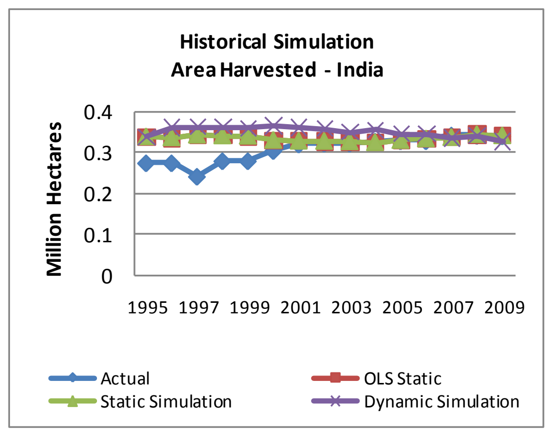

Historical Simulation
Price Linkage - Colombia
US $/60 kg bag
300
200
100
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

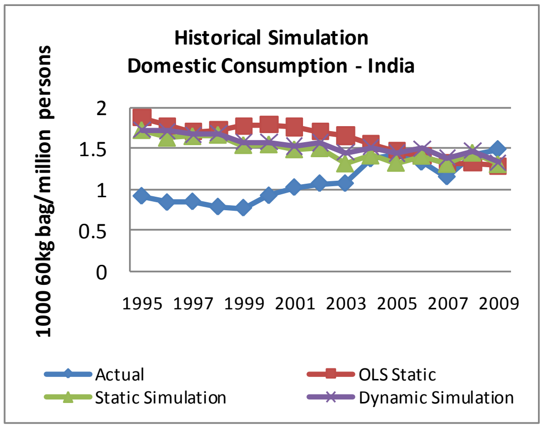

Historical Simulation
Domestic Consumption - European Union
1000 60kg bag/million persons
200
150
100
50
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

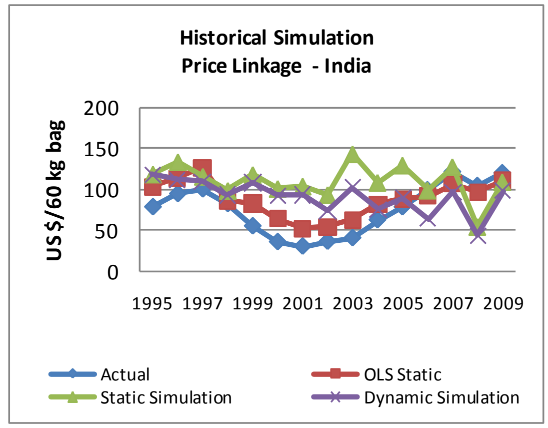

Historical Simulation
Area Harvested - Honduras
Million Hectares
0.3
0.2
0.1
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

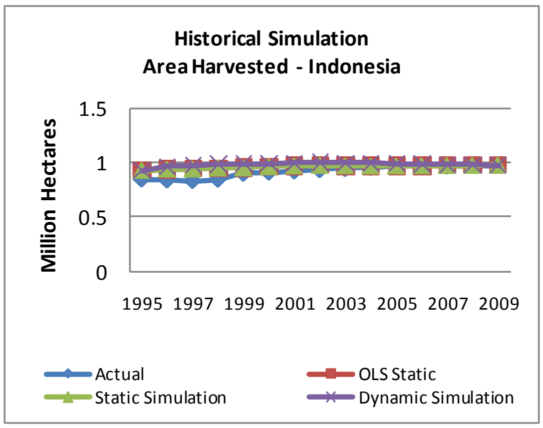

Historical Simulation
Domestic Consumption - Honduras
1000 60kg bag/million persons
80
60
40
20
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

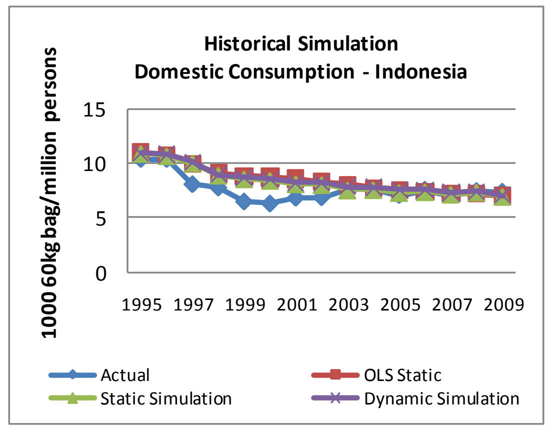

Historical Simulation
Price Linkage - Honduras
US $/60 kg bag
200
150
100
50
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

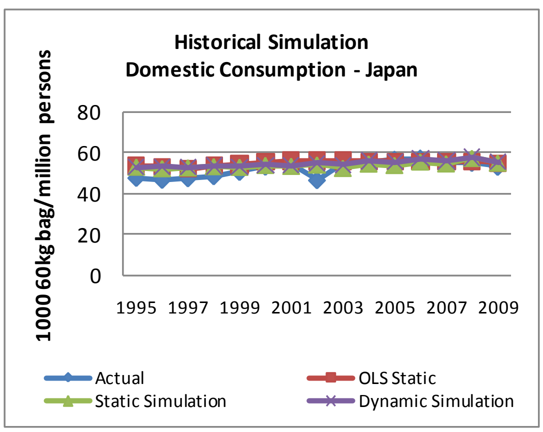

Historical Simulation
Area Harvested - India
Million Hectares
0.4
0.3
0.2
0.1
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

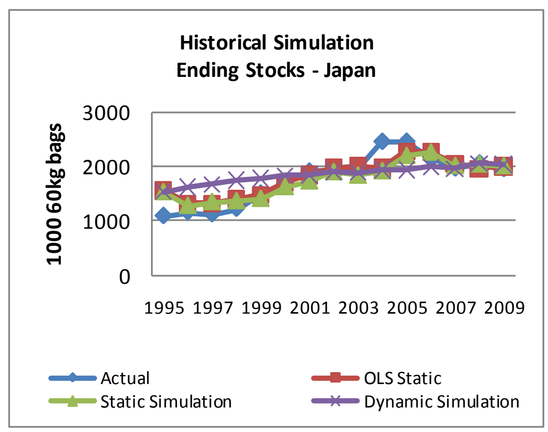

Historical Simulation
Domestic Consumption - India
1000 60kg bag/million persons
2
1.5
1
0.5
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

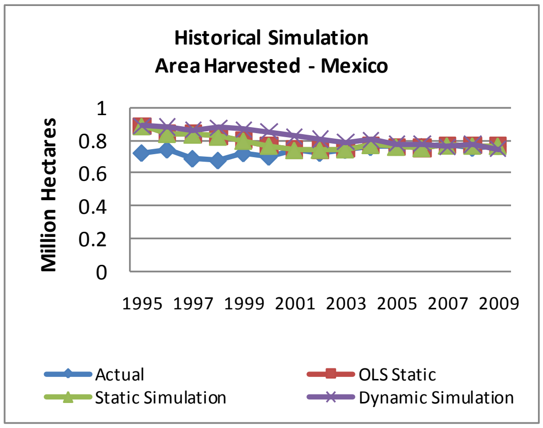

Historical Simulation
Price Linkage - India
US $/60 kg bag
200
150
100
50
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

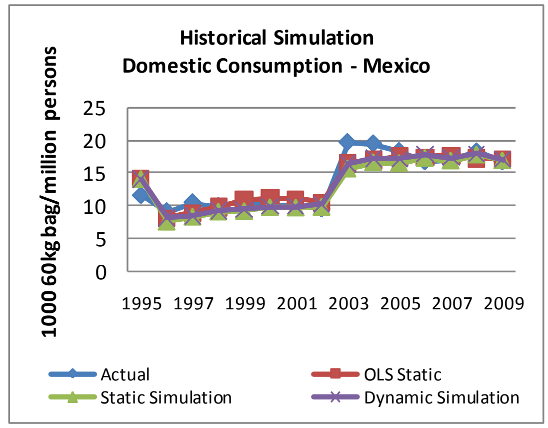

Historical Simulation
Area Harvested - Indonesia
Million Hectares
1.5
1
0.5
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

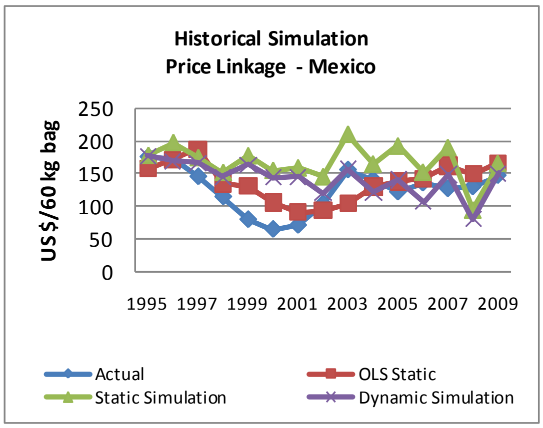

Historical Simulation
Domestic Consumption - Indonesia
1000 60kg bag/million persons
15
10
5
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

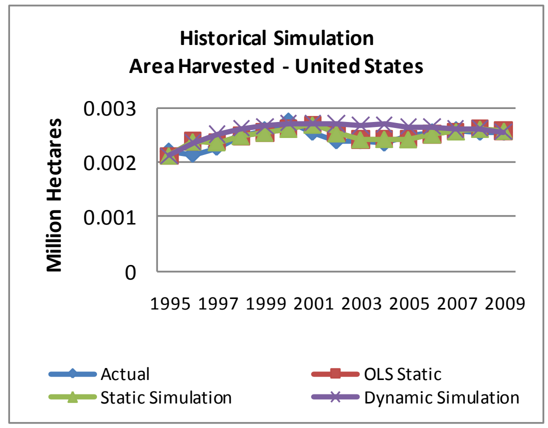

Historical Simulation
Domestic Consumption - Japan
1000 60kg bag/million persons
80
60
40
20
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

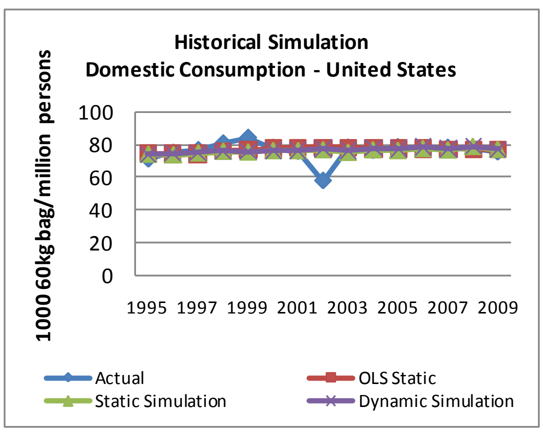

Historical Simulation
Ending Stocks - Japan
1000 60kg bags
3000
2000
1000
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

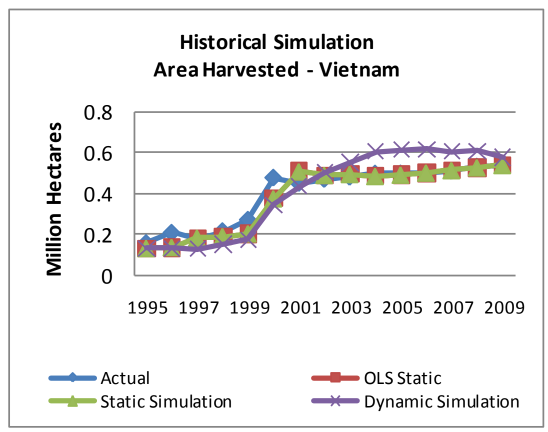

Historical Simulation
Area Harvested - Mexico
Million Hectares
1
0.8
0.6
0.4
0.2
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

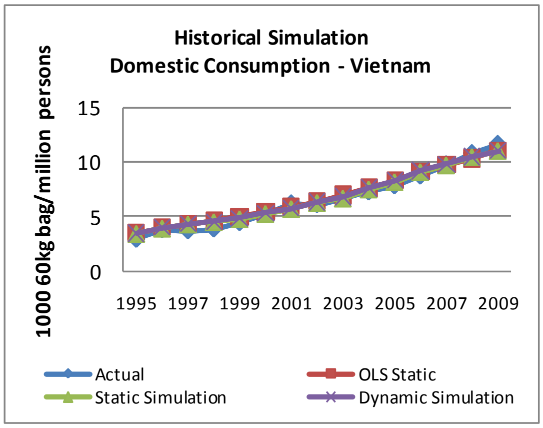

Historical Simulation
Domestic Consumption - Mexico
1000 60kg bag/million persons
25
20
15
10
5
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

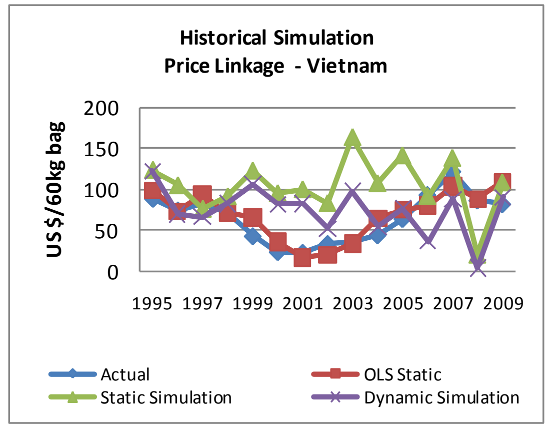

Historical Simulation
Price Linkage - Mexico
US $/60 kg bag
250
200
150
100
50
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation


Historical Simulation
Area Harvested - United States
Million Hectares
0.003
0.002
0.001
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation


Historical Simulation
Domestic Consumption - United States
1000 60kg bag/million persons
100
80
60
40
20
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation


Historical Simulation
Area Harvested - Vietnam
Million Hectares
0.8
0.6
0.4
0.2
0
1995 1997 1999 2001 2003 2005 2007 2009
Actual
OLS Static
Static Simulation
Dynamic Simulation


Historical Simulation
Domestic Consumption - Vietnam
1000 60kg bag/million persons
15
10
5
0
1995
1997
1999
2001
2003
2005
2007
2009
Actual
OLS Static
Static Simulation
Dynamic Simulation


Historical Simulation
Price Linkage - Vietnam
US $/60kg bag
200
150
100
50
0
1995
1997
1999
2001
2003
2005
2007
2009
Actual
OLS Static
Static Simulation
Dynamic Simulation

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