Domestic Support and Border Measures for Processed Horticultural Products:
Analysis of EU Tomato Protection and Subsidies

Draft Paper
April 2006

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We thank Julian Alston, David Hart and Mark Evans among others for assistance with this research.

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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 devoted relatively little attention to the interactions between subsidy and protection applied to related products in the vertical marketing chain. 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, researchers have examined the economic impact of including domestic support policies directly on the negotiating agenda of the WTO (Sumner 2000; Bagwell and Staiger 2001). 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 agreed 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 solely on field crops and livestock products.[1] We begin to redress this imbalance here. We model carefully 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 very 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 and Europe and that is also important in developing countries. Second, the processing tomato industry has significant import tariffs and has long been subject to large subsidies in the European Union. 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 has ranged between 25 and 30 million metric tons per year (Tomato News). Using a per ton price of approximately $640 for tomato paste (Morning Star Company), the production of processed tomato products are valued at more than $3 billion per year. Processing tomatoes are relatively low unit-cost raw materials that are also perishable and bulky. Therefore, processing plants are located nearby to growing areas. Major producers export tomato products but also import, suggesting that products are not perfect substitutes. The European Union produces about 30% of processing tomato products in the world and accounts for approximately 50% of exports. United States contributes another 35% of production and 15% 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 35% of exports (USDA-FAS).

Processing Tomato Policy

Since the European Union 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 euro per ton of processing tomatoes in Italy, Greece, Portugal, and France, and 29.36 in Spain. This regime includes 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 ton (Pazos 2004) so the ad valorem equivalent rate of domestic support has been approximately 43%.

The EU tariff for processed tomato products 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. 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; Menghini 2004).[3]

The ad valorem rate for the import tariff applied to processed tomato products shipped into the United States is 12.5%, and into the rest-of-the-world region is approximately 20.0% (APEC, Inter-American Development Bank).

Simulation Model

We designed 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 has been 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 is used both to provide analytical results and to simulate proportional changes in economic variables (prices, quantities, and welfare measures) for input and output markets.

An equilibrium displacement model has been 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, or a linear elasticity model. The equations are solved for proportional changes in quantity 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. For example, this type of model was used by Floyd (1965) to examine the effects of farm policy, by Gardner (1975) to examine the farm-retail price spread, by Sumner and Wohlgenant (1985) to study changes in excise taxes, by Sumner, Lee, and Hallstrom (1999) to assess trade liberalization, and by Brester, Marsh, and Atwood (2004) to examine impacts of country-of-origin labeling.

The basic structure of the model includes: a) demand for processed products: b) supply of inputs; c) derived demand for inputs; d) derived supply of outputs; and e) market clearing conditions. Parameters are: i) the elasticity of supply for each input; ii) the elasticity of demand for each output; iii) the elasticity of substitution between inputs; iv) input shares; v) initial equilibrium quantities; vi) cost shares; and vii) policy shocks.

The following notational convention is used: **Y** is a vector of regions, and superscript y refers a particular region; **J** is a vector of output products, and subscript j refers to a specific output product; **I** is a vector of inputs, and subscript i refers to a specific input. Superscript z refers to countries other than y, subscript k refers to output products other than j, and subscript h refers to inputs other than i.

In the three-region, two-input, five-output model that follows, the vector **Y** includes regions *E* (European Union), *U* (United States), and *R* (rest-of-the-world region), that is $\mathbf{Y}=[E, U, R]$, $y\in\mathbf{Y}$, and $z\in\mathbf{Y}$ where $z\neq y$. For simplicity, all regions outside the EU and the United States are aggregated, as the empirical focus later is on these two regions.

The vector **I** includes inputs *F* (farm-produced commodity) and *M* (marketing and processing services), that is $\mathbf{I}=[F, M]$, $i\in\mathbf{I}$, and $h\in\mathbf{I}$ where $h\neq i$. The vector **J** includes five output products and $\mathbf{J}=[J1, J2, J3, J4, J5]$, $j\in\mathbf{J}$, and $k\in\mathbf{J}$ where $k\neq j$. Products *J1* and *J2* represent canned tomato products, and products *J3*, *J4*, and *J5* are used to represent tomato paste products. Product *J1* is canned tomato products exported from the EU, *J2* is all other canned tomato products, product *J3* is the standard tomato paste products that are produced in many regions, product *J4* is the low-cost tomato paste products that are imported into the EU duty-free, and product *J5* is the tomato paste products that are produced in, and exported from, the EU. Processed tomato products at the wholesale level include bulk tomato paste and bulk canned tomato products, often referred to as Stage I products. The processed tomato products are further differentiated to account for the observed intra-industry trade within Stage I products. The various processed tomato products utilize the same inputs in production, although in different proportions.

In equation (1) through (7), 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 this industry exhibits constant returns to scale, the industry total cost function (TC^y_j) is the product of the unit cost function of product j in region y, namely c^y_j, and the quantity supplied of processed product j in region y, namely QS^y_j. We assume that the unit cost functions are independent across products.

(1)	$QD^y_j = f^y_j\,(\mathbf{P^y_j}; \mathbf{v^y_j})$	Output Demand
(2)	$XD^y_{ij} = (\partial c^y_j(\cdot)/\partial WD^y_i)QS^y_j$	Factor Demand
(3)	$XS^y_i = f^y_i\,(WS^y_i; \mathbf{u^y_i})$	Factor Supply
(4)	$P^y_j = \partial TC^y_j(\cdot)/\partial QS^y_j$	Market Clearing Condition (MCC)
(5)	$P^y_j = P^y_j(1+\beta^y_j)$	MCC with Trade Distortions
(6)	$WS^y_i = WD^y_i(1+\delta^y_i)$	Factor Market MCC with Distortions
(7)	$QD^y_j = QS^y_j + \sum_z(QS^z_j - QD^z_j)$	International Market MCC

(8) $XS^y_i = \sum_j XD^y_{ij}$ Factor Market MCC

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 ($\boldsymbol{v}^y_j$). Equation (2) represents the derived demand for input *i*, as it is used in the production of product *j*, in region *y*. Equation (3) represents the supply of input *i* in region *y*; it is a function of input prices and a vector of exogenous variables ($\boldsymbol{u}^y_i$). Linkages between agriculture and the rest of the economy are represented by $f^y_i(\cdot)$, an upward sloping supply function for input *i*. Equation (4) represents the long-run condition that the processed product price equals the minimum average total cost for product *j*.

Market clearing conditions begin with equation (4), which determines the price of product *j* in region *y* under the assumption of perfect competition. Equation (5) represents the relationship between prices of the traded outputs, where β^y_j represents the ad valorem price wedge created by a border measure applied to product *j* by region *y*. For an import tariff, β^y_j is expressed as a positive parameter, and for an export subsidy, β^y_j is expressed as a negative parameter. Regardless of whether β^y_j 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 farmers; δ^y_i represents the ad valorem price wedge created by a domestic support policy for input *i* in region *y*. In cases where domestic support does not apply to a specific input, δ^y_i is set equal to zero, and the price paid by processors is equivalent to the price received by farmers. 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). These equations do not involve any explicit or implicit assumptions about the functional forms used, and it is not necessarily assumed that the elasticities are constant. However, it is assumed that the supply-and-demand functions are approximately linear at the initial point of market equilibrium (Alston, Norton, and Pardey 1995). Equilibrium adjustments can be simulated by exogenously specifying changes in the policy parameters. Values for elasticity and share parameters are held constant as exogenous changes to policy are applied.

The technology is characterized as constant returns to scale at the zero profit point. In the following equations, for any variable A, E(A) represents the relative change in A, that is, E(A) represents dA/A where d refers to a total differential.

(9) $E(QD^y_j) = \eta^y_{jj}[E(P^y_j) - \psi^y_j] + \sum_j\{\eta^y_{jk}[E(P^y_k) - \psi^y_k]\}$

(10) $E(XD^y_{ij}) = E(QS^y_j) - \sum_h \kappa^y_{hj}\sigma^y_j E(WD^y_i) + \sum_i \kappa^y_{hj}\sigma^y_j E(WD^y_h)$

(11) $E(XS^y_i) = \varepsilon^y_i[E(WS^y_i) - \phi^y_i]$

(12) $E(P^y_j) = \sum_i \kappa^y_{ij} E(WD^y_i)$

(13) $E(P^z_j) = E(P^y_j) + E(1+\beta^y_j)$

(14) $E(WS^y_i) = E(WD^y_i) + E(1+\delta^y_i)$

(15) $E(QD^y_j) = (QS^z_j{}'/QD^y_j{}')E(QS^y_j) + \sum_z\{(QS^z_j{}'/QD^y_j{}')E(QS^z_j) - (QD^z_j{}'/QD^y_j{}')E(QD^z_j)\}$

(16) $E(XS^y_i) = \sum_j \lambda^y_{ij} E(XD^y_{ij})$

The price elasticity of demand for the processed product j with respect to the price of the other processed product k in region y, is represented by η^y_{jk}. The own-price elasticity of supply of input i in region y is represented by $\varepsilon^y{}_i$. The Allen partial elasticity of input substitution for producing j, in region y, is denoted by $\sigma^y{}_j$. The cost share of input i in the production of j in region y is denoted as $\kappa^y{}_{ij}$. The industry share of input i used in the production of j in region y is $\lambda^y{}_{ij}$.

The term $E(1+\beta^y{}_j)$ represents a change in the ad valorem rate of the border measure, and the term $E(1+\delta^y{}_i)$ represents a change in the ad valorem rate of domestic support. A relative increase in the marginal cost of input i, (a vertical shift up) is denoted $\phi^y{}_i$, and a relative increase in the demand for output j, (a vertical shift up) is denoted $\psi^y{}_j$. In equation (15), a parameter denoted with a prime represents an initial equilibrium quantity, and each ratio represents a quantity share. For example, $(QS^z{}_j'/QD^y{}_j')$ 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 results from the model can be used to calculate the relative change in the traded quantity for each processed product j in region y in response to a policy shock. Equation (17) represents traded quantity of product j in region y, denoted $QT^y{}_j$. The traded quantity is the absolute value of the excess supply, and describes the trade flow quantity, regardless of whether region y is an importer or exporter.

$$(17) \qquad QT^y{}_j = |QS^y{}_j - QD^y{}_j|$$

Totally differentiating equation (17) yields equation (18), and combined with the results from the model in equations (9) to (16) can be used to calculate the proportional change in the traded quantity.

$$(18) \qquad E(QT^y{}_j) = (QS^y{}_j'/|QS^y{}_j' - QD^y{}_j'|)E(QS^y{}_j) - (QD^y{}_j'|QS^y{}_j' - QD^y{}_j'|)E(QD^y{}_j)$$

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^{y}_{j}) and to the factors of production in region *y* (ΔPS^{y}_{i}) are measured in terms of changes in factor and product prices and quantities. In equations (19) and (20) primed variables denote the use of initial equilibrium values.

(19) $\Delta CS^{y}_{j} = -P^{y}_{j}{}'QD^{y}_{j}{}'\mathrm{E}(P^{y}_{j})[1 + 0.5\mathrm{E}(QD^{y}_{j})]$

(20) $\Delta PS^{y}_{i} = WS^{y}_{i}{}'\mathrm{XS}^{y}_{i}{}'\mathrm{E}(WS^{y}_{i})[1 + 0.5\mathrm{E}(XS^{y}_{i})]$

The change in total producer surplus in region *y* is the sum of the producer surplus from each factor market, $\Delta PS^{y} = \sum_{i}(\Delta PS^{y}_{i})$, and the change in the total consumer surplus in region *y* is the sum of the consumer surplus across output markets, $\Delta CS^{y} = \sum_{j}(\Delta CS^{y}_{j})$.

The change in net surplus depends on the change in taxpayer surplus, denoted as ΔTS^{y}_{ij}. Changes in the taxpayer surplus accrue when either border measures or domestic policies change or when the quantities to which they apply change. Equation (21) includes the welfare effects for taxpayers in the EU from changes in export subsidies, import tariffs, and domestic support. Equation (22) includes the welfare effects for taxpayers in the United States and equation (23) includes the welfare effects for taxpayers in the rest-of-the-world region, from changes in import tariffs. Note that $P^{x}_{j}{}'$ represents the initial equilibrium export price (net of tariffs) for product *j*, and $QT^{y}_{j}{}'$ represents the traded quantity at the initial equilibrium.

$$
\begin{aligned}
(21)\quad \Delta TS^{E} = {} & P^{x}_{J1}{}'QT^{E}_{J1}{}'[\mathrm{E}(P^{x}_{J1}) + \mathrm{E}(QT^{E}_{J1}) + \mathrm{E}(P^{x}_{J1})\mathrm{E}(QT^{E}_{J1})] \\
& - P^{E}_{J1}{}'QT^{E}_{J1}{}'[\mathrm{E}(P^{E}_{J1}) + \mathrm{E}(QT^{E}_{J1}) + \mathrm{E}(P^{E}_{J1})\mathrm{E}(QT^{E}_{J1})] \\
& + \textstyle\sum_{j=[J2,\ldots J5]}\{P^{E}_{j}{}'QT^{E}_{j}{}'[\mathrm{E}(P^{E}_{j}) + \mathrm{E}(QT^{E}_{j}) + \mathrm{E}(P^{E}_{j})\mathrm{E}(QT^{E}_{j})] \\
& - P^{x}_{j}{}'QT^{E}_{j}{}'[\mathrm{E}(P^{x}_{j}) + \mathrm{E}(QT^{E}_{j}) + \mathrm{E}(P^{x}_{j})\mathrm{E}(QT^{E}_{j})]\}
\end{aligned}
$$

$$+ \sum_i \{WD^E_i{}'XS^E_i{}'[\mathrm{E}(WD^E_i) + \mathrm{E}(XS^E_i) + \mathrm{E}(WD^E_i)\mathrm{E}(XS^E_i)]$$

$$- WS^E_i{}'XS^E_i{}'[\mathrm{E}(WS^E_i) + \mathrm{E}(XS^E_i) + \mathrm{E}(WS^E_i)\mathrm{E}(XS^E_i)]\}$$

(22) $$\Delta TS^U = \sum_j \{P^U_j{}'QT^U_j{}'[\mathrm{E}(P^U_j) + \mathrm{E}(QT^U_j) + \mathrm{E}(P^U_j)\mathrm{E}(QT^U_j)]$$

$$- P^x_j{}'QT^U_j{}'[\mathrm{E}(P^x_j) + \mathrm{E}(QT^U_j) + \mathrm{E}(P^x_j)\mathrm{E}(QT^U_j)]\}$$

(23) $$\Delta TS^R = \sum_j \{P^R_j{}'QT^R_j{}'[\mathrm{E}(P^R_j) + \mathrm{E}(QT^R_j) + \mathrm{E}(P^R_j)\mathrm{E}(QT^R_j)]$$

$$- P^x_j{}'QT^R_j{}'[\mathrm{E}(P^x_j) + \mathrm{E}(QT^R_j) + \mathrm{E}(P^x_j)\mathrm{E}(QT^R_j)]\}$$

Combining the welfare effects from equations (19), (20), (21), (22), and (23), equation (24) represents the change in net surplus in region y (ΔNS^y).

(24) $$\Delta NS^y = \sum_j(\Delta CS^y_j) + \sum_i(\Delta PS^y_i) + \Delta TS^y$$

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^y_j, or a domestic support parameter, namely δ^y_i. 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 a reduction in the ad valorem price wedge (δ^y_i) between the price received by farmers and the price paid by processors for the farm input in the EU. Reductions in the border measures are modeled as a reduction in the ad valorem price wedge (β^y_j) between the price of product j in the exporting country and the price in the importing countries. 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 baseline parameters used here are from empirical estimates from the literature, and data supplied by industry sources. 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.

The own- and cross-price elasticities of demand were calculated following an Armington specification (Armington 1969). For a review of the limitations of the Armington specification, and of Armington-type models that have been used in earlier agricultural applications, see Alston et al. (1990); Davis and Kruse (1993); and Alston, Gray, and Sumner (1994). The calculation used to parameterize the Armington own-price elasticity of demand is shown in Equation (25) and the calculation used to parameterize the Armington cross-price elasticity of demand is shown in Equation (26).

(25) $\eta^{y}_{jj} = \zeta^{y}_{j}\eta^{y} - (1 - \zeta^{y}_{j})\sigma^{y}$

(26) $\eta^{y}_{jk} = \zeta^{y}_{k}(\eta^{y} + \sigma^{y})$

The own-price elasticity of demand for product *j* is represented by η^{y}_{jj}, and η^{y}_{jk} represents the cross-price elasticity of demand for product *j* with respect to the price of another output product, namely *k*. In equations (25) and (26), η^{y} is the overall elasticity of demand for processed tomato products in country *y*.

Based on previous estimates from the literature (Chern 1976) we define the overall elasticity of demand for processed tomato products as –0.5 in the United States. We considered a range of elasticities in the EU and the rest of the world; the results reported below use –0.3 as the overall elasticity of demand for processed tomato products in the EU and –0.7 in the rest-of-the-world region. In addition to the overall demand elasticities, the Armington specification requires the elasticity of substitution (across the differentiated goods) for each consuming country, and the share of consumption devoted to product *j* in country *y*. The elasticity of substitution between the five processed tomato products, represented by σ^y, 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^y_j, is derived from industry sources (Amézaga, Morning Star), and where applicable, from trade flow data (e.g., Menghini 2004; Pazos 2004). For each region, baseline parameters for the consumption shares, elasticity of substitution, and overall elasticity of demand for processed tomato products are defined and used to calculate the matrix of Armington elasticities shown in the Appendix in table A1.

The supply function for processed tomato products is derived from supply functions in the factor input markets. The supply functions in the factor input markets apply to that market as a whole, but reflect the supply decisions made by individual firms in that market. The model assumes that these input markets are competitive, that is, the prices of the inputs used are exogenous to individual firms in the processing tomato industry. 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 subsidy reductions.

The two inputs used to produce processed tomato products in the simulation model are the farm-produced input (*F*) and the marketing input (*M*). 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 long-run it is expected that the supply elasticity of processing tomato input and the marketing input would be quite elastic, but in the short-run, the supply elasticities of these inputs would be inelastic as the decision to produce processing tomatoes is made annually. We expect the supply elasticity to be more elastic in the rest of the world than in the two developed country regions. Finally, noting that tomato processing uses specialized capital, but that manufacture of that capital can be readily expanded with some lag, we use larger supply elasticities for the manufacturing input. We also note that results are relatively robust to moderate variations in these parameter choices. The full set of shares, initial quantities and supply parameters are contained in the Appendix in table A2.

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.

We use the model to simulate a 50% reduction in the rate of EU domestic support for tomatoes using the parameter δ^{E}_{F}. The EU is only a significant importer of standard paste (*J3)* and paste from the rest of the world (*J4)*. Recall product *J4* represents processed tomato products that are eligible for the duty drawback (or are subject to a zero tariff under preferential trading agreements). We consider a 50% reduction in import tariff rates for product *j* in country *y*, using the parameter $\beta^y{}_j$.

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 domestic support from 43% to 21.5%;
2. A 50% reduction in EU tariffs from 14.4% to 7.2%, but tariff no cut elsewhere;
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 EU domestic support.

Each simulation imposes a policy shock to the system of equations and generates new equilibrium prices and quantities for the two inputs and the five processed products. The changes in prices and quantities are used to calculate changes in welfare measures. Table 1 shows price effects from each scenario for input and product in each region. Table 2 shows the associated quantity effects from each scenario. We will refer to these quantity and price effects to help understand the implications of policy changes, but our major interest is on the welfare implications shown in table 3.

Column 1 of each table shows the effects of a reduction in EU tariffs alone. The tariff cut only applies to standard paste, imported mainly from the United States and standard canned products, of which little is imported. The ROW-type paste enters the EU duty free. The result of the tariff reduction is lower prices in the EU for all affected products and EU-type paste. The higher prices outside the EU for standard paste and

ROW-type paste raises welfare for growers and manufacturers in the United States and the rest of the world. The gain to growers and manufactures in the United States, a net exporting region, is enough to offset consumer and tariff revenue losses such that the United States gains $12.7 million per year. Growers and manufacturers in the rest of the world gain by $2.7 million, but the overall loss is $1.8 billion.

It is useful to compare column 1 with column 2, which shows the effects of removal of EU domestic support alone. Column 2 shows results of a 50% reduction in the per-unit subsidy applied in the EU. As table 1 shows, 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 EU grower price by approximately 9.3% and therefore raise the price paid by processors for tomatoes by approximately 12.2%. With fewer tomatoes produced the demand for the manufacturing input falls, despite the small substitution effect. These input price impacts trace through to changes in product prices and quantities as well. In turn, EU producer surplus would fall by approximately $87 million, yet EU taxpayer surplus would increase enough that the net surplus in the EU would increase by approximately $45 million.

Reducing EU domestic support by 50% would lead to changes in the prices of the processed tomato products, and small increases in prices of tomatoes and the manufacturing input in the United States and the rest of the world. U.S. tomato producers and manufacturers gain $8.5 million and those in less developed countries gain $5.3 million per year. Following the legal analysis reported by Oxfam (Stuart 2005) this result is consistent with the notion that these policies may be vulnerable to a WTO challenge. At the same time, consumers in the United States and the rest of the world lose with subsidy reduction. The aggregate impact is slightly positive for the United States and negative $3.4 million 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. In particular, the effects of 50% cuts in domestic subsidies have smaller price and welfare impacts in the United States than do the 50% cuts in EU tariffs, even though initial domestic subsidy rates are far higher than initial tariffs.

Column 3 shows the effects of a global tariff reduction of 50%. Cutting global tariffs allows lower prices in importing regions and higher prices in exporting regions. All regions gain overall welfare improvements with growers and manufacturers gaining substantially in the EU and the United States and consumers gaining in the rest of the world. Of course tariff revenue is down in all countries, and the additional subsidy costs contribute to the loss of tariff revenue in the EU. In the United States prices of raw tomatoes rise by 6.2% (table 1) and quantity produced rises by 3.1% for a gain of $34.6 million per year in grower surplus. Because the rest of the world is a net importer, growers and manufacturers lose from reduced global tariffs. Overall world welfare increases by $54.8 million per year, with more than half that gain in the United States.

Column 4 in table 3 shows the welfare effects from the simulation that considers both a 50% reduction in global import tariffs and a 50% reduction in EU domestic support. This scenario is consistent with a moderate outcome of the Doha WTO negotiations. In this case, the price of U.S. tomatoes would increase by 7.2%, and this result is driven almost entirely by the reduction in global import tariffs rather than the reduction in EU domestic support. Aggregate gains in the United States are larger (consumer costs are also larger) and aggregate gains in the rest of the world are smaller than when only tariffs are cut. The results in column 4 are approximately additive from those in column 2 and column 3. The global gains of about $100 million per year are dominated by the saving in EU taxpayer outlays of about $131 million per year. In the United States gains by producers 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

Horticultural products and processed products are an increasing part of international agricultural trade, but are understudied in the policy literature. Understanding how policies applied at different stages in the marketing and processing chain affect growers, food manufacturers and consumers is an important research topic in this area. Furthermore, there is little in the literature on how policies for horticultural products applied in rich countries affect developing country producers and consumers. This article has developed a detailed model that allows analysis of reductions in farm commodity subsidies and processed product border protection. The model recognizes that raw farm commodities may be used to produce several related processed products, that there is some albeit limited substitution between raw materials and other inputs, and that intra-industry international trade is common. We apply the model to the important case of the processing tomato industry.

We find that cuts in EU processed tomato product tariffs have larger benefits to producers in the United States (a net exporting region) than do equal percentage cuts in EU raw tomato subsidies, despite the much larger initial subsidies. In the rest of the world (a net importing region), the effects of the subsidy cuts are larger. Overall, EU subsidy cuts would redistribute welfare from growers and manufacturers ($87 million) to taxpayers ($136 million) in the EU, and yield a substantial net welfare gain ($45 million).

We also examine a scenario of global tariff cuts and one that combines global tariff cuts with a reduction in EU domestic support for processing tomatoes. These 50% reductions approximate one potential outcome of the Doha WTO negotiation. For tariff cuts global welfare improves by about $55 million with U.S. growers and rest of world consumers as the major beneficiaries. Adding the reduction in EU domestic support adds about $45 million to the total global gains and most of that is from a net welfare increase in the EU itself.

This article has demonstrated with a detailed study of an important industry the significance of policy reform for horticultural commodities. It has documented the effects of reform of EU domestic subsidies and global trade barriers. We find support for the suggestions of Panagariya (2005) that developing country consumers and overall economies of net importers lose from reductions of rich country subsidies. We also show that reducing such subsidies for raw farm products can have major effects on producers in other countries, although not as large as the effects of reducing trade barriers for processed products. We also show that, as with bulk commodities, trade policy reform can have large and quantifiable impacts in horticultural and processed product markets.

Table 1. Price Effects of Policy Reductions in the Processing Tomato Industry

Region/ Product	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Price change (%)			
EU				
Tomatoes	-1.8	-9.3	1.4	-7.9
Manufacturing Input	-1.0	-3.1	0.8	-2.3
EU Canned Tomatoes	-1.1	-0.8	0.9	0.1
Standard Canned	-1.1	-0.4	0.9	0.5
Standard Tomato Paste	-5.7	0.8	-2.4	-1.6
ROW-type Paste	0.4	0.7	-4.0	-3.2
EU-type Paste	-1.4	3.6	1.0	4.7
United States				
Tomatoes	1.9	1.0	6.2	7.2
Manufacturing Input	1.0	0.5	3.4	3.9
EU Canned Tomatoes	-1.1	-0.8	-4.6	-5.5
Standard Canned	-1.1	-0.4	-4.6	-5.0
Standard Tomato Paste	1.5	0.8	4.8	5.6
ROW-type Paste	0.4	0.7	-9.5	-8.7
EU-type Paste	-1.4	3.6	-4.5	-0.8
ROW				
Tomatoes	0.5	1.0	-5.5	-4.5
Manufacturing Input	0.2	0.5	-2.4	-2.0
EU Canned Tomatoes	-1.1	-0.8	-9.1	-10.0
Standard Canned	-1.1	-0.4	-9.1	-9.5
Standard Tomato Paste	1.5	0.8	-5.2	-4.4
ROW-type Paste	0.4	0.7	-4.0	-3.2
EU-type Paste	-1.4	3.6	-9.0	-5.3

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

Region/ Product	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Quantity change (%)			
EU				
Tomatoes	-0.9	-4.6	0.7	-3.9
Manufacturing Input	-1.0	-3.1	0.8	-2.3
EU Canned Tomatoes	-7.0	8.0	-2.8	5.2
Standard Canned	0.4	3.4	-3.1	0.2
Standard Tomato Paste	-0.1	-2.4	1.6	-0.8
ROW-type Paste	n/a	n/a	n/a	n/a
EU-type Paste	-2.7	-16.8	3.7	-13.1
United States				
Tomatoes	1.0	0.5	3.1	3.6
Manufacturing Input	1.0	0.5	3.4	3.9
EU Canned Tomatoes	n/a	n/a	n/a	n/a
Standard Canned	1.8	11.8	58.6	70.7
Standard Tomato Paste	0.9	-0.7	-2.9	-3.7
ROW-type Paste	n/a	n/a	n/a	n/a
EU-type Paste	n/a	n/a	n/a	n/a
ROW				
Tomatoes	0.3	0.6	-3.3	-2.7
Manufacturing Input	0.3	0.7	-3.6	-2.9
EU Canned Tomatoes	n/a	n/a	n/a	n/a
Standard Canned	n/a	n/a	n/a	n/a
Standard Tomato Paste	2.8	5.4	-29.7	-24.4
ROW-type Paste	0.1	0.1	-0.2	-0.1
EU-type Paste	n/a	n/a	n/a	n/a

[a] Not all of the processed tomato products are produced in all regions. For example, there is no ROW-type tomato paste produced in the EU, and this will not be affected by any change in policy. We use the notation n/a to denote that this change in production is not applicable.

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

Region/ Welfare of:	A 50% reduction in: EU Import Tariffs	EU Domestic Support	Global Import Tariffs	Global Import Tariffs and EU Domestic Support
	Welfare change (million 2003 U.S. dollars)			
EU				
Tomato Growers	-13.9	-69.4	10.8	-59.2
Tomato Manufacturers	-5.8	-17.9	4.5	-13.6
Growers and Manufacturers	-19.7	-87.3	15.3	-72.8
Consumers	40.0	-3.9	1.8	-2.4
Taxpayers	11.3	136.1	-5.2	131.3
Region Overall	31.7	44.9	11.8	56.2
United States				
Tomato Growers	10.5	5.5	34.6	40.3
Tomato Manufacturers	5.8	3.0	18.9	22.0
Growers and Manufacturers	16.3	8.5	53.5	62.3
Consumers	-9.1	-6.2	-19.8	-24.6
Taxpayers	5.5	-1.6	-2.4	-3.2
Nation Overall	12.7	0.6	31.3	34.5
ROW				
Tomato Growers	1.8	3.7	-19.5	-15.9
Tomato Manufacturers	0.8	1.6	-8.5	-6.9
Growers and Manufacturers	2.7	5.3	-28.0	-22.8
Consumers	-3.4	-6.9	44.5	37.0
Taxpayers	-1.1	-1.9	-4.8	-5.4
Region Overall	-1.8	-3.4	11.7	8.9
Overall Global Welfare	42.6	42.1	54.8	99.6

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Table A1. Matrix of Armington Demand Elasticities

Region/ Assumptions/ Product	Consumption Share	Demand Elasticity with Respect to the Price of:				
EU $\eta^E = -0.3$, $\sigma^E = 5$		EU Canned	Standard Canned	Standard Paste	ROW-type Paste	EU-type Paste
EU Canned	0.16	–4.25	0.99	1.97	0.09	0.89
Standard Canned	0.21	0.75	–4.01	1.97	0.09	0.89
Standard Paste	0.42	0.75	0.99	–3.03	0.09	0.89
ROW-type Paste	0.02	0.75	0.99	1.97	–4.91	0.89
EU-type Paste	0.19	0.75	0.99	1.97	0.09	–4.11
United States $\eta^U = -0.5$, $\sigma^U = 7$						
EU Canned	0.01	–6.94	0.72	5.59	0.07	0.07
Standard Canned	0.11	0.07	–6.29	5.59	0.07	0.07
Standard Paste	0.86	0.07	0.72	–1.41	0.07	0.07
ROW-type Paste	0.01	0.07	0.72	5.59	–6.94	0.07
EU-type Paste	0.01	0.07	0.72	5.59	0.07	–6.94
ROW $\eta^R = -0.7$, $\sigma^R = 10$						
EU Canned	0.01	–9.91	0.09	1.21	7.63	0.28
Standard Canned	0.01	0.09	–9.91	1.21	7.63	0.28
Standard Paste	0.13	0.09	0.09	–8.79	7.63	0.28
ROW-type Paste	0.82	0.09	0.09	1.21	–2.37	0.28
EU-type Paste	0.03	0.09	0.09	1.21	7.63	–9.72

Table A2. Baseline Parameters used in the Simulation Models[a]

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^E_j ζ^U_j ζ^R_j	*J1*=0.16, *J2*=0.21, *J3*=0.42, *J4*=0.02, *J5*=0.19 *J1*=0.01, *J2*=0.11, *J3*=0.86, *J4*=0.01, *J5*=0.01 *J1*=0.01, *J2*=0.01, *J3*=0.13, *J4*=0.82, *J5*=0.03
Elasticity of substitution between processed products	σ^y	*E*= 5, *U*= 7, *R*= 10
Price elasticity of supply for input *i*	$\varepsilon^y{}_F$ $\varepsilon^y{}_M$	*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*	$\kappa^E{}_{Fj}$ $\kappa^U{}_{Fj}$ $\kappa^R{}_{Fj}$	*J1* =0.15, *J2*=0.18, *J3*=0.45, *J4*=0, *J5*=0.44 *J1*=0, *J2*=0.17, *J3*=0.50, *J4*=0, *J5*=0 *J1*=0, *J2*=0, *J3*=0.50, *J4*=0.50, *J5*=0
Industry share of input *i* used in the production of *j*	$\lambda^E{}_{Fj}$ $\lambda^E{}_{Mj}$ $\lambda^U{}_{Fj}$ $\lambda^U{}_{Mj}$ $\lambda^R{}_{Fj}$ $\lambda^R{}_{Mj}$	*J1*=0.17, *J2*=0.22, *J3*=0.39, *J4*=0, *J5*=0.22 *J1*=0.17, *J2*=0.22, *J3*=0.39, *J4*=0, *J5*=0.22 *J1*=0, *J2*=0.1, *J3*=0.9, *J4*=0, *J5*=0 *J1*=0, *J2*=0.1, *J3*=0.9, *J4*=0, *J5*=0 *J1*=0, *J2*=0, *J3*=0.11, *J4*=0.89, *J5*=0 *J1*=0, *J2*=0, *J3*=0.11, *J4*=0.89, *J5*=0
Elasticity of input substitution for processed product *j*	$\sigma^y{}_j$	0.1 (for all processed products in all regions)
Initial equilibrium quantity supplied of product *j*	$QS^E{}_j{}'$ $QS^U{}_j{}'$ $QS^R{}_j{}'$	*J1*=1.5, *J2*=2.0, *J3*=3.5, *J4*=0, *J5*=2.0 *J1*=0, *J2*=1.0, *J3*=9.0, *J4*=0, *J5*=0 *J1*=0, *J2*=0, *J3*=1.0, *J4*=8.0, *J5*=0
Initial equilibrium quantity demanded of product *j*	$QD^E{}_j{}'$ $QD^U{}_j{}'$ $QD^R{}_j{}'$	*J1*=1.4, *J2*=1.85, *J3*=3.55, *J4*=0.35, *J5*=1.60 *J1*=0.05, *J2*=1.10, *J3*=8.80, *J4*=0.05, *J5*=0.20 *J1*=0.05, *J2*=0.05, *J3*=1.15, *J4*=7.60, *J5*=0.20

[a] There are five processed tomato products in our model: product *J1* represents a canned tomato product exported from the EU with an export subsidy; product *J2* represents a standard canned tomato product; product *J3* represents a tomato paste product produced in all regions and exported from the United States; product *J4* represents a tomato paste product exported from the ROW; and product *J5* represents a tomato paste product exported from the EU.

Footnotes

[1] For example, the FAPRI, OECD, and the 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). 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 (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.