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Economic Evaluation of Non-Tariff Trade Barriers: Sanitary Regulations and the Broiler Market in the Western Hemisphere

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Abstract

Exporting countries are concerned that sanitary standards might shield domestic industry from foreign competition. This study analyzes economic effects of changes in Western Hemisphere sanitary requirements on broiler trade in the Americas. A mathematical programming model detects that if Brazil and Mexico are allowed to export fresh, chilled, and frozen poultry meat to the United States and Canada then the United States becomes an importer of value added broiler products and looses market share to Brazil in world broiler market. Due to geographic location, Mexico expands exports to the United States.

- **JEL Classification:** C61, D21, F12, F02, Q18
- **Key words:** Mathematical programming, Firm behavior, Imperfect substitution, Endogenous value-added, Differentiated products, United States, Canada, Mexico, Brazil, Sanitary and phytosanitary standards (SPS), World Trade Organization (WTO), Broiler trade, Nontariff trade barriers (NTBs)

I. Introduction

The Doha Round provides an opportunity to fundamentally reform the three pillars of agricultural market protection. The agreement calls for (1) an increase in market access, (2) the reduction or elimination of export subsidies, and (3) the

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reduction of domestic support. In many cases, market access for imported foods are blocked by sanitary and phytosanitary standards (SPS). SPS are meant to protect human, animal, and plant health. While negotiators recognized the importance of protecting human, animal, and plant health, they were concerned that in some cases SPS were being used to shield domestic industry from foreign competition. To prevent abuses of SPS, a number of reforms addressing them were included in the Doha Round Agreement.

In January 1995, the World Trade Organization (WTO) implemented the application of the SPS Agreement with the purpose of minimizing the negative effects of unjustified health barriers on international trade. Under this agreement, codes were established to prevent the introduction of infectious agents and diseases into importing countries through trade of animals or animal products (OIE 2003). Although the SPS Agreement requires transparency and science-based regulations, it does not require the adoption of international standards (harmonization). In addition, nations have accepted the concept of “regionalization”, thereby recognizing disease-free regions or zones within a country. This would allow exports from distinct regions within a country that present evidence of the absence or low incidence of pests and diseases (Roberts 1998a, Roberts 1998b, Salin et al. 2002, Kassum and Morgan 2002). Nonetheless, there is limited published research in the area of the economic impact of SPS, especially on the poultry industry.

The United States and Canada protect their poultry industries from Exotic Newcastle Disease (END). END is endemic throughout the rest of the Western Hemisphere. Both Mexico and Brazil have eradicated END from some of their States, opening the possibility that they can ship fresh or frozen poultry to the United States and Canada. This paper is the first to analyze in a unique approach the economic impact of these changes in North America sanitary requirements on Western Hemisphere broiler production and trade flows. The United States and Brazil are the worlds two most important poultry exporters. Changes in production and trade in the Western Hemisphere will have global implications.

The economic model developed for this paper is a mathematical-programming model designed specifically to measure the changes and distribution of the economic welfare arising from reform of SPS and other policies on Western Hemisphere broiler (chicken meat) markets. This analysis focuses on SPS reform and does not address the impacts of other policies. This model uses a new approach to model product differentiation. Products are differentiated by different levels of value-added service, and the level of value-added embedded in goods is endogenous. The model focuses on the four major players in the Western Hemisphere broiler market: Canada, the United States, Mexico, and Brazil. Other regions in the Western Hemisphere and the rest of the world are modeled with less detail.

II. Overview of the World Broiler Market

Before discussing policy and modeling issues, it is useful to place the Western Hemisphere poultry market in its global perspective. Poultry production and consumption have grown rapidly worldwide. Reasons for this expansion include short production cycle, cooking versatility, low fat content, and relatively low prices compared with beef and pork. Broiler markets are highly concentrated in production and international broiler trade is dominated by a few countries (Rogowsky, 1998). In 2002, world broiler production totaled about 54 million tons, in ready to cook (RTC) equivalent form. The United States is the worlds largest producer followed by China, Brazil, European Union (EU), and Mexico. These five countries account for more than 70 percent of the world's production (FAS, 2003a). Broiler production has become highly concentrated, especially in the United States, Brazil, Mexico, and Thailand, where a few large firms account for most of the production (Orden *et al.*, 2002, UNA, 2002). The United States is the world's top broiler consuming country, accounting for about one-quarter of global consumption, followed by China, EU, and Brazil. These four countries account for 65 percent of the worlds broiler consumption. The United States and Brazil dominate international broiler trade globally. These two countries account for more than two-thirds of the world's broiler exports (FAS, 2003a). Russia, Japan, and China are the worlds largest importers accounting for more than half of worlds broiler imports, followed by the EU, Saudi Arabia, Mexico, and Hong Kong. These seven countries account for 85 percent of total world broiler imports (FAS, 2003a).

In the North American region, broiler production totaled 17.6 million tons in 2002. This represents 32 percent of total world broiler production. This region consumed 15.7 million tons of broilers in 2002, comprising 30 percent of total world broiler consumption (FAS, 2003a). The United States is the largest broiler producer and consumer worldwide. In addition, it is the only net broiler exporting country in the region, accounting for 38 percent of total world exports. Mexico is the fifth largest world broiler producer and consumer country. Mexico and Canada are among the top 10 broiler importing countries, accounting for about 8 percent of the worlds broiler imports.

III. Policy Environment in Western Hemisphere Broiler Trade

While SPS have important effects on poultry trade in the Western Hemisphere, these are not the only policies that have a significant impact on broiler production and trade. In addition to the SPS, which are discussed later, the following policies are included in the model:

Of the four countries modeled in detail, only Canada has a major domestic program to support its poultry industry. Canadian poultry supply controls place an upper limit on poultry production in Canada. To further protect its industry, Canada established import quotas. Prior to NAFTA it was common for the Canadian government to offer “supplementary” quotas allowing additional imports to enter. Under its NAFTA obligations, Canada expanded and reformed its poultry import quota regime. After signing the Doha-Round Agreement, Canada replaced its quota with a tariff-rate-quota (TRQ). The current, over-quota-rate on poultry has been set high enough to eliminate imports over the quota.

Prior to NAFTA, Mexico protected its poultry industry from U.S. competition with a number of different (and frequently changing) policies. As part of its NAFTA obligations, Mexico replaced these policies with a TRQ, with an expanding quota and contracting over-quota rate. During the period between the signing of NAFTA and 2002, the Government of Mexico often allowed poultry imports to exceed the quota without imposing the over-quota tariff. By 2002, poultry trade with the United States was supposed to be liberalized. Starting in 2003, the Government announced a provisional safeguard TRQ on imports of U.S. leg quarters which is (a) legal under NAFTA and (b) meant to stay in place until 2008. The 2004 duty-free quota is 101,000 metric tons (MT) with an over-quota rate of 79%. The quota grows to 104,600 MT in 2008 with the over-quota rate dropping to 19.8%.

Direct domestic support to the poultry industry is low in both Brazil and the United States. Poultry tariffs are low in the United States, ranging from 4.4 to 23.3 cents per kilogram depending on the product. Poultry imports from its NAFTA partners could enter tariff-free; however, U.S. poultry imports are negligible. SPS are the important factor limiting poultry imports to the United States.

END and highly pathogenic avian influenza (HPAI), included in List A of the

International Organization for Epizootics (OIE) classification of transmissible poultry diseases, are two highly infections diseases that restrict poultry trade (Table 1). Countries in which END exists can export only processed poultry meat but not fresh, chilled, or frozen poultry to the United States. (Salin et al. 2002, FSIS 2003). Currently, the U.S. Animal and Plant Health Inspection Service (APHIS) considers END to exist in all but 16 regions of the world (table 2). In addition, APHIS recognizes two Mexican states, Sinaloa and Sonora, as having a low risk of END transmission.

The United States has not been fully successful in preventing END and avian influenza from entering the country. However, it has been able to contain those outbreaks that it experienced. Avian influenza is a common problem; the last U.S.

Table 1. OIE Classification of Poultry Diseases, 2003

List A-major importance in the international trade of animals and animal products	**List B-significant in the international trade of animals and animal products**
Highly pathogenic avian influenza	Avian chlamydiosis
	Avian infectious bronchitis
Newcastle disease	Avian infectious laryngotracheitis
	Avian mycoplasmosis (M. gallisepticum)
	Avian tuberculosis
	Duck virus enteritis
	Duck virus hepatitis
	Fowl cholera
	Fowl pox
	Fowl typhoid
	Infectious bursal disease (Gumboro disease)
	Marek s disease
	Pullorum disease

Source: International Organization for Epizootics (OIE). Data on Animal Diseases, OIE Classification of Diseases. <http://www.oie.int/eng/normes/mcode/a_summry.htm>. March 20, 2003.

Table 2. Countries declared by APHIS to be free of exotic Newcastle disease (END)

Regions	Disease Free Regions
Europe	Finland, France, Great Britain (England, Scotland, Wales, and the Isle of Man), Greece, Iceland, Luxembourg, Republic of Ireland, Spain, Sweden, Switzerland.
Others	Australia, Fiji, New Zealand, Canada, Chile, Costa Rica.
All other countries are considered to contain these pathogens	

Source: National Archives of Records Administration, Code of Federal Regulations, Title 9, Vol. 1, Chapter 1, Section 94.6, January 1, 2003.

outbreak at the time this is written was in February 2004. END is less common. On October 1, 2002, an outbreak of END was confirmed in California. This outbreak originally occurred in small backyard flocks and spread later to commercial egg laying operations. Subsequently, END has been confirmed in noncommercial flocks in Nevada, Arizona, and parts of Texas and New Mexico. Since the beginning of the outbreak, 3.5 million birds have been killed (APHIS, 2003). This represents slightly over 1 percent of the total U.S. commercial egg laying hen population. The END outbreak did not affect the U.S. commercial broiler industry, but did disrupt U.S. exports while the outbreak was being brought under control.

APHIS has recognized two Mexican states as low-risk for END, which means that imports from these two states are not considered a threat to chicken health. However, SPS also protect human health. In order to export fresh, chilled, or frozen poultry to the Untied States, Mexico must have its plants and inspection system certified and by the USDA Food Safety and Inspection Service (FSIS). Mexico is in the process of getting its inspection system for poultry certified by FSIS and is also working on the elimination and control of END in additional states.

While Mexico has been working to be able to export poultry to the United States, Brazil has succeeded in getting access to the Canadian market. Effective August 1, 2002, Canada recognized Brazil's poultry inspection system. In addition, eight[1] Brazilian states were recognized free of END by the Canadian Food Inspection Agency (CFIA 2002). At the time this is written, Brazil has yet to ship poultry to Canada. U.S. concern about cross-shipment of product seems to be an important factor underlying this lack of Brazilian exports to Canada.

IV. Model Overview

The *Broiler Trade Model* (BTM) is a mathematical programming (MP) model (See Appendix), with a structure similar to the North American Trade Model for Animal Products (NATMAP) (Hahn, 1993). The use of MP as a method for modeling equilibrium in competitive markets dates back to 1952 (Samuelson). We use the BTM to evaluate the effects of allowing the low-END-risk regions of Mexico and Brazil to export poultry to the United States and Canada.

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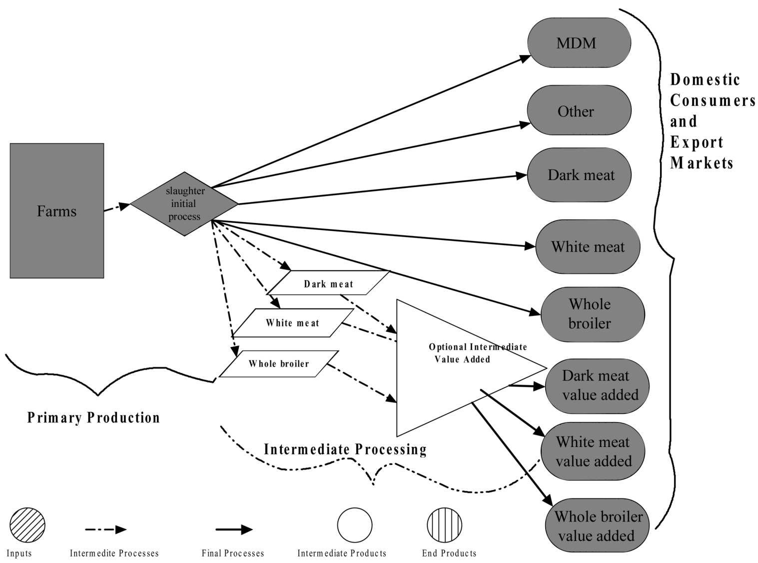
[1]Mato Grosso do Sul, Minas Gerais, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Goiás, Mato Grosso or the Federal District of Brazil.

The BTM divides the world into eight regions; however only four of these are modeled in detail. The four regions with the detailed specification are Canada, the United States, Mexico, and Brazil. These countries will be referred to as the major players. The BTM has a full set of supply and demand relationships for the major players. The four other regions are represented as excess-demand regions. These areas are net importers of chicken from the United States and Brazil. The excess demand regions are the Caribbean, Central America, the rest of South America, and the Eastern Hemisphere. The model starts with a baseline set of prices, quantities, and policies and assumes that the current production and trade pattern is optimal. Changes in policies may lead to changes in the optimal pattern of production and trade.

Figure 1 is a flow chart that outlines product flow in each of the major players. There are two production phases, the second one is optional, and a single, domestic demand structure. The model looks at broiler and broiler cut supply and demand at the wholesale level. The BTM models the wholesale level, because this is the level at which trade in broiler and broiler products occur.

Policies are modeled either as restrictions on the model or as cost factors. For example, tariffs and other import fees increase the costs of broiler trade. Sanitary barriers are treated as absolute restrictions preventing broiler-product exports from Mexico and Brazil to the United States and Canada. Canada's supply controls are

Figure 1. Flow chart of the model's structure.



modeled as an upper bound on total production. Because Canada's over-quota tariff rates on all broiler products and Mexico's on dark meat are high, these quotas are treated as if they were absolute limits on imports. If the over-quota rates were low enough to allow trade, they could be modeled as an additional cost of importing product in excess of the quota. U.S. tariffs on (potential) Brazilian imports are treated as a cost of shipping product.

Although it is a wholesale-market model, the demand structure is a consumer-level demand specification. Wohlgenant and Haidacher show that when markets are competitive, derived demands have the same properties as consumer demands provided one adds in the demand for marketing inputs (Wohlgenant and Haidacher, 1989). We maintain the typical, partial equilibrium assumption that changes in broiler prices do not cause changes in other product prices. If the prices of all other goods are fixed, including broiler marketing inputs, then we can aggregate their expenditures into a single good, using Hicksian aggregation as suggested by Lewbel (Lewbel, 1996). The consuming sector buys chicken products and the aggregate "other" good.

The primary production phase is a combination of the farm, slaughter, and preliminary processing phase of production. This structure is consistent with the business organization of broiler production in the major players. Most of the broiler production in the Western Hemisphere is integrated. While farms are usually separate enterprises, it is common for bird producers to contract with slaughter/processing companies, the integrators. The primary production phase produces two types of chickens that are turned into five types of poultry products. The two types of chickens are (1) those that end up being sold as whole chickens and (2) those that are processed into parts. When chickens are processed for parts, they produce four kinds of chicken parts in fixed proportions. Parts chickens' outputs are approximately 32% white meat, 44% dark meat (leg and thigh or leg quarters), 22% other meat (wings, backs, necks) and 2% mechanically deboned meat (MDM).

Whole chickens and parts chickens are modeled as joint products. The types of chickens that farmers produce for their integrators vary by the chicken's end use. An alternative modeling structure could start with a generic chicken that is either sold "whole" or processed into parts. This alternative does not fit reality. A further problem is that (at least in the United States) it is common for the sum of the value of chicken parts prices to be lower than the value of a whole chicken. This implies negative value-added, a sub-optimal solution. What is actually happening is that U.S. integrators use a cheaper chicken to produce parts. Modeling whole and parts chickens as distinct but joint products better captures the working of the market and allows the observed baseline to be optimal.

The usual economic model of trade is based on the concept of comparative advantage, a theory based entirely on costs of supplying products. Once one introduces joint production, consumer tastes begin to have an important effect on trade flows. Cost factors alone cannot explain how chicken parts should be priced. In competitive equilibrium, the total value of the parts has to equal the marginal cost of producing the birds. Given our assumption of fixed-proportions parts production, demand determines relative prices for chicken parts. U.S. as well as Canadian consumers have a strong preference for white meat and are willing to pay a high price for it. High white-meat prices cause low dark-meat prices. Low U.S. dark-meat prices are the most important factor driving U.S. broiler-meat exports.

Each of the five basic chicken products can be sold to the domestic market or exported. Three of the five, whole chickens, white meat, and dark meat, can be further processed to make value-added products. This is the second stage of the production process. Some of the firms involved in primary production of chicken products also produce these value-added products. We have excluded "other" chicken from the value-adding process, as this low-valued item is not traded. MDM is an important export item for the United States. However, it is used as an input in other products, and there is no identifiable demand for value-added MDM.

Value-added white and dark meat includes categories of products such as boneless, skinless, and processed products for restaurant use/trade. We included whole broilers in the value-added category to account for the importance of rotisserie broilers in Mexico. Differences in processing or other services applied to value-added products are a market-determined source of imperfect substitutability. One of the innovative features of our model is that it incorporates this source of imperfect substitutability. We have developed a means of incorporating endogenous levels of value-added in domestic and international trade. Our theory of endogenous, product differentiation is outlined below.

A. Product Differentiation, Value-added, and Trade

It is common for countries to engage in significant bilateral trade that involves trade in the "same" commodity. By "same" we mean having the same tariff code or international commodity code. Economic modeling of "same" commodities bilateral trade is problematic. One way to deal with bilateral trade is through more detailed specification of the products traded. This is one reason why we include so much chicken-product detail in our model. The price of dark meat and MDM relative to white meat is one of the reasons that the United States is a major poultry exporter. Brazil is much more competitive in the whole-bird market. Differences in consumer tastes and prices for broiler cuts determine a large part of the trade. By accounting for consumer taste, we can differentiate a countrys imports and exports.

Another method that economists have adopted to deal with bilateral trade is to assume that the products with the same name are actually "differentiated", hence imperfect substitutes. One example of the differentiated product approach is the Armington specification (Alston et al. 1990). The Armington approach is based on the hypothesis that one country's products are imperfect substitutes for another's. Another approach to dealing with bilateral trade in an undifferentiated commodity involves introducing regions within nations and internal/external transportation costs.

One of the problems in using the Armington approach in this context is that SPS have prevented Mexico and Brazil from shipping chicken products to the United States or Canada. In most applications, the Armington approach is implemented by using some elasticity of substitution for domestic and imported products. With no observed trade, we have no idea about how these imports substitute for domestic product. The maximum impact of policy reform is likely to occur when domestic and imports are perfect substitutes. We have assumed that the "generic" poultry products are perfect substitutes.

One of the apparent advantages of Mexico and Brazil as exporters is their low labor costs relative to the United States and Canada. These low labor costs suggest that they would be strongest in those market niches demanding value-added products. Value-added products are obviously differentiated. To deal with this possibility, we developed a model of endogenous value added.

Unlike the arbitrary and unrealistic assumption of the Armington approach, this paper uses natural sources of product differentiation and substitutability. That is differences in value-added to a "generic" commodity. In our discussion of endogenous value added, we are going to focus on a single-good, single country case. Extension to our multiple country, multiple product case is trivial.

We consider a *value-added product* a combination of *ingredients* and *services*. By ingredients, we mean the physical product. In this case, ingredients are whole chickens and chicken cuts. Services are largely confined to processing. Examples of services in this case include boning and skinning, packaging, and further processing. *Portion control*, the production of standard-sized portions for the restaurant use/trade, is another example of services applied to an ingredient.

Adding value to basic ingredients via the use of service allows a country to export both products and services. The “compounded” exported good can then be classified based on its main ingredient. That is, a country with low ingredient costs and high costs of services could have bilateral trade with a country with high ingredient costs and low value-added costs. In this case, a low-ingredient, high service product is an imperfect substitute of a high-ingredient, low service product.

BTM uses simple types of value-added products. Our discussion will focus on the simple case captured in the model, but we will note obvious extensions. One simplifying assumption that we make is to define a value-added product with only one ingredient and one service. There will be a fixed proportion relationship between the ingredient, the service and the value-added product. Doubling the production of the value added product requires a doubling of the ingredients and service. Two obvious extensions to our basic model would be to (1) allow for multiple ingredients and services and (2) more complex production relationships.

The amount of service added to the ingredient is fixed in our model. Our model resembles a supply-side version of Lancasters model of the demand for characteristics (Lancaster 1966). In this approach, the goods consumers buy are modeled as bundles of characteristics. In our model, the value-added product is literally a bundle of characteristics. If we were to model consumer demand using characteristic demand, it would be possible to make the desired amount of service added to the ingredient endogenous. The amount of “service” added to each product varies by product and country. We would normally expect that the demand for services would be income elastic. The United States and Canada with high income consumers are likely to demand more highly-processed products than consumers in Mexico or Brazil.

Our theory of product differentiation also draws on household production theory or the theory of “boundary of the firm.” Both theories attempt to explain those activities that are done internally and those that are purchased in the market. We assume that the consumer desires some value-added product. Another obvious generalization is to make the end product endogenous as well.

For example, the consumer wants a chicken dinner. In the Western Hemisphere, one observes a range of options for providing chicken dinners. Some consumers raise their own chickens that they make into dinners. On the other extreme, some buy their chicken dinner from a restaurant. We can allow for a range of options between the two extreme cases by allowing the agent to buy partially processed products. In our two-characteristic case, the partially processed products are a combination of raw commodity and purchased value-added. The partially processed product is going to be treated as a bundle of characteristics, just as in the characteristic model of demand.

Since we have assumed a fixed proportions relationship between ingredients and services, we can focus initially on the per-unit relationship between embedded bought service and self-produced service. The partially processed product will be defined so that one unit of it has enough ingredients to make one unit of the final product. The amount of value added by the processor to the partially-processed product will be denoted by "*b*". The term "*m*" stands for the per-unit value-added made by the firm or consumer. The term "*v*" is the per-unit value-added target. Our model hypothesizes a production function that relates v, b, and m as follows:

$$v = f(b, m) \tag{1}$$

A general form as in (1) allows the two types of value-added service to be either perfect or imperfect substitutes. Imperfect substitution can result in interior solutions to the make-versus-buy decision. The BTM uses a constant-elasticity-of-substitution (CES) function for (1). Our assumptions about how the final product is produced allow us to further separate the supply of ingredients from the supply of services. In a competitive equilibrium, the optimal amount of "bought" versus "made" service is going to be determined by equating the marginal value product (MVP) of bought services to that of made services. The MVP of "made" service in the consumer demand for partially processed products reflects the currency-equivalent value of marginal utility. The level of embedded service in the partially processed product is endogenous. The price of the partially processed product (p_p) is going to be the marginal cost of the ingredient (p_i) plus the marginal cost of the embedded service (p_b) times the amount of embedded service:

$$p_p = p_i + b^* p_b \tag{2}$$

Generally, higher-income consumers buy more services and more products with embedded, value-added services. Different household costs of "do-it-yourself" explains why we observe the same basic ingredients with different levels of services attached being marketed to final consumers. As noted above, our programming model simplifies reality by assuming only a limited number of value-added products. We allow the amount of desired service to vary across countries. In our approach, we include products at the wholesale level, not at the retail end-user consumption products. Since we expect less diversity in firm technology than in consumer's preferences, limiting the range of value-added products at this wholesale level is likely to be less restrictive.

We developed a two-country test model using our approach and were able to get bilateral trade between a country with low service and high ingredient costs and one with low ingredient and high service costs. It was also possible to set up examples that lead to one-way trade flows. Armington models with bilateral trade in one scenario generally produce bilateral trade in others. One way to allow for even more possibility for bilateral trade in our kind of model is to introduce more producer and consumer diversity. In the BTM, there is one aggregate consumer, one aggregate value-adding sector, and only one type of value-added in each country. Introducing more kinds of consumer's, producers, and expanding the types of end-use value-added will allow for more potential for bilateral trade.

V. Predicting Broiler Market Impacts: Model Assumptions and Results

The BTM starts with a baseline set of prices, quantities, and policies and the assumption that this baseline represents a competitive market equilibrium. If there are no changes in the policies or other exogenous variables, then the BTM's optimal solution replicates the baseline.

Total broiler production, consumption, and the trade patterns for the four countries are based on 2002 estimates, as published by the USDA. Production is calculated on a ready-to-cook (RTC) basis. However, trade is measured on a product-weight basis. Value-added products lose bone and skin in processing. When creating the baseline, we adjusted production, trade, and consumption numbers where necessary to account for processing.

Production and trade statistics are generally aggregate all broiler products. We had additional information on the U.S. and Mexican markets which we used to disaggregate total production. Seventeen percent of U.S. broiler production is sold as whole birds (Parsons, 2003). This ratio was also used for Canada. We assumed that fifty percent of Mexican and Brazilian broiler production is whole birds. Although Mexican broiler processors market 80 percent of their production as whole birds (UNA, 2002), this does not imply that consumers usually buy whole birds.

Consumers often buy broiler parts/cuts at supermarkets, public markets, and butcher shops where the cut-up operation takes place (Salin and Hahn, 2003). Consumer demand for parts determines Mexico's demand for imported broiler parts. Our use of 50 percent reflects a compromise between plant-level production and final consumption. We used the same disaggregation of production for Brazil that we used for Mexico.

We were able to get Brazilian prices for an industry contact. Canadian prices are based on U.S. prices plus an estimated quota rent of U.S. $0.20/KG. The USDA publishes a wide range of prices for wholesale chicken products and even has price reports for Mexican chicken products. The problem with the Mexican wholesale chicken prices is that they are not directly comparable to the U.S. prices. Mexican prices are collect closer to the end-user than U.S. prices. Given the trade pattern between Mexico and the United States for baseline trade flows to be in equilibrium, Mexican prices for dark meat and MDM must be U.S. plus transportation. Since other chicken products are not exported to Mexico, Mexican prices have to be less than U.S. prices plus transportation. We used the Mexican wholesale prices and the equilibrium U.S.-Mexico price differences for dark meat and MDM to estimate the markup between the plant and the Mexican wholesale market level. We used this estimated markup to create plant-level prices for generic chicken cuts in Mexico.

Our treatment of value-added products is based on a mix of discussion with the poultry industry and judgement. U.S and Canadian consumers demand the same amount of processing in value-added broiler cuts and have similar broiler value-added costs. We assumed that U.S. and Canadian value-added broiler cuts have 5 times more embedded services than Mexican and Brazilian cuts due to higher income consumers in these countries. Mexicos cost of adding value is assumed to be 33 percent of the U.S. cost, while Brazils cost is 20 percent of the U.S. cost (ACMF, 2002). Salin and Hahn (2003) indicate that typical Mexican wholesale-retail markup on broiler is about 33 percent, as opposed to 100 percent in the United States. The difference in price between U.S. and Canadian value-added and "generic" cuts is 15 times more than the Mexican price difference and 25 times the Brazilian price difference. The U.S. or Canadian products are more highly processed with higher costs for that processing. We also assumed that 75 percent of the value-added of processing broiler parts in the United States and Canada is performed at the processor level, while the remaining 25 percent of the value added is completed by the final seller of the product. We reversed these percentages for Mexico because Salin and Hahn indicate that most broiler processing in Mexico occurs closer to the final users. We also assume that Brazils “bought” versus “made” shares of embedded services are the same as Mexico’s.

Since we are focusing on SPS changes, we kept the other baseline policies the same. There are no tariffs on the within-quota chicken trade in the NAFTA countries. We assumed that both Canada and Mexico maintain their TRQs on chicken. This is one deviation from the 2002 baseline as Mexico’s TRQ on dark meat was initiated in 2003. Mexico has a 5 percent ad-valorem tariff on broiler meat from non-NAFTA sources. We applied this tariff to potential imports from Brazil.

The U.S. tariff on broilers varies by cuts and source. Canadian and Mexican broilers can enter the U.S. duty-free. For broilers imported from Brazil, U.S. tariff rate was set to its minimum rate, 4.4 cents per kilogram. Brazilian import tariffs are irrelevant to the model, as Brazil does not import broiler in the baseline or any of the alternative scenarios.

Currently in Mexico only two states are recognized as being relatively low-risk of END transmission by APHIS. Sinaloa and Sonora account for 4 percent of total Mexican poultry production (Salin et al. 2002). In some scenarios, we assume that additional states in Mexico will be recognized as free of END. The eight Brazilian states that Canada has recognized to be free of END account for about 72% of Brazilian production. In addition, we assume that at some point in time Mexico and Brazil are certified to export fresh, chilled, or frozen broiler products to the United States and Canada.

A. Scenarios

To determine the economic impact of allowing Mexico and Brazil to export fresh, chilled or frozen broiler to the United States and Canada, four scenarios were developed:

- Scenario 1: the baseline, representing current sanitary policies, which prevent exports from Mexico and/or Brazil to the U.S. and Canada.
- Scenario 2 (regionalization of SPS): 4-percent of total Mexican production and 50% of Brazilian production occurs in END-free areas and is eligible to be exported to Canada and the United States.
- Scenario 3 (regionalization of SPS): 15 percent of total Mexican production and 70 percent of Brazilian production is recognized as END-free. In this scenario, an additional important poultry-producing state in Mexico is recognized as free of

END. The important poultry-producing states are: Jalisco, Veracruz, Coahuila, Querétaro Puebla, Nuevo León, Aguascalientes, and Estado de México (UNA, 2002). Each of these states accounts for between 6 to 13 percent of national broiler production. 70 percent of Brazilian production is now recognized as low-risk by Canada.

●Scenario 4 Both Mexico and Brazil eliminate END from 100% of their production

B. Empirical Results

Low labor costs and relatively low white meat prices give Mexico and Brazil a competitive advantage in supplying value-added white meat to the United States and Canada. Exports from Mexico and Brazil to the United States and Canada grow as more regions within these two countries are recognized as free of END (table 3). U.S. production contracts as Mexican and Brazilian production expands. The largest increase in Brazilian production occurs in the alternative where only 15 percent of Mexican production is eligible to be exported to the north. As its END-free area grows (from scenario 2 to scenario 4), Mexicos advantageous location makes it relatively more competitive.

Canadian broiler consumption changes little as more of Mexican and Brazilian production is eligible for export (table 4). Canadian production and import quotas make ending consumption relatively inflexible. The small drop in Canadian consumption is due to the shift toward more value-added products, which have skin and bones removed. The United States shows declines in broiler consumption (relative to the baseline) and Mexico and Brazil show increases in broiler consump-tion (again, relative to the baseline) when all of Mexico's and Brazil's broiler

Table 3. Broiler production (RTC equivalent) with expansion of low-risk-of-END areas in Mexico and Brazil

Countries	Scenarios[1]	U.S.A.	Canada	Mexico	Brazil
			1,000 metric tons		
Baseline, 2002	1	14,467	945	2,188	7,355
Mexico 4%, Brazil 50%	2	13,142	945	2,318	8,507
Mexico 15%, Brazil 70%	3	13,147	945	2,307	8,517
Mexico and Brazil 100%	4	13,076	945	2,409	8,491

[1]The "Baseline" scenario represents current conditions under which Mexico and Brazil cannot ship fresh, chilled, or frozen poultry to the United States and Canada.
The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.

Table 4. Broiler consumption (wholesale product-weight basis) with expansion of low-risk-of-END areas in Mexico and Brazil

Countries	Scenarios[1]	U.S.A.	Canada	Mexico	Brazil
		1,000 metric tons			
Baseline, 2002	1	12,165	995	2,400	5,722
Baseline, 2002	1	12,165	995	2,400	5,722
Mexico 4%, Brazil 50%	2	11,952	994	2,397	5,945
Mexico 15%, Brazil 70%	3	11,952	994	2,391	5,949
Mexico and Brazil 100%	4	11,944	994	2,409	5,945

[1]The "Baseline" scenario represents current conditions under which Mexico and Brazil cannot ship fresh, chilled, or frozen poultry to the United States and Canada.
The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.

Table 5. Consumption by cut[1] under scenario 4

Countries	Whole chickens	White meat	D ark meat	Other	MDM	Total
		Changes (1,000 metric tons)				
USA	9	36	-13	-254	-1	-223
Canada	1	2	-5	1	0	-1
Mexico	1	-2	4	36	-29	10
Brazil	3	-44	95	153	28	235

[1]Whole chickens, dark meat, and white meat are the sum of value-added and "generic" cuts.

production (scenario 4) is eligible to be exported the United States and Canada.

Table 5 shows how chicken consumption changes by cut between the baseline and scenario 4. Most of the reduction in U.S. broiler consumption is due to the decline in the consumption of the "other" broiler cuts. Consumption of white meat and whole birds actually increases in the United States. The declining consumption of "other" is largely due to the overall decline in U.S. broiler production. Because Mexico and Brazil expand broiler production in order to sell white meat to the United States and Canada, they end up increasing production and consumption of "other" and dark meat. Consumption of white meat and whole birds declines in Mexico and Brazil.

Sanitary reforms have small impacts on the prices of non-value-added broiler and broiler cuts in the United States and Canada (tables 6 and 7). The prices of whole broilers and white meat decline slightly in the two Northern-most countries and rise in Mexico and Brazil. The difference in prices for white meat without trade makes it profitable for Mexico and Brazil to export white meat to the Untied States. U.S., Brazilian and Mexican white meat prices equalize except for

Table 6. Wholesale broiler prices with expansion of low-risk-of-END areas in Brazil and Mexico

Scenarios[1]	USA	Canada	Mexico	Brazil
	Dollars per kg			
	Whole chickens			
Baseline, 2002	1.37	1.51	1.38	1.30
Mexico 4%, Brazil 50%	1.36	1.49	1.38	1.31
Mexico 15%, Brazil 70%	1.36	1.49	1.39	1.31
Mexico and Brazil 100%	1.36	1.49	1.39	1.31
	White meat			
Baseline, 2002	1.89	2.04	1.76	1.65
Mexico 4%, Brazil 50%	1.81	1.97	1.79	1.83
Mexico 15%, Brazil 70%	1.81	1.97	1.78	1.84
Mexico and Brazil 100%	1.80	1.96	1.83	1.83
	Dark meat			
Baseline, 2002	0.48	0.63	0.59	0.50
Mexico 4%, Brazil 50%	0.49	0.66	0.60	0.47
Mexico 15%, Brazil 70%	0.49	0.66	0.60	0.46
Mexico and Brazil 100%	0.49	0.65	0.59	0.47
	Other chicken cuts			
Baseline, 2002	0.26	0.31	0.30	0.30
Mexico 4%, Brazil 50%	0.30	0.30	0.28	0.20
Mexico 15%, Brazil 70%	0.30	0.30	0.28	0.20
Mexico and Brazil 100%	0.31	0.30	0.26	0.20
	Mechanically deboned meat			
Baseline, 2002	0.28	0.29	0.33	0.33
Mexico 4%, Brazil 50%	0.28	0.29	0.33	0.33
Mexico 15%, Brazil 70%	0.28	0.29	0.34	0.33
Mexico and Brazil 100%	0.28	0.29	0.33	0.33

[1]The "Baseline" scenario represents current conditions under which Mexico and Brazil cannot ship fresh, chilled, or frozen poultry to the United States and Canada.
The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.

transportation costs. In response to higher prices, Mexico and Brazil expand their production.

Eradication of END in Mexico and Brazil has both trade-creating and trade-diverting effects. U.S. exports to Canada are displaced by Mexican and Brazilian exports (table 8). This displacement is driven by their advantage in supplying lower-cost value-added products. U.S. exports to Mexico shrink as extra production of value-added white meat for the Northern markets leads to increased domestic supplies of dark meat and MDM. The increase in Brazilian prices for whole broilers makes

Table 7. Value added wholesale chicken prices with expansion of low-risk-of-END areas in Brazil and Mexico

Scenarios[1]	USA	Canada	Mexico	Brazil
		Dollars per kg		
		Whole chickens		
Baseline, 2002	1.75	1.93	1.52	1.43
Mexico 4%, Brazil 50%	1.69	1.88	1.53	1.45
Mexico 15%, Brazil 70%	1.68	1.88	1.53	1.45
Mexico and Brazil 100%	1.68	1.89	1.54	1.45
		White meat		
Baseline, 2002	2.48	2.64	1.88	1.75
Mexico 4%, Brazil 50%	2.37	2.56	1.91	1.95
Mexico 15%, Brazil 70%	2.37	2.56	1.88	1.96
Mexico and Brazil 100%	2.36	2.55	1.97	1.95
		Dark meat		
Baseline, 2002	0.76	0.91	0.61	0.53
Mexico 4%, Brazil 50%	0.76	0.95	0.62	0.50
Mexico 15%, Brazil 70%	0.76	0.95	0.62	0.50
Mexico and Brazil 100%	0.76	0.94	0.62	0.50

[1]The "Baseline" scenario represents current conditions under which Mexico and Brazil cannot ship fresh, chilled, or frozen poultry to the United States and Canada.
The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.

Brazil less competitive in the world market for this segment of the broiler industry. However, as Brazil expands white meat production, it ends up with additional dark meat. Brazil expands its exports of dark meat, displacing some of the U.S. exports globally. Total Brazilian exports of broiler meat increase. In other words, as more Brazilian regions are recognized as low-risk of END transmission, the United States loses market share in the world market.

Table 9 captures how three groups of economic agents fare as Mexico and Brazil eliminate END. The three groups are the integrated broiler producers (broiler farming and slaughtering), further processors of broiler, and consumers of wholesale broiler. The net economic benefits do not include the costs of END control and eradication. The economic benefits for integrated production and further processing are measured by the change in profits. The "consumer" sector is actually a combination of consumers and the firms that buy wholesale broiler products for sale to the final consumers. The "consumer" benefits are the sum of the change in firm and consumer surplus (see assumptions in the previous section).

U.S. and Canadian integrated broiler production and broiler processing sectors

Table 8. World broiler trade flows (product-weight basis) with expansion of low-risk-of-END areas in Mexico and Brazil

Exporting country[2]	Importing country										
	USA		Canada		Mexico		Brazil		ROW	total
	1,000 metric tons										
	Baseline										
USA	0	(0%)[3]	72	(100%)	239	(25%)	0	(0%)	1822	2134
Mexico	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	0
Brazil	0	(0%)	0	(0%)	0	(0%)	0	(0%)	1588	1588
	Mexico 4%, Brazil 50%										
USA	0	(0%)	0	(0%)	162	(37%)	0	(0%)	1759	1922
Mexico	26	(100%)	0	(0%)	0	(0%)	0	(0%)	0	26
Brazil	847	(100%)	72	(100%)	0	(0%)	0	(0%)	1603	2522
	Mexico 15%, Brazil 70%										
USA	0	(0%)	0	(0%)	185	(32%)	0	(0%)	1758	1943
Mexico	72	(100%)	0	(0%)	0	(0%)	0	(0%)	0	72
Brazil	817	(100%)	72	(100%)	0	(0%)	0	(0%)	1609	2498
	Mexico and Brazil 100%										
USA	0	(0%)	0	(0%)	142	(37%)	0	(0%)	1758	1900
Mexico	100	(100%)	10	(100%)	0	(0%)	0	(0%)	3	114
Brazil	809	(100%)	62	(100%)	0	(0%)	0	(0%)	1607	2477

[1]The “Baseline” scenario represents current conditions under which Mexico and Brazil cannot ship fresh, chilled, or frozen poultry to the United States and Canada.
The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.
[2]Canada exports nothing in all the scenarios.
[3]Numbers in parentheses show the percentage (in product weight terms) of intra-hemisphere value-added exports.

face lower earnings as Mexico and Brazil eradicate END, but U.S. and Canadian consumers gain. In the case of Canada, consumer’s and producers’ gains/losses depend on the supply and level of import quotas. The situation is reversed in Mexico and Brazil as their producers and processors gain while consumers lose because higher prices in the United States and Canada are transmitted to Mexico and Brazil. The net benefits in each country are positive. Each country’s aggregate economy gains as Mexico and Brazil eradicate END as the increased benefits to the gaining sectors outweigh the losses to losing sectors.

Table 9. Economic welfare with expansion of low-risk-of-END areas in Mexico and Brazil

Scenarios[1]	USA	Canada	Mexico	Brazil
		Millions of U.S.$/year		
		Poultry integrators		
Mexico 4%, Brazil 50%	-159	-11	16	132
Mexico 15%, Brazil 70%	-159	-11	17	132
Mexico and Brazil 100%	-167	-15	29	129
		Further processors		
Mexico 4%, Brazil 50%	-109	-2	1	38
Mexico 15%, Brazil 70%	-110	-2	4	36
Mexico and Brazil 100%	-112	-2	7	36
		Consumers of wholesale poultry		
Mexico 4%, Brazil 50%	318	16	-17	-101
Mexico 15%, Brazil 70%	320	15	-19	-101
Mexico and Brazil 100%	333	20	-30	-99
		Total change in surplus		
Mexico 4%, Brazil 50%	50	3	0	69
Mexico 15%, Brazil 70%	51	2	2	68
Mexico and Brazil 100%	53	3	5	66

[1]The percent scenarios are that portion of Mexican and Brazilian production occurring in relatively low-risk of END transmission states.

VI. Conclusions

The United States and Brazil are the world's two largest broiler exporters. The END outbreak in the United States has not had any significant impact on U.S. exports since it has not affected the major broiler exporting states. The presence of END in certain regions in Brazil prevents shipment of Brazilian fresh, chilled, or frozen poultry meat to the United States. Mexico has a significant broiler industry, but also has END. Because of the Uruguay Round Agreement, the United States is committed to the regionalization of sanitary barriers. U.S. recognition of portions of Mexico or Brazil as free of END and acceptance of their poultry inspection systems could have a major impact on world broiler trade.

U.S. and Canadian consumers have a stronger preference for white meat than Mexican and Brazilian consumers. This strong preference for white meat raises U.S. and Canadian white meat prices and also helps keep dark meat prices low. Low dark-meat prices are one of the most important factors fueling U.S. exports. Coupling lower white meat prices with lower processing costs and elimination of END makes Mexico and Brazil competitive suppliers to the U.S. market. Net economic welfare in all four countries increases. However, the model does not account for costs associated with the elimination of END in Mexico and Brazil. These costs will reduce the net gains. The net gains presented in this paper are welfare changes per year. The largest part of the costs of END eradication will be a one-time cost.

Brazil and Mexico have an advantage in supplying value-added broiler products. If these countries can achieve END free status and are certified that their inspection system is equivalent to the United States, their exports of value-added to the United States will reduce U.S. broiler production. In response to these policies changes, U.S. broiler industry might have to intensify its efforts to increase its competitiveness. However, our analysis does not account for improvement in Brazilian and Mexican productivity arising from the elimination of END.

A large portion of world broiler trade is driven by subtle differences in countries' economic development and consumers' purchasing power. The model finds a long-run equilibrium under the assumption that the rest of the economy is not affected by changes in the broiler sector. Current trends in the Mexican and Brazilian economies as a whole are likely to reduce the estimated long-run impacts of sanitary barrier reforms. White meat is the more expensive cut in Mexico, and it is likely that the preference for white meat will grow along with Mexico's economic development. If economic growth in Mexico and Brazil accelerates, this is expected to lead to improved wages and more environmental regulations, which in turn could decrease their relative competitiveness in the further processing of broiler cuts.

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Appendix: The Structure of the MP Model

The MP model minimizes the costs of producing, processing, and shipping broilers subject to a representative-consumer-utility constraint. The typical mathematical programming model maximizes the sum of producer and consumer surplus. Consumer surplus does not exist when two or more prices change. One cannot *integrate* under multiple demand functions. Multi-product MP models typically use compensated demand functions, which have symmetric derivatives and can be integrated. Hahn (1993) showed that minimizing costs subject to a utility constraint and maximizing surplus with compensated demand functions are equivalent approaches. The use of a compensated demand system allows one to do a welfare analysis of changes in policy or exogenous variables.

The MP model uses quadratic utility functions. The quadratic utility function is locally flexible. The modeling process starts with a baseline set of prices, consumption, and elasticities. The elasticities are required to be (1) homogeneous of degree 0 in prices and expenditures and (2) consistent with the budget constraint. The compensated elasticities (3) must exhibit Slutsky symmetry and (4) be negative, semi-definite. The first three conditions on the elasticities imply equality constraints. As a result, over half the elasticities in the system are functions of the others. The fourth constraint is an inequality constraint.

The demand elasticities used in the model are based on published sources. There are two problems. The first is that while economists often impose the equality restrictions of demand theory, they often do not check the inequality restrictions. Many published elasticities are not negative, semi-definite. We generally correct this problem by making cross-price elasticities closer to zero. The other problem we had is that no published set of demand elasticities with the same level of poultry product detail we have in this model. We made some arbitrary assumptions relating the detailed elasticities to the aggregate estimates. We tested our model by using different disaggregation assumptions. It turns out that varying the demand elasticities had only small effects on the model results.

Given sets of demand elasticities for the United States, Canada, Mexico, and Brazil, the modeling system finds a set of quadratic utility functions consistent with those elasticities and the baseline prices and quantities. The utility constraints for the MP model can be written:

$$\sum_{k} A_{i,k} D_{i,k}^{b} + \sum_{k,l} B_{i,k,l} D_{i,k}^{b} {}^{*} D_{i,l}^{b} \leq \sum_{k} A_{i,k} D_{i,k} + \sum_{k,l} B_{i,k,l} D_{i,k} {}^{*} D_{i,l} \qquad (1)$$

In equation 1, the subscripts “i” vary with the four countries, while “k” and “l” vary over the consumption quantities. The terms $A_{i,k}$ and $B_{i,k,l}$ are quadratic utility function parameters. The term $D_{i,k}$ is the models solution for the demand for product k in country i and the term $D^b_{j,k}$ is the baseline demand for product k in country i. The constraint in equation 1 requires that the representative consumers utility is a least as great as the baseline utility.

There are five sources of costs. The first cost is in the production of broilers. There are two types of broilers in the model: parts-type broilers and whole-type broilers. These are joint products. The parts-type and whole-type birds produced in country i are denoted by $B_{i,p}$ and $B_{i,w}$ respectively. The joint cost function for production of birds is:

$$\alpha_{i,b}(d_{i,b,p}B_{i,p}^{\sigma_{i,b}} + d_{i,b,w}B_{i,w}^{\sigma_{i,b}})^{f_{i,b}/\sigma_{i,b}} \tag{2}$$

In equation 2, $\alpha_{i,b}$, $\sigma_{i,b}$, $d_{i,b,.}$ and $f_{i,b}$ are parameters. Equation (2) looks like a constant elasticity of substitution (CES) production function; however, because the $\sigma_{i,b}$ are greater than 1, the level sets curve away from the axes rather than toward them. The “f” parameters are 1 equal to one plus the flexibility of supply. If the supply of birds were perfectly elastic in some country, its “f” will be one. Research shows that chicken supply seems to be extremely elastic. We set the value of “f” to imply a supply elasticity of 8. The $\alpha_{i,b}$ and $d_{i,b,}$ parameters are set so that the marginal costs of producing the baseline amount of whole birds equals the baseline whole bird price and the marginal costs of broilers parts equals the weighted value of its parts.

Another production activity that induces costs is the adding of value to broiler cuts. There are three value-added broiler cuts, whole birds, white meat, and dark meat and two sources of value added in each country, the processor and the intermediate consumer. The model calculates the total value added to each of the three cuts by each of the two sources in each of the three countries. The value-added by parts is aggregated by source and country using a CES-like approach as in equation 2. The aggregate supply of value-added supplied by each country’s two sources is upward sloping, so that marginal and total costs increase with increasing levels of value-added processing.

Another set of cost arises when broiler meat is exported. Exports incur transport costs and import tariffs in the receiving countries. The fourth cost in the model is the cost of buying the aggregate other good. As noted above, the typical partial equilibrium assumptions allow one to combine all other goods into a Hicksean aggregate. This good is supplied at constant marginal cost.

Exports to the other regions of the world are modeled as creating a benefit. The benefit is the net surplus change from changes in exports. Other regions are treated as excess demand regions. That is, the supply responses and demand responses are combined to yield an excess demand. The other regions of the world are demanders of U.S. and Brazilian broiler and broiler cuts. The net benefit from exports is subtracted from the costs.

The cost and utility functions in the MP model are non-linear. Most of the rest of the equations in the model are linear identities. There are identities relating the production to exports, demand to imports, and the distribution of demand and production between value-added and "generic" cuts. There is also a set of linear identities relating per-unit-value-added to cuts to the total value added produced in a country. The unit-value-added variable allows us to make value-added endogenous. Let the unit-value-added variable be denoted by $U_{i,j,k,m}$. The unit value added term has 4 subscripts: i for the producing/exporting country, j for the importing/consuming country, k for the value-added cut, and m for the source of value added. The subscript "m" takes two values depending on whether the value-added is made by the intermediate consumer or bought from a processor. "Made" and "bought" value-added can be imperfect substitutes and are related through a (simplified) CES production function constraint:

$$1 = (w_{i,j,k,made}{}^{*}(U_{i,j,k,made})^{\sigma_{i,j,k}} + w_{i,j,k,bought}{}^{*}(U_{i,j,k,bought})^{\sigma_{i,j,k}}) \quad (3)$$

The MP model was set up to allow the production function for final products to vary according to the source and use country as well as by the value-added cut. The "w" parameters are set so that equation 3 fits the baseline data.