Domestic Support and Border Measures for Processed Horticultural Products

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Abstract

In horticultural markets, trade barriers often apply to the processed products whereas domestic support applies to farm-produced raw commodities. Here we assess the effects of such trade barriers and domestic support by simulating the effects of policy reform on global processing tomato markets, which are faced with modest processed product tariffs and high domestic support in the European Union (EU). Both protection and EU subsidy drive down world welfare, but we find that reducing import tariffs for tomato products would yield greater effects on markets and larger welfare impacts outside Europe than would reductions in EU domestic support.

Key words: agricultural trade policy, equilibrium displacement model, EU subsidies, horticulture, processing tomatoes, tariffs, welfare analysis, WTO negotiations.

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International trade in fruits, vegetables, processed products and other high unit-value products has been expanding rapidly relative to trade in bulk commodities. For example, in the United States trade in high-valued exports rose from 30% of agricultural exports in 1976 to 63% in 2002 (Whitton 2004). At the same time, most analysis of the effects of agricultural border measures and domestic support on trade patterns has dealt with grains, cotton and similar bulk commodities with much less analysis of trade and trade policy for horticultural products.

For raw or bulk commodities domestic support and border measures may often apply directly to the same agricultural product. However, when processing is important and especially in horticultural markets, such policies apply to different vertically-linked products within the same agricultural industry. Including the distortions from both raw product subsidies and border measures on processed products provides a richer analysis of the effects of policy reform. Economists have studied policy effects in vertically-linked markets, e.g., Sumner and Wohlgenant (1985) examine policies applied to tobacco-cigarette markets, and Lusk and Anderson (2004) examine policies applied to livestock-meat markets. However relatively little attention has been devoted to the interactions between subsidy and protection applied to horticultural products. Here we examine, specifically, the effects of domestic support applied to a non-traded farm-produced commodity together with border measures applied to value-added products in the processed tomato industry.

Much research has been devoted to understanding the economic consequences of domestic support applied to agricultural markets and the effects of introducing reform to these policy instruments. As one component of this, Sumner (2000) and Bagwell and Staiger (2001) examined the economic impact of including domestic support policies directly on the negotiating agenda of the World Trade Organization (WTO). With an eye to effects on developing countries, Beghin, Roland-Holst, and van der Mensbrugghe (2003), Hoekman, Ng, and Olarreaga (2004), and Hertel and Keeney (2005) examined the impact of reductions in domestic support and compared it to reductions in tariffs for agricultural products. Using aggregated product groupings these studies found that reductions in border measures have a greater impact than reductions in domestic support for the overall welfare in developing countries.

The Uruguay Round Agreement on Agriculture (URAA) initiated gradual and partial reductions of both domestic support and border measures in agriculture and there remains much room for further reductions (e.g., see Josling and Tangermann 1999; Sumner and Tangermann 2002). During the current Doha Development Agenda negotiations, members have proposed to reduce subsidies and import barriers, and eliminate export subsidies on a global basis (WTO 2004; Josling 2005).

This article makes several interrelated contributions. Studies of global policy reform typically neglect horticultural commodities and focus primarily on field crops and livestock products.[1] We begin to redress this imbalance here. We model reform of policies that apply at different stages along the vertical supply chain and show the importance of even limited input substitution between raw materials and other inputs. We also show the international impacts of border measures relative to domestic support in a case in which both measures are important. Finally, our results for the processing tomato industry are the first for this important subsidized and protected industry.

Processing tomato markets are particularly appropriate for this study. First, this is a large global industry and one of the most important processed horticultural industries in the United States, Europe, and several developing countries. Second, the processing tomato industry has significant import tariffs and has long been subject to large subsidies in the European Union (EU). These subsidies and trade barriers have substantial effects on trade partners and as suggested in recent legal analysis are vulnerable to WTO challenge (Stuart 2005).

Between 1999 and 2003, world production of processing tomatoes ranged between 25 and 30 million metric tons per year (Tomato News 2004). Using a per ton price of approximately $640 for tomato paste (Morning Star Company 2005), the production of processed tomato products are valued at more than $3 billion per year. Major producers export tomato products but also import, suggesting that products are not perfect substitutes. The EU produces about 30% of processing tomato products in the world and accounts for approximately 50% of (extra-EU) exports. The United States contributes another 35% of production and 20% of exports. The rest of the world, including leading producers such as China, Turkey, and Brazil, then accounts for 35% of production and the remaining 30% of exports (USDA/FAS 2004).

Processing Tomato Policy

Because the EU is a main producer and the only significant subsidizer of processing tomatoes, it is important to describe briefly the policies employed in the EU. The EU has had a domestic support policy for processing tomatoes for several decades. Since 2001 domestic support for processing tomatoes has been in the form of producer payments, and is 34.50 euros per metric ton in Italy, Greece, Portugal, and France, and 29.36 in Spain.

The payment is made directly to growers and therefore creates a wedge between the price received by tomato growers and the price paid for tomatoes by processors. Producer payments are applied to a "threshold" quantity for each EU member nation.[2] In recent years the average grower price—including the per-unit subsidy—in the EU was approximately 80 euros per metric ton (Pazos 2004) so the *ad valorem* equivalent rate of domestic support has been approximately 43%. Processing tomatoes are perishable and bulky, and processing plants are located nearby to growing areas. Unlike fresh market tomatoes, processing tomatoes are not traded and tariffs or other government barriers to trade are not relevant.

Processed tomato products are traded and face *ad valorem* tariffs in the EU without the complexities introduced for trade in fresh tomatoes (Gallezot 2006). The EU tariff for canned tomato products and tomato paste has been 14.4% since full implementation of the URAA in 2001. The tariff applies to all imports of processed tomato products with two exceptions. First, some product enters the EU under preferential trade agreements with Mediterranean partners (European Commission 2004). Second, imported product that is destined for re-export (perhaps after additional processing or re-packaging) is allowed an import tariff refund or duty drawback. Although data describing the EU quantity of processed tomato products imported under preferential trade agreements are readily available, data related to EU imports with duty drawbacks are not. Evidence from EU industry sources indicates that the EU imports some processed tomato products under a duty drawback program, and that these imported products do not have domestically produced substitutes. Industry sources claim that this is due, partly, to EU firms that blend EU bulk processed tomato products with inexpensive foreign products (Amézaga 2002; Menghini 2004).[3]

The *ad valorem* rate for the import tariff applied to processed tomato products shipped into the United States is 12.5% (USITC 2006). Many other countries import processed tomato products with tariffs, e.g., Canada and Australia apply tariffs between 5% and 10%; Brazil, Argentina, Venezuala, and Mexico apply tariffs between 16% and 23%; and Japan, Korea, China, and the Philippines apply tariffs between 20% and 34%. The share-weighted *ad valorem* tariff rate applied to processed tomato products in the rest-of-the-world region is approximately 20% (APEC 2005; Inter-American Development Bank 2005).

Simulation Model

We design a multi-market simulation model to assess how reductions of domestic support compare to reductions of border measures in the global processing tomato industry. The model is designed with the processing tomato industry in mind, but the basic structure could be applied to industries with differentiated products and vertically linked markets. The model provides analytical results and simulates proportional changes in economic variables (prices, quantities, and welfare measures) for input and output markets.

An equilibrium displacement model is adapted here to examine the effects of reducing the role of government support (domestic support and border measures) along a vertical market chain. Importantly, the model is adapted to allow intra-industry trade and substitution between farm and marketing inputs. The multi-market model facilitates a comparison of the effects of changes in domestic support and border measures when they apply at different stages within an industry.

A set of basic equations is used to describe the supply, demand, and market clearing conditions for each market. Totally differentiating these equations and converting them to elasticity form yields a system of linear (logarithmic differential) approximations that is a linear elasticity model. The equations are solved for proportional changes in quantities and prices as functions of various elasticity and share parameters. The linear transformation framework is convenient as an approximation but none of the results hinge on this simplification.

Muth (1964) provided the derivations for the one-output, two-input model, and applied it to a case in housing and urban land economics. Gardner (1987), Piggott (1992), Alston, Norton, and Pardey (1995), and Alston and James (2002) review the derivations of various equilibrium displacement models, and agricultural economists have adapted them to study a wide range of research topics. The basic structure of the model includes demand for processed products, supply of inputs, derived demand for inputs, derived supply of outputs, and market clearing conditions. Parameters include the elasticity of supply for each input, the elasticity of demand for each output, the elasticity of substitution between inputs, input shares, initial equilibrium quantities, cost shares, and supply and demand shocks.

The model considers three regions, two inputs, and five outputs. The three regions are the European Union (E), United States (U), and rest of the world (R). For simplicity, all countries outside the EU and the United States are aggregated. Inputs include the farm-produced commodity (F) and marketing and processing services (M). Processed tomato products at the wholesale level include bulk tomato paste and bulk canned tomato products, often referred to as stage one products. The processed tomato products are further differentiated to account for the observed intra-industry trade within stage one products. Product *J1* is canned tomato products produced and exported by the EU, *J2* is canned tomato products produced and exported by the United States, *J3* is the tomato paste product produced and exported by the EU, *J4* is the tomato paste product produced and exported by the United States, and *J5* is the tomato paste product produced and exported by the rest-of-the-world region and imported into the EU duty-free. The various processed tomato products utilize the same inputs in production, although in different proportions.

In equation (1) through (8), the term Q is used to denote a quantity in an output market, X denotes a quantity in an input market, P denotes a price in an output market, and W denotes a price in an input market. For prices in input markets and quantities in input and output markets, the suffix D denotes a variable on the demand side, and the suffix S denotes a variable on the supply side. Assuming that each production function in the industry exhibits constant returns to scale, the industry total cost function (TC_j^y) is the product of the unit cost function of product j in region y, namely c_j^y, and the quantity supplied of processed product j in region y, namely QS_j^y. We assume that the unit cost functions are independent across products.

(1)	$QD_j^y = f_j^y(\boldsymbol{P^y}, \boldsymbol{v^y})$	Output demand
(2)	$XD_{hj}^y = (\partial c_j^y(\cdot)/\partial WD_h^y)QS_j^y$	Factor demand
(3)	$XS_h^y = f_h^y(WS_h^y, \boldsymbol{u^y})$	Factor supply
(4)	$P_j^y = \partial TC_j^y(\cdot)/\partial QS_j^y$	Marginal cost equals domestic price
(5)	$P_j^y = P_j^w(1+\beta_j^y)$	Internal arbitrage conditions
(6)	$WS_h^y = WD_h^y(1+\delta_h^y)$	Factor price market clearing condition

(7) $QD_j^y = QS_j^y + \sum_{z \neq y}(QS_j^z - QD_j^z)$ International market clearing condition

(8) $XS_h^y = \sum_j XD_{hj}^y$ Factor quantity market clearing condition

Equation (1) represents demand for the processed product *j* at the wholesale level, in region *y*. Demand for the processed product is a function of all output prices, and a vector of exogenous variables ($\boldsymbol{v}^y$). Equation (2) represents the derived demand for input *h*, as it is used in the production of product *j*, in region *y*. Equation (3) represents the supply of input *h* in region *y*; it is a function of input prices and a vector of exogenous variables ($\boldsymbol{u}^y$). Linkages between agriculture and the rest of the economy are represented by $f_h^y(\cdot)$, an upward sloping supply function for input *h*. Equation (4) represents the long-run condition that the processed product price equals the marginal cost for product *j* in region *y*.

Market equilibrium conditions begin with equation (4), which determines the price of product *j* in region *y*. There are 300 growers of processing tomatoes and nearly 30 processors in California, and the industry is even less concentrated in Europe. Prices and market information for inputs and processed tomato products in many regions are widely available (Tomato Land 2006). For these reasons, and to simplify our model, we assume that the processing tomato industry operates under perfect competition. Equation (5) represents the relationship between price of the traded output and the world price (P_j^w), where β_j^y represents the *ad valorem* price wedge created by a border measure applied to product *j* by region *y*. For an import tariff, β_j^y is expressed as a positive parameter, and for an export subsidy, β_j^y is expressed as a negative parameter. Regardless of whether β_j^y represents an import tariff or an export subsidy, equation (4) is used to represent the price of product *j* from the exporting region, and equation (5) is used to represent the prices of products in the importing regions. Equation (6) represents the relationship between the price paid for inputs by processors, and the price received by growers; δ_h^y represents the *ad valorem* price wedge created by a domestic support policy for input *h* in region *y*. (In the processing tomato market, this condition applies only in the EU.) In cases where domestic support does not apply to a specific input, δ_h^y is set equal to zero, and the price paid by processors is equivalent to the price received by growers. Equation (7) is the international market clearing condition for the quantities of processed products. Equation (8) is the equilibrium condition in the input markets.

Totally differentiating equations (1) to (8), and converting to elasticity form yields the linear elasticity model in equations (9) to (16). Equilibrium adjustments can be simulated by exogenously specifying changes in the policy parameters. In the following equations, for any variable *A*, E(*A*) represents the relative change in *A*, that is, E(*A*) represents d*A*/*A* where d refers to a total differential. The model will be applied to examine the effects of changes in policy. Therefore, parameters that accommodate other shifts in supply and demand have been omitted for simplicity of exposition.

(9) $\mathrm{E}(QD_j^y) = \eta_{jj}^y \mathrm{E}(P_j^y) + \sum_{k \neq j} \eta_{jk}^y \mathrm{E}(P_k^y)$

(10) $\mathrm{E}(XD_{hj}^y) = \mathrm{E}(QS_j^y) + \sum_{i \neq h} \kappa_{ij}^y \sigma_j^y [\mathrm{E}(WD_i^y) - \mathrm{E}(WD_h^y)]$

(11) $\mathrm{E}(XS_h^y) = \varepsilon_h^y \mathrm{E}(WS_h^y)$

(12) $\mathrm{E}(P_j^y) = \sum_h \kappa_{hj}^y \mathrm{E}(WD_h^y)$

(13) $\mathrm{E}(P_j^y) = \mathrm{E}(P_j^w) + \mathrm{E}(1+\beta_j^y)$

(14) $\mathrm{E}(WS_h^y) = \mathrm{E}(WD_h^y) + \mathrm{E}(1+\delta_h^y)$

(15) $\mathrm{E}(QD_j^y) = (QS_j^y/QD_j^y)\mathrm{E}(QS_j^y) + \sum_{z \neq y}[(QS_j^z/QD_j^y)\mathrm{E}(QS_j^z) - (QD_j^z/QD_j^y)\mathrm{E}(QD_j^z)]$

(16) $\mathrm{E}(XS_h^y) = \sum_j \lambda_{hj}^y \mathrm{E}(XD_{hj}^y)$

The price elasticity of demand for the processed product j with respect to the price of another processed product k in region y, is represented by η_{jk}^y. The own-price elasticity of supply of input h in region y is represented by ε_h^y. The Allen partial elasticity of input substitution for producing j, in region y, is denoted by σ_j^y. The cost share of input h in the production of j in region y is denoted as κ_{hj}^y. The industry share of input h used in the production of j in region y is λ_{hj}^y.

The term $E(1+\beta_j^y)$ represents a change in the *ad valorem* rate of the border measure applied to product j by region y, and the term $E(1+\delta_h^y)$ represents a change in the *ad valorem* rate of domestic support applied to product h by region y. In equation (15), (QS_j^z/QD_j^y) is the initial quantity produced in region z relative to consumption in region y, for product j. The model with five outputs, two inputs, and three regions (with trade in the output markets) yields a system of ninety-three equations.

The net traded quantity is calculated for each product in each region, and describes the traded quantity regardless of whether the region imports or exports. The proportional change in the net traded quantity of product j from region y, denoted as $E(QT_j^y)$, is represented in equation (17).

(17) $E(QT_j^y) = (QS_j^y/QS_j^y - QD_j^y)E(QS_j^y) - (QD_j^y/QS_j^y - QD_j^y)E(QD_j^y)$

The results from the simulation model also yield changes in measures of economic welfare. The changes in economic welfare accruing to consumers of product j in region y (ΔCS_j^y) and to the factors of production in region y (ΔPS_h^y) are measured in terms of changes in factor and product prices and quantities.

(18) $\Delta CS_j^y = -P_j^y QD_j^y E(P_j^y)[1 + 0.5E(QD_j^y)]$

(19) $\Delta PS_h^y = WS_h^y XS_h^y E(WS_h^y)[1 + 0.5E(XS_h^y)]$

The change in total producer surplus in region y is the sum of the producer surplus from each factor market, $\Delta PS^y = \sum_h(\Delta PS_h^y)$, and the change in the total consumer surplus in region y is the sum of the consumer surplus across output markets, $\Delta CS^y = \sum_j(\Delta CS_j^y)$.

The change in net surplus depends on the change in taxpayer surplus, denoted as ΔTS_{hj}^y. Changes in taxpayer surplus accrue when either border measures or domestic policies change or when the quantities to which they apply change. Equation (20) includes the welfare effects for taxpayers in region y.

$$\begin{aligned}(20)\quad \Delta TS^y = {} & \textstyle\sum_j\{P_j^y QT_j^y[\mathrm{E}(P_j^y) + \mathrm{E}(QT_j^y) + \mathrm{E}(P_j^y)\mathrm{E}(QT_j^y)] \\ & - P_j^w QT_j^y[\mathrm{E}(P_j^w) + \mathrm{E}(QT_j^y) + \mathrm{E}(P_j^w)\mathrm{E}(QT_j^y)]\} \\ & + \textstyle\sum_h\{WD_h^y XS_h^y[\mathrm{E}(WD_h^y) + \mathrm{E}(XS_h^y) + \mathrm{E}(WD_h^y)\mathrm{E}(XS_h^y)] \\ & - WS_h^y XS_h^y[\mathrm{E}(WS_h^y) + \mathrm{E}(XS_h^y) + \mathrm{E}(WS_h^y)\mathrm{E}(XS_h^y)]\}\end{aligned}$$

Combining the welfare effects from equations (18), (19), and (20), equation (21) represents the change in net surplus in region y (ΔNS^y).

$$(21)\quad \Delta NS^y = \textstyle\sum_j(\Delta CS_j^y) + \sum_h(\Delta PS_h^y) + \Delta TS^y$$

Using the linear elasticity model outlined in equations (9) to (16), equilibrium adjustments can be simulated by specifying an exogenous change in a border measure parameter, namely β_j^y, or a domestic support parameter, namely δ_h^y. The model will be used to solve for proportional changes in prices and quantities in all markets. To calculate the effects of partial reform (e.g., reducing domestic support or border measures) only the relevant terms are included in the simulation model, thereby simplifying the equations.

Reductions in the EU domestic support regime are modeled as reductions in the *ad valorem* price wedge (δ_h^y) between the price received by growers and the price paid by processors for the farm input in the EU. Reductions in the border measures are modeled as reductions in the *ad valorem* price wedge (β_j^y) between the price of product *j* in the exporting region and the price in the importing region. The effects of reducing import tariff rates and domestic support are simulated separately, as are the effects of reducing border measures and domestic support simultaneously. The results from the simulation model will describe the changes in prices, quantities, and welfare measures across the various output products, factors of production, and regions.

Model Parameterization

The full set of baseline parameters used in the model—including elasticities, shares, and initial quantities—are contained in the table 1, and each is discussed in detail below. Applying work by Davis and Espinoza (1998, 2000), Griffiths and Zhao (2000), and Zhao et al. (2000) prior distributions are applied to selected baseline parameters to understand the sensitivity of our results. A central tendency (equal to the baseline parameter) and a variance of 0.04 is specified and used to develop beta (3,3) distributions that are applied to all supply, demand, and substitution elasticities (Brester, Marsh, and Atwood 2004). The beta distribution is a continuous two parameter distribution that is symmetrical when the parameters are equal, and is equivalent to the uniform distribution when the parameters are equal to 1. The beta distribution is often used to model events which are constrained to take place within an interval defined by a minimum and maximum value. The beta distributions selected here constrain demand elasticities to be negative and supply elasticities and substitution elasticities to be positive. Using the beta (3,3) distribution, the supply elasticity for the manufacturing and processing services input in the United States centered at 1.0 ranges between 0.5 and 1.5 and has 37% of the distribution between 0.9 and 1.1.

The simulation model draws values for these parameters to generate an empirical distribution of results. The empirical distribution includes the results from 1000 iterations of the simulation model. No prior distributions are applied to parameter values that were based on information supplied by industry sources such as cost and industry shares, or parameters describing initial quantities.

The own- and cross-price elasticities of demand were calculated following an Armington specification (Armington 1969). The calculation used to parameterize the Armington own-price elasticity of demand is shown in equation (22) and the calculation used to parameterize the Armington cross-price elasticities of demand is shown in equation (23).

(22) $\eta_{jj}^{y} = \zeta_{j}^{y}\eta^{y} - (1 - \zeta_{j}^{y})\sigma^{y}$

(23) $\eta_{jk}^{y} = \zeta_{k}^{y}(\eta^{y} + \sigma^{y})$

The own-price elasticity of demand for product *j* is represented by η_{jj}^{y}, and η_{jk}^{y} represents the cross-price elasticity of demand for product *j* with respect to the price of product *k*. In equations (22) and (23), η^{y} is the overall elasticity of demand for processed tomato products in country *y*.

Based on estimates from the literature (e.g., Chern 1976) we define the mean and variance for a distribution that describes the overall elasticity of demand for processed tomato products in each region; the mean for the United States was set to –0.5, the mean for the EU was set to –0.3, and the mean in the rest-of-the-world region was set to –0.7. In addition to the overall demand elasticities, the Armington specification requires the elasticity of substitution (across the differentiated goods) for each consuming region, and the share of consumption devoted to product j in region y. The elasticity of substitution between the five processed tomato products, represented by σ^y, also was drawn from a prior distribution. The central tendency for this distribution has been set at 5 in the EU, 7 in the United States, and 10 in the rest-of-the-world region based on parameters used in other studies (e.g., Alston, Gray, and Sumner 1994). Information on consumption shares, represented by ζ_j^y, is derived from industry sources (Amézaga 2002; Morning Star 2005), and where applicable, from trade flow data (e.g., Menghini 2004; Pazos 2004).

In selecting the supply parameters, we assumed that the EU reduces domestic support for competing commodities equally, and not only to processing tomatoes. Therefore, we expect the elasticity of supply of processing tomatoes is relatively inelastic in response to reductions of subsidies through trade negotiations. In this case, reductions in subsidies would be part of a larger reform package. We note that for analysis envisioning change in tomato subsidy alone, say in response to a trade dispute, we would consider the case in which other subsidy programs were fixed and the relative supply elasticity for processing tomatoes would be larger.

The two inputs used to produce processed tomato products in the simulation model are the farm-produced input (F) and the marketing and processing services input (M). There is no substitution between processing tomatoes and other field crops, including fresh tomatoes. Processing tomatoes are mechanically harvested and contain much higher levels of soluble solids than fresh tomatoes (CTGA 2006). The manufacturing technology allows for some substitution between tomatoes and the processing time required to produce tomato paste. In our model we allow limited substitution between inputs, and we set the elasticity of substitution between inputs at 0.1 for all products in all regions.

The supply elasticities for each input in each region were drawn from distributions with specified means and variances. Using data between 1967 and 1975, Chern (1976) and Chern and Just (1978) estimated the price elasticity of processing tomato acreage response in California as 0.8. Over the short-run it is expected that the supply elasticity of both inputs would be inelastic as the decision to produce processing tomatoes is made annually, but in the intermediate-run, the supply elasticities of these inputs would be more elastic. We expect the supply elasticity to be more elastic in the rest-of-the-world region than in the two developed country regions. Finally, tomato processing uses some specialized capital, but such capital can be expanded with some lag. Other inputs are not specialized to tomatoes. We therefore use larger supply elasticities for the marketing and processing services input.

Overall, the baseline parameters should be interpreted as those in the intermediate run (three to five years). It is expected that the quantity effects of reducing the subsidies would be larger and the price effects smaller if a longer time horizon were considered. That is, with more time to adjust, farms and processing firms would gradually shift more resources out of the processing tomato industry in response to a reduction in subsidies.

Policy parameters that describe domestic support and border measures are also required in the simulation model. Domestic support parameters are required for the EU only, as no domestic support was applied in the other regions. Region-specific border measures are applied to all regions in the model, and the settings are based on 2005 rates.

Effects of Global Reductions in Tariffs and Subsidies for Processed Tomatoes

We report results for the following four simulations:

1. A 50% reduction in EU tariffs from 14.4% to 7.2%, but no tariff cut elsewhere;
2. A 50% reduction in EU domestic support from 43% to 21.5%;
3. A 50% reduction in global tariff rates, including a cut from 14.4% to 7.2% in the EU, 12.5% to 6.25% in the United States, and 20% to 10% in the rest-of-the-world region; and
4. A 50% reduction in global tariff rates and EU domestic support.

Each simulation imposes a policy shock to the system of equations and generates empirical distributions for the changes in prices and quantities, and associated welfare measures, for the two inputs and the five processed products. The empirical distributions are used to calculate the mean and a 95% confidence interval for price, quantity, and welfare variables across 1000 iterations.[4] We report price and quantity effects from each scenario for inputs and products in each region.

Table 2 shows price effects from each scenario for inputs and products in each region. Consider first column 1 of table 2 which shows the price effects of a reduction in EU tariffs alone. The tariff cut only applies to canned tomato products and tomato paste imported from the United States; the ROW tomato paste enters the EU duty free. The result of the tariff reduction is lower prices in the EU for all processed tomato products, including those produced in the EU. It is useful to compare column 1 with column 2, which shows the price effects of a 50% reduction in the per-unit subsidy applied in the EU. Table 2 shows how the price effect of this subsidy cut would be shared between tomato producers and processors. The 21.5 percentage point cut in the per-unit subsidy would decrease the effective EU grower price by approximately 9.3%, and therefore raise the price paid by processors for tomatoes by approximately 12.2%. (The sum of the two effects is 21.5% percent.) Table 2 also shows the 95% confidence intervals for the impacts. The range of values in the 95% confidence interval are relatively small and do not change the major thrust of the results, therefore, in the discussion below we will focus on the central values.

Reducing EU domestic support by 50% would lead to changes in the prices of the processed tomato products, which are trade internationally, and small increases in prices of tomatoes and the manufacturing input in the United States and the rest of the world. These impacts for input prices are small, in part because the EU subsidizes the tomato input but does not subsidize the other input. Furthermore, substitution between tomatoes and the other input allows the subsidy impact to be diffused to these other markets and tomato products from the EU are not perfect substitutes for the products produced in the United States or the rest of the world.[5] The domestic support cut has larger input price and European output price effects than the EU tariff cut, but smaller price effects on the imported tomato products. The effects of domestic support cuts are larger than the effects of EU tariff cuts for prices in the United States and the rest of the world.

Column 3 in table 2 shows the price effects of a global tariff reduction (including the EU) of 50%. Cutting global tariffs causes lower prices in importing regions and higher prices in exporting regions with the exception of the price of paste produced in the rest of the world, which falls. Column 4 shows the price effects from the simulation that considers both a 50% reduction in global import tariffs and a 50% reduction in EU domestic support, and the results in column 4 are the approximate sum of those in column

2 and column 3. In this case, the price of U.S. tomatoes would increase by 2.4%, and this result is driven largely by the reduction in global import tariffs rather than the reduction in EU domestic support. The price of EU tomatoes would fall by 5.2% and the price of rest-of-the-world tomatoes would fall by 2.4%.

Table 3 shows the quantity effects from each of the four simulations. The quantity effects of a decrease in EU tariffs are relatively small in the EU and elsewhere. A 50% decrease in EU domestic support will decrease tomato production in the EU by 4.6% and with fewer tomatoes produced the demand for the manufacturing input falls by 3.1%, despite the small substitution effect. As processing tomatoes become more expensive, there is a significant shift from production of tomato-intensive products, such as paste, and the production of manufacturing-intensive canned products increases in the EU. A 50% reduction in global tariffs will increase tomato production in the EU by 2.1%, increase production by less than 1% in the United States, and decrease production in the rest of the world by 2.4%.

Welfare impacts for tomato growers, tomato manufacturers, consumers of processed tomato products, and taxpayers are shown in table 4 for each simulation. A 50% decrease in EU tariffs (column 1) would lead to losses for growers and manufacturers in the EU but gains to consumers and gains overall in Europe. The higher prices for U.S. tomato products would raise welfare for growers and manufacturers in the United States. The gain to growers and manufacturers in the United States is enough to offset consumer and tariff revenue losses such that the United States as whole gains $400 thousand per year. Growers and manufacturers in the rest of the world lose $700 thousand, but the overall gain in the rest of the world is $500 thousand.

The welfare effects in the EU of the cut in domestic support are larger than the effects from EU tariff cuts. Column 2 of table 4 shows that a 50% reduction in EU domestic support would decrease welfare to EU growers and manufacturers (together) by approximately $87 million per year, yet EU taxpayer surplus would increase enough that the net surplus in the EU would increase by approximately $40 million. U.S. tomato growers would gain $3.9 million per year, U.S. tomato manufacturers would gain $2.1 million per year, and tomato growers and manufacturers in less developed countries would gain $8.3 million per year.

Elimination of EU domestic support for tomatoes would increase welfare to non-EU growers and manufacturers by $14.3 million per year. We calculate the total capitalized benefit of eliminating EU domestic support to assess the importance of this impact, and found it would amount to $286 million for growers and manufacturers of tomatoes outside the EU (using a relatively high discount rate of 10%). These results and the legal analysis reported by Oxfam (Stuart 2005) are consistent with the notion that these policies could be vulnerable to a WTO challenge.

Of course, consumers in the United States and the rest of the world lose with EU subsidy reduction. Adding growers, manufacturers, and consumers, the aggregate impact is slightly negative for the United States and negative $5.4 million per year for the rest of the world. The welfare loss in the rest of the world, comprised mainly of less developed country importers, is consistent with findings and arguments of Bhagwati (2005) and Panagariya (2005), as outlined in Tangermann (2005). Overall, reducing EU domestic support would lead to large effects in EU markets, and smaller overall effects in markets and welfare in the other regions.

Growers and manufacturers gain substantially in the EU and the United States and consumers gain in the rest of the world from global tariff reductions. Of course, tariff revenue is down in all countries. Furthermore, because cutting tariffs causes additional subsidy costs (from expanded EU production) this contributes to the additional taxpayer cost in the EU. Overall world welfare decreases by $15.3 million per year because the tariff cut increases the welfare losses associated with the EU domestic support policy. This "second best" result demonstrates the misleading character of considering tariff reductions without recognizing their effect on the costs of a domestic subsidy regime.

Column 4 in table 4 shows the welfare effects from a 50% reduction in global import tariffs and a 50% reduction in EU domestic support considered together. The global gains of about $20 million per year are dominated by the saving in EU taxpayer outlays of about $117 million per year. Aggregate gains to U.S. producers are larger (consumer costs are also larger) and aggregate gains in the rest of the world are smaller than when only tariffs are cut. In the United States, gains by growers and manufacturers are larger than losses by consumers, while in the rest of the world, a net importer, consumer gains are larger than losses of growers and manufacturers.

Implications and Conclusion

Our detailed simulations find important interactions between reductions in farm commodity subsidies and processed product border protection. We also show how (even limited) substitution between raw materials and other inputs diffuses the impacts of raw material subsidies and how less than perfect substitution between products from different regions reduces international effects of country specific subsidies or tariffs.

We demonstrate the importance of the "second best" result that reducing tariffs alone can lower world welfare when one effect is to increase production of a subsidized commodity. This suggests an additional reason to include domestic subsidy reductions in commodity policy reforms. In the case of processing tomatoes, the main welfare losses from the domestic subsidies occur mainly within the EU, which provides the subsidies. However, EU subsidies also reduce prices, quantities and welfare for tomato growers and manufacturers outside the EU. Our simulations for processed tomato products also document the degree to which developing country consumers and overall economies of net importers lose from reductions in rich country subsidies. We demonstrate for this case that in multilateral reform efforts EU industry resistance to domestic support cuts can be mitigated by including global tariff cuts. Also, industry resistance to tariff cuts in the rest-of-the-world region can be mitigated by including EU subsidy cuts in a package. As a non-subsidized industry that faces tariffs in both regions the U.S. industry gains most if both parts of the package are included.

Horticultural and processed products are an increasing part of international agricultural trade, but are under studied in the policy literature. This article shows how policies applied at different stages in the marketing and processing chain affect growers, food manufacturers and consumers. It is also one of the few articles to show, in an important case, how policies for horticultural products applied in rich countries affect developing country producers and consumers. This paper raises several important issues for analysis of trade in processed products and horticultural products and indicates how analysis of these markets may differ from that applied more commonly to bulk commodities.

Table 1. Baseline Parameters used in the Simulation Models[a, b]

Parameter description	Parameter notation	Baseline parameter value
Overall price elasticity of demand for processed tomato products	η^y	*E*= –0.3, *U*= –0.5, *R*= –0.7
Consumption share of product *j*	ζ_j^E ζ_j^U ζ_j^R	*J1*=0.37, *J2*=0.01, *J3*=0.51, *J4*=0.02, *J5*=0.09 *J1*=0.02, *J2*=0.10, *J3*=0.02, *J4*=0.86, *J5*=0.01 *J1*=0.02, *J2*=0.01, *J3*=0.09, *J4*=0.04, *J5*=0.84
Elasticity of substitution between processed products	σ^y	*E*= 5, *U*= 7, *R*= 10
Price elasticity of supply for input *h*	$\varepsilon_F{}^y$ $\varepsilon_M{}^y$	*E*=0.5, *U*=0.5, *R*=0.6 *E*=1.0, *U*=1.0, *R*=1.5
Cost share for input *F* in the production of *j*	$\kappa_{Fj}{}^E$ $\kappa_{Fj}{}^U$ $\kappa_{Fj}{}^R$	*J1*=0.15, *J3*=0.45 *J2*=0.17, *J4*=0.50 *J5*=0.40
Industry share of inputs used in the production of *j*	λ_j^E λ_j^U λ_j^R	*J1*=0.39, *J3*=0.61 *J2*=0.10, *J4*=0.90 *J5*=1.0
Elasticity of substitution between inputs for processed product *j*	σ_j^y	0.1 (for all processed products in all regions)
Initial equilibrium quantity supplied of product *j*	QS_j^E QS_j^U QS_j^R	*J1*=3.5, *J3*=5.5 *J2*=1.0, *J4*=9.0 *J5*=9.0
Initial equilibrium quantity demanded of product *j*	QD_j^E QD_j^U QD_j^R	*J1*=3.20, *J2*=0.01, *J3*=4.30, *J4*=0.20, *J5*=0.75 *J1*=0.15, *J2*=0.95, *J3*=0.20, *J4*=8.40, *J5*=0.05 *J1*=0.15, *J2*=0.04, *J3*=1.00, *J4*=0.40, *J5*=8.20

[a] There are five processed tomato products in our model: *J1* represents a canned tomato product produced and exported by the EU; *J2* represents a canned tomato product produced and exported by the United States; *J3* represents a tomato paste product produced and exported by the EU; *J4* represents a tomato paste product produced and exported by the United States; and *J5* represents a tomato paste product produced and exported by the rest-of-the-world region.

[b] Prior distributions were used for price elasticities of demand and supply, and all elasticities of substitution. Values shown represent the mean used in the beta (3,3) distribution.

Table 2. Price Effects of Policy Reductions in the Processing Tomato Industry[a]

Region and Product	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Percent change in price (Confidence interval[b])			
EU				
Tomatoes[c]	-0.42	-9.3	4.2	-5.2
	(-0.47, -0.36)	(-10.2,-8.5)	(4.0, 4.4)	(-5.9, -4.5)
Manufacturing Input	-0.23	-3.1	2.3	-0.82
	(-0.26, -0.20)	(-3.3, -2.9)	(2.1, 2.4)	(-1.0, -0.65)
EU Canned Tomatoes	-0.26	-0.81	2.6	1.8
	(-0.30, -0.21)	(-1.2, -0.39)	(2.3, 2.8)	(1.5, 2.0)
U.S. Canned Tomatoes	-6.9	0.45	-6.2	-5.7
	(-7.0, -6.8)	(0.34, 0.55)	(-6.3, -6.0)	(-5.9, -5.5)
EU Tomato Paste	-0.31	3.8	3.1	6.9
	(-0.37, -0.26)	(3.2, 4.4)	(2.9, 3.3)	(6.5, 7.3)
U.S. Tomato Paste	-6.9	0.55	-5.9	-5.4
	(-7.0, -6.8)	(0.43, 0.69)	(-6.1, -5.7)	(-5.6, -5.1)
ROW Tomato Paste	-0.10	1.1	-2.7	-1.6
	(-0.13, -0.07)	(0.89, 1.2)	(-3.1, -2.2)	(-2.0, -1.2)
U.S.				
Tomatoes	0.39	0.72	1.7	2.4
	(0.34, 0.42)	(0.60, 0.84)	(1.5, 1.9)	(2.2, 2.6)
Manufacturing Input	0.21	0.39	0.92	1.3
	(0.19, 0.23)	(0.33, 0.45)	(0.82, 1.0)	(1.2, 1.4)
EU Canned Tomatoes	-0.26	-0.81	-3.7	-4.5
	(-0.30, -0.21)	(-1.2, -0.39)	(-3.9, -3.5)	(-4.7, -4.3)
U.S. Canned Tomatoes	0.24	0.45	1.1	1.5
	(0.20, 0.27)	(0.34, 0.55)	(0.88, 1.2)	(1.3, 1.7)
EU Tomato Paste	-0.31	3.8	-3.1	0.64
	(-0.37, -0.26)	(3.2, 4.4)	(-3.4, -2.9)	(0.23, 1.0)
U.S. Tomato Paste	0.30	0.55	1.3	1.9
	(0.25, 0.34)	(0.43, 0.69)	(1.1, 1.5)	(1.6, 2.1)
ROW Tomato Paste	-0.10	1.1	-8.9	-7.8
	(-0.13, -0.07)	(0.89, 1.2)	(-9.3, -8.4)	(-8.2, -7.5)

Table 2 continued. Price Effects of Policy Reductions in the Processing Tomato Industry[a]

Region and Product	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Percent change in price (Confidence interval[b])			
ROW				
Tomatoes	-0.15	1.6	-4.0	-2.4
	(-0.18, -0.12)	(1.4, 1.8)	(-4.4, -3.5)	(-2.8, -2.0)
Manufacturing Input	-0.06	0.70	-1.8	-1.1
	(-0.08, -0.05)	(0.62, 0.78)	(-2.0, -1.5)	(-1.3, -0.87)
EU Canned Tomatoes	-0.26	-0.81	-7.5	-8.3
	(-0.30, -0.21)	(-1.2, -0.39)	(-7.7, -7.3)	(-8.5, -8.1)
U.S. Canned Tomatoes	0.24	0.45	-9.0	-8.5
	(0.20, 0.27)	(0.34, 0.55)	(-9.1, -8.8)	(-8.7, -8.3)
EU Tomato Paste	-0.31	3.8	-6.9	-3.1
	(-0.37, -0.26)	(3.2, 4.4)	(-7.1, -6.7)	(-3.5, -2.7)
U.S. Tomato Paste	0.30	0.55	-8.7	-8.2
	(0.25, 0.34)	(0.43, 0.69)	(-8.9, -8.5)	(-8.4, -7.9)
ROW Tomato Paste	-0.10	1.1	-2.7	-1.6
	(-0.13, -0.07)	(0.89, 1.2)	(-3.1, -2.2)	(-2.0, -1.2)

[a] Price changes in the United States and the rest-of-the-world region are identical for simulations that only reduce EU tariffs or EU domestic support.

[b] These 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

[c] EU tomato price reflects the price the grower receives. In the case of a 50% reduction in EU domestic support, the EU grower price would fall by 9.3% and the price processors would pay for tomatoes would increase by 12.2%.

Table 3. Production Effects of Policy Reductions in the Processing Tomato Industry

Region and Product	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Percent change in quantity (Confidence interval[a])			
EU				
Tomatoes	-0.21	-4.6	2.1	-2.6
	(-0.24, -0.17)	(-5.2, -4.0)	(1.7, 2.4)	(-2.9, -2.2)
Manufacturing Input	-0.23	-3.1	2.3	-0.83
	(-0.26, -0.19)	(-3.6, -2.5)	(1.9, 2.6)	(-1.1, -0.58)
Canned Tomatoes	-0.63	12.4	0.59	13.0
	(-0.82, -0.44)	(8.3, 16.5)	(0.30, 0.85)	(8.9, 17.2)
Tomato Paste	0.04	-13.8	3.2	-10.6
	(-0.04, 0.13)	(-17.1,-10.6)	(2.5, 3.9)	(-13.6, -7.8)
U.S.				
Tomatoes	0.19	0.36	0.83	1.2
	(0.16, 0.22)	(0.25, 0.46)	(0.70, 0.96)	(0.95, 1.4)
Manufacturing Input	0.21	0.39	0.91	1.3
	(0.17, 0.24)	(0.28, 0.50)	(0.78, 1.0)	(1.1, 1.5)
Canned Tomatoes	0.23	0.99	1.8	2.8
	(0.15, 0.32)	(0.61, 1.4)	(1.3, 2.3)	(1.9, 3.7)
Tomato Paste	0.20	0.31	0.77	1.1
	(0.15, 0.25)	(0.18, 0.45)	(0.58, 0.95)	(0.76, 1.4)
ROW				
Tomatoes	-0.09	0.97	-2.4	-1.4
	(-0.11, -0.07)	(0.70, 1.2)	(-2.9, -1.9)	(-1.7, -1.2)
Manufacturing Input	-0.10	1.1	-2.6	-1.6
	(-0.12, -0.08)	(0.77, 1.3)	(-3.1, -2.1)	(-1.8, -1.3)
Tomato Paste	-0.09	0.99	-2.5	-1.5
	(-0.12, -0.07)	(0.64, 1.4)	(-3.2, -1.8)	(-1.9, -1.2)

[a] These 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

Table 4. Welfare Effects of Policy Reductions in the Processing Tomato Industry

Welfare of:	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Welfare change in 2003 million USD (Confidence interval[a])			
EU				
Tomato Growers	-3.2	-69.8	32.1	-39.1
	(-3.6, -2.8)	(-76.3, -63.6)	(30.6, 33.6)	(-44.4, -34.1)
Tomato Manufacturers	-1.3	-17.9	13.4	-4.8
	(-1.5, -1.2)	(-19.2, -16.5)	(12.6, 14.3)	(-5.8, -3.8)
Consumers	7.2	-7.2	-43.1	-51.2
	(6.8, 7.6)	(-10.3, -3.5)	(-44.6, -41.7)	(-53.0, -49.3)
Taxpayers[b]	0.41	135.1	-21.3	116.9
	(0.24, 0.59)	(133.9,136.3)	(-21.8, -20.7)	(115.7,118.1)
Region Overall	3.1	40.3	-18.8	21.8
	(2.8, 3.3)	(39.0, 41.7)	(-19.2, -18.5)	(20.8, 23,0)
U.S.				
Tomato Growers	2.1	3.9	9.3	13.3
	(1.9, 2.3)	(3.3, 4.6)	(8.4, 10.2)	(11.9, 14.5)
Tomato Manufacturers	1.2	2.1	5.1	7.3
	(1.0, 1.3)	(1.8, 2.5)	(4.5, 5.7)	(6.5, 8.0)
Consumers	-3.2	-6.8	-10.8	-17.5
	(-3.4, -3.1)	(-7.4, -6.2)	(-11.8, -9.8)	(-18.6, -16.6)
Taxpayers	0.37	0.06	-4.2	-4.1
	(0.30, 0.44)	(-0.06, 0.17)	(-4.4, -3.9)	(-4.4, -3.9)
Country Overall	0.42	-0.66	-0.51	-1.1
	(0.34, 0.50)	(-0.93, -0.37)	(-0.79, -0.26)	(-1.6, -0.69)

Table 4 continued. Welfare Effects of Policy Reductions in the Processing Tomato Industry

Welfare of:	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Welfare change in 2003 million USD (Confidence interval[a])			
ROW				
Tomato Growers	-0.54	5.8	-14.2	-8.6
	(-0.66, -0.41)	(5.1, 6.5)	(-15.8, -12.6)	(-10.0, -7.2)
Tomato Manufacturers	-0.24	2.5	-6.2	-3.8
	(-0.30, -0.18)	(2.3, 2.8)	(-7.0, -5.5)	(-4.4, -3.1)
Consumers	1.1	-11.2	42.2	29.8
	(0.96, 1.2)	(-12.0, -10.5)	(41.0, 43.4)	(28.4, 31.3)
Taxpayers	0.21	-2.5	-17.8	-18.4
	(0.18, 0.24)	(-2.9, -2.1)	(-18.5, -17.1)	(-19.1, -17.7)
Region Overall	0.52	-5.4	4.0	-0.90
	(0.48, 0.56)	(-6.1, -4.6)	(3.0, 4.9)	(-2.0, 0.15)
Overall Global	4.0	34.2	-15.3	19.8
	(3.7, 4.4)	(32.0, 36.7)	(-17.0, -13.9)	(17.2, 22.5)

[a] These 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

[b] Reductions in global tariffs increase EU taxpayer costs through losses in tariff revenue and increases in domestic support spent on additional EU tomato production. Here, $19.9 million of the $21.9 million increase in EU taxpayer costs is due to the cost of supporting the additional production of EU processing tomatoes.

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Footnotes

[1] For example, the FAPRI, OECD, and GTAP models typically do not include important horticultural products in the analysis (see http://www.fapri.org/models/).

[2] Aggregate production in each nation relative to its threshold quantity serves as a basis for adjusting payment rates in future years, but does not affect payment rates in any current year. Growers in a region are only penalized if they collectively exceed their threshold level by at least 10%, and the EU exceeds the total EU threshold level (Brans 2000; European Commission 2005). In practice, Spain has exceeded their threshold level in recent years and the per-ton payment to growers in Spain was reduced to 29.36 euros per metric ton (Pazos 2004).

[3] The EU also applies export subsidies to selected canned tomato products. The export subsidy applies to a less than 2% of the total quantity of processed tomato products supplied in the EU. The rate of subsidy on the small share of output to which it applies is less than 10%, and in the overall market for processed tomato products in the EU, the *ad valorem* rate of export subsidy is approximately 0.2% (Brans 2003; Santella 2003). We therefore leave aside any further discussion of the export subsidy in this paper.

[4] Results from 2000 iterations of the model were also computed, however did not differ from results reported here using 1000 iterations.

[5] Simulations using less substitution between inputs and more substitution between processed tomato products show larger price and quantity effects.

[6] Furthermore, as discussed earlier, a tomato specific analysis relevant to a WTO challenge would appropriately use a larger EU supply elasticity. This would result in somewhat larger price effects than those reported in these simulations.