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ABSTRACT

This paper models linkages between upstream and downstream goods in the U.S. market for flat-rolled steel. These vertical linkages are important to account for when estimating the impact of trade restrictions on imports of flat rolled steel because some types of flat rolled steel are predominately used to produce other types of flat rolled steel and in some cases also make up a large share of their production costs. Previous research has modeled the linkages between upstream and downstream goods with CGE models and vertically linked partial equilibrium models. Drawing upon this literature, this paper builds a vertically linked version of the CES COMPAS model that incorporates vertical linkages as constant cross price elasticities in both downstream supply functions and upstream factor demand functions. Compared to estimates from the CES COMPAS without vertical linkages, introduction of a trade restriction increases demand for upstream goods and decreases supply of downstream goods, increasing prices of both upstream and downstream goods, while increasing shipments of upstream goods and decreasing shipments of downstream goods. In estimating the impact of the safeguard measures imposed on the flat rolled steel market, accounting for the vertical linkages is most important when estimating the impact on domestically produced slab since all downstream products produced from slab were subject to the safeguard tariffs.

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Introduction

This paper models linkages between upstream and downstream goods in the U.S. market for flat-rolled steel. These vertical linkages are important to account for when estimating the impact of trade restrictions on imports of flat rolled steel because some types of flat rolled steel are predominately used to produce other types of flat rolled steel and in some cases also make up a large share of their cost of production.[1] Therefore prices for all flat-rolled steel products can fluctuate as the result of trade restrictions applied to any flat-rolled steel product.

Linkages between upstream and downstream goods have been incorporated in CGE models such as GTAP and USITC (2003). However, since most CGE models use data aggregated to at least the 4-digit SIC code level, they are useful for modeling linkages between broad product groups, but not between not between specific products. The vertically linked partial equilibrium models used in Roningen (1997), Sanders, Moxey, and Roningen (2001), and Ferrantino and Hall (2001) have been created to model linkages between specific products.[2]

For the vertically linked version of the CES (Constant Elasticity of Substitution) COMPAS (Commercial Policy Analysis System) model build in this paper, similar linkages are incorporated in two ways: (1) constant cross price elasticities in downstream supply functions based on the cost share of each of the upstream goods multiplied by the negative of the domestic supply elasticity and (2) constant cross price elasticities in upstream factor demand functions based on the share of the upstream good that is used to produce each of the downstream goods multiplied by the negative of the aggregate demand elasticity.

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[1]In the steel section 201 investigation, five of the six USITC Commissioners found that slab, hot-rolled steel, plate, cold-rolled steel, and coated steel to be the article, "certain carbon flat-rolled steel" and the same like product. They also found tin mill products to be one like product. USITC (2001c), *Steel*, Volume 1, p. 36. Commissioner Devaney found a single like product consisting of slab, hot-rolled steel, plate, cold-rolled steel, coated steel, tin mill products, and grain-oriented electrical steel. USITC (2001c), Volume 1, footnote 65 on p. 36.

The use of the word "product" in reference to carbon and alloy flat rolled steel in this paper is based on the categories established by the Commission for the collection of data in the steel section 201 investigation (USITC (2001c)) and does not endorse or dispute any like product finding by the USITC, the President, or any USITC Commissioner.

[2]"Vertically linked" refers to markets for the different upstream and downstream goods.

This provides a transparent and parsimonious model that approaches the CES COMPAS model without vertical linkages as the cost share of upstream goods and usage share of downstream goods approach zero.

When estimating the impact of trade restrictions on a good while accounting for vertical linkages, demand for upstream goods increase and supply for downstream goods decrease, *ceteris paribus*. This causes prices of both upstream and downstream goods to increase, increasing shipments of upstream goods and decreasing shipments of downstream goods. In estimating the impact of the safeguard measures imposed on imports of flat rolled steel in 2002, accounting for the vertical linkages is most important when estimating the impact on domestically produced slab since all downstream products produced from slab were subject to the safeguard tariffs.

Literature Review

Although partial equilibrium models do not account for as many linkages between product groups as computable general equilibrium (CGE) models do, they can provide a transparent and focused analysis of how a limited number of products are affected by the imposition of trade restrictions. The advantage that CGE models have by accounting for the linkages between all goods in the economy is offset by the additional assumptions required. In some cases the number of additional assumptions required limit the transparency of the model. Also, the highly aggregated baseline data in CGE models can make it very difficult to estimate the impact a policy change has on specific products within the aggregation of the base data. CGE models are most appropriate for analysis where constructing a partial equilibrium model to estimate the direct effects of the policy change would be intractable, such as estimating the effects of broad changes in trade policy (such as preferential trade agreements) which directly affect many sectors of the economy or when estimating the effects of a very specifically defined policy change (such as single tariff reduction) on the entire economy. Partial equilibrium models are most appropriate for analysis of changes in very specific trade policies on the markets for specific products.[3]

Studies that have used partial equilibrium models to account for vertical linkages have used a variety of specifications. Typically, supply depends on the prices of upstream goods, and demand depends on either prices or quantities of downstream goods in these models. Recent examples of these models include, Sanders, Moxey, and Roningen's (2001) model of the dairy market; Ferrantino and Hall's (2001) examination of the effect of the entry of the UK in NAFTA; USITC's (2001a) and USITC's (2001b) model of processed food and bulk agricultural food markets using a vertically linked version of the CES COMPAS model (which is similar, but not the same as the model used in this paper); Babula et al.'s (2002) modeling of interactions between the pear industry in the E.U. and the canned pear industry in the U.S.; and Kaplan and Riker's (2001) modeling of the impact of potential steel safeguard measures.

While most vertically linked partial equilibrium models specify the supply linkage to upstream goods in a similar fashion, the method used to calculate this cross price elasticity varies. Roningen (1997), Sanders, Moxey, and Roningen (2001), Ferrantino and Hall (2001), USITC (2001a) and USITC (2001b) incorporate the supply linkages to upstream goods by assuming a constant cross price elasticity of supply, multiplying the supply functions in each region by the price of the corresponding region's upstream good raised to the power of the cross supply price elasticity. Kaplan and Riker's (2001) supply linkages have a similar functional form to the above papers, but model supply as a function of absolute differences between the price of the good and the price of each downstream product, not the relative differences in supply as in other papers.

When specified, the cross-price elasticities of supply in these models sometimes depend on the cost share of upstream goods, the own price supply elasticity, or both. Ferrantino and Hall (2001)

[3]Hertel (1992) finds that while in the case of a broad based shock the results from a partial equilibrium model were very different from general equilibrium models with similar underlying assumptions, the results in the case of a sector-specific shock were very similar for that particular sector.

explicitly assume that the cross price supply elasticities are equal to the cost share of each upstream good times the own price elasticity of supply. USITC (2001a) and USITC (2001b) assume the cross price elasticity of supply is equal to the cost share of each upstream good and independent of the own price elasticity of supply, restricting it always to be inelastic or unit elastic, while Kaplan and Riker (2001) assumes the cross price elasticity of supply to be equal to the own price supply elasticity and does not depend on the cost share of upstream goods.

Specification of the demand linkage to upstream goods vary by model. Sanders, Moxey, and Roningen (2001) link most of their demand functions to prices of downstream goods similar to how they link their supply functions to upstream goods. In most cases they specify factor demand linkages between markets using a constant cross-price elasticity of demand function by multiplying factor demand functions by the prices of each downstream good raised to the power of its cross price elasticity of demand. The exception is demand for nitrogen fertilizer and concentrate use which is specified as a function of the level of production. Roningen (1997) uses a similar approach, except that factor demand in this model uses constant cross-*quantity* (instead of price) elasticity of demand by multiplying each region's upstream demand function by the quantity of the region's downstream good to the power of the cross quantity elasticity of demand. He assumes that the cross quantity elasticity of demand is equal to the share of the upstream good used to produce the downstream good (usage share).

Similar to the approach taken in many CGE models, the upstream linkages in Babula et al. (2001) and Kaplan and Riker (2001) are specified by deriving input demand from a CES production function. The resulting functional form is similar to the demand functions used in the above papers, except that prices of substitute goods and downstream goods are represented by an Armington price index instead of a constant cross-price elasticity of factor demand. While there are fewer parameters for their models, the assumptions behind the upstream linkages are also more restrictive and less intuitive than the approach taken in the other papers.

In USITC (2001a) and USITC (2001b), demand is linked to the downstream good by multiplying the demand function by the product of the usage share and the percentage increase in the expenditure on the downstream good. When all shipments of a good are used to produce the downstream good in question, this specification reduces down to a functional form similar to the demand function in Babula et al. (2001) and Kaplan and Riker (2001). Ferrantino and Hall (2001), ignores any effect that prices of downstream goods have on demand.

The vertically linked version of the CES COMPAS model used here to model the flat rolled steel market uses the constant cross price elasticity specifications of demand and supply used in Sanders, Moxey, and Roningen (2001). This form of supply function is used in most of the models surveyed above while this form of demand function is consistent with the supply function. As in Ferrantino and Hall (2001), cross price elasticities of supply are assumed to equal the product of the cost share and price elasticity of supply, taking both these important pieces of information into account. Similar to Roningen (1997), USITC (2001a) and USITC (2001b), demand linkages depend on the usage share of upstream good used to produce the downstream good. These modifications to the model provide a transparent and parsimonious model that approaches the CES COMPAS model without vertical linkages as the cost share of upstream goods and usage share of downstream goods approach zero.

CES COMPAS model

The CES COMPAS model (Francois and Hall (1997)) assumes that the market segments for the domestically produced and imported products are each perfectly competitive (operate according to supply and demand), but that the products from each country (or a group of countries) are differentiated as reflected in the elasticity of substitution. Imposition of a tariff, quota or tariff rate quota causes the supply curves for subject imports to shift to left and/or become vertical in certain regions, increasing the price of the imports from countries subject to the safeguards and decreasing its quantity. Figure 3 shows this for the imposition of a tariff. The magnitudes of these changes depend on the aggregate demand elasticity and the elasticity of substitution.

As seen in figure 4, the increased price in subject imports affects demand for the domestic product and nonsubject imports in two ways: (1) as an increase in the price of a substitute good it pushes both the price and quantity of the domestic product and nonsubject imports up by shifting their demand curves to the right (substitute good effect); (2) as an increase in the price of the composite product in the domestic market from all sources, it causes the price and quantity of the domestic product and of nonsubject imports to fall by shifting their demand curves to the left (aggregate demand effect).

The magnitudes of the changes of price and quantity of the domestically produced product and nonsubject imports resulting from the substitute good effect depend on the elasticity of substitution, market share and the supply elasticity; the changes resulting from the aggregate demand effect depend on the aggregate demand elasticity, market share and the supply elasticity. However, as long as the elasticity of substitution exceeds the aggregate demand elasticity in magnitude the substitute good effect will dominate the aggregate demand effect (Henning conundrum constraint) and the price and quantity of the domestic product and nonsubject imports will rise. This increase in price of the domestic and nonsubject products will also shift demand for the product from subject countries to the right, exacerbating the initial increase in price and dampening the initial decrease in quantity.

The imposition of a binding quota has a similar effect, with the quantity of subject imports fixed at the quota level and price rising according to the strength of demand. The domestic and non subject markets are affected as in the case of a tariff, and any second order feedback effects on the subject import will only affect the price level.

In the case of a tariff rate quota, the effect depends on demand, if demand is small enough or large enough such that the quota amount is less than or greater than actual subject imports, the effect is the same as a tariff on that range of subject imports. If demand is such that the quota exactly binds, the effect is the same as a quota.

Extensions to the CES COMPAS model

Capacity constraints can limit the response of the domestic industry and nonsubject countries to imposition of any of these trade restrictions. These can be modeled as a "quota" on the domestic industry. Although this approach does not account for the lowering of the price elasticity of supply that most likely occurs as the capacity constraint is approached, it does prevent the output for the domestic industry to exceed what it actually can produce, allowing the price to rise in response to the resulting excess quantity of the good that is demanded.

Also, as the price and quantity adjust for subject imports, domestic shipments, and non-subject imports, other factors affecting supply and demand may be changing. For example, if aggregate demand is falling over time (g), the demand curves of all products will shift to left lowering their price and quantity. If this is the case, price and quantity may actually decrease for domestic shipments (on non-subject imports) when the duty is imposed, despite the direct effects of its imposition. Likewise, a decrease in supply in individual countries (g_i) (technological innovations for example) will shift the supply curve for those countries to the left. The curves will shift right if the appropriate growth rate is positive.

If the fall in aggregate demand growth is large enough, prices and quantities for goods in all countries will fall, despite the imposition of the duty. In figures 3 and 4 we see that the effect of the growth in aggregate demand (g) is large enough to dominate the effects on price and quantity by the imposition of the duty so that the domestic price and quantity both fall to (P_{US}^3 , Q_{US}^3) and the subject country's price and quantity both fall to (P_{sub}^3, Q_{sub}^3). The price and quantity for the good from non-subject countries will also increase similar to figure 4.

In a similar fashion, increases in prices of upstream goods increase demand while increases in prices of downstream goods increase supply with the amount of the increase depending on the magnitude of change in the price and the magnitude of the corresponding cross price elasticity. The vertically linked version of the CES COMPAS model used here provides a way to explicitly model the effects of these price changes as exogenous shocks to the markets of interest or to model their effect endogenously if data is available to construct a COMPAS model for these goods.

Theoretical underpinnings of the CES COMPAS model[4]

The CES COMPAS model assumes that the market being considered has a set of competitive sub-markets for each of a group of imperfect substitutes, usually differentiated by country of origin. Following Armington (1969), it assumes that buyers have well behaved, weakly separable preferences over products within an industry with similar, but not identical products (based usually on country of origin) and market preferences over the different groups are of the constant elasticity of substitution (CES) form. Because preferences are weakly separable, demand for goods from each of the n different countries (or group of countries) is a function of industry prices and total industry expenditure alone as follows:

(1) $$q_i = \beta_i^{\sigma} \left(\frac{P_i}{P} \right)^{1-\sigma} \frac{Y}{P_i}$$

for i=1,2,...,n where q_i is the market demand for products in the ith country, β_i is a constant, P_i is the consumer price, Y is total spending on products in the industry. A price index may be defined as follows:

(2) $$P = \left(\sum_{j=1}^{n} \beta_j^{\sigma} P_j^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

and industry expenditure depends upon the general price level in the industry (as represented by the price index) and an aggregate price elasticity of demand (η) as below:

[4] Most of this section (with the exception of references to exogenous aggregate demand and supply shocks) is based on pp. 139-142 of Francois and Hall (1997).

(3) $$Y = kP^{\eta+1} + g$$

where k is a constant and g is the exogenous percentage growth in market demand.

Supply of each product in the industry is represented in Constant Supply Elasticity form:

(4) $$q_i = k_i \hat{P}_i^{\varepsilon_i} + g_i$$

for i=1,2,...,n countries where k_i is a constant, $\hat{P}_i$ is the supply (pre-tariff) price, ε_i is the price elasticity of supply to the domestic market, and g_i is the exogenous percentage growth in supply

The effects of an in-place duty may be estimated as follows:

(4') $$q_i = k_i \left(\frac{P_i}{1+t_i} \right)^{\varepsilon_i} + g_i \quad \text{for } i=1,2,...,n.$$

Calibrating the model (converting quantities to units that leaves all initial prices equal to one and exogenous growth rates to zero) leads to constant values as follows: $\beta_i^{\sigma}=q_i/k\equiv s_i$ from equation (1); k=Y from equation (3); and $k_i=s_i$ from equation (4). Combining (1) and (4'), substituting (3) into (1), and rearranging, we have the following equilibrium condition:

(5) $$\left(\frac{P_i}{1+t_i} \right)^{\varepsilon_i} + g_i = \left(\frac{P_i}{P} \right)^{1-\sigma} \frac{\left(P^{\eta+1} + g\right)}{P_i}$$

Application of a quota or TRQ (*multflat.wb3*)

The supply curves for countries subject to a quota become vertical at their quota allocation QTA_i[5]:

[5]QTA_i is the effective quota allocation in cases where the quota binds at shipment levels that are less than the statutory quota allocation.

$$
(6) \quad \begin{cases} q_i = k_i\left(\dfrac{P_i}{1+t_i}\right)^{\varepsilon_i} & \text{if} \quad P_i < \left(1+t_i\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \\ q_i = QTA_i & \text{if} \quad P_i \geq \left(1+t_i\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \end{cases}
$$

for i=1,2,...,n.

When the quota is binding, the quantity of subject imports is fixed at the quota level while the price rises depending on the strength of demand. The domestic and non subject markets are affected as in the case of a tariff, and any second order feedback effects on the subject imports will only affect the price level and not the quantity.

When a tariff rate quota[6] (TRQ) is applied, the supply curve is similar to the case of a quota with the addition of allowing importers to supply quantities above their quota allocation subject to an over quota tariff t_{2i} for country i.

Assuming the tariff on imports below the effective quota allocation is t_{1i}, the supply curve for countries facing tariff rate quotas is:

$$
(7) \quad \begin{cases} q_i = k_i\left(\dfrac{P_i}{1+t_{1i}}\right)^{\varepsilon_i} & \text{if} \quad P_i < \left(1+t_{1i}\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \\ q_i = QTA_i & \text{if} \quad \left(1+t_{1i}\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \leq P_i \leq \left(1+t_{2i}\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \\ q_i = k_i\left(\dfrac{P_i}{1+t_{2i}}\right)^{\varepsilon_i} & \text{if} \quad P_i > \left(1+t_{2i}\right)\left(\dfrac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \end{cases}
$$

for i=1,...n.

In the case of a tariff rate quota, if demand is small enough or large enough so that the quota allocation is not binding, the effect is the same as applying the corresponding tariff. If demand is such

[6]A two-tier TRQ is discussed here. However, the analysis can easily be extended to a multi-tier TRQ.

that the quota allocation exactly binds, the effect is same as a binding quota.

Combining (1) and (7), substituting (3) into (1), and rearranging, we have the following equilibrium condition:

$$
(8) \qquad
\begin{aligned}
&\left(\frac{P_i}{1+t_{1i}}\right)^{\varepsilon_i} = \left(\frac{P_i}{P}\right)^{1-\sigma}\frac{P^{\eta+1}}{P_i} && \text{if} \quad P_i < (1+t_{1i})\left(\frac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \\
&QTA_i = \left(\frac{P_i}{P}\right)^{1-\sigma}\frac{P^{\eta+1}}{P_i} && \text{if} \quad (1+t_{1i})\left(\frac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \le P_i \le (1+t_{2i})\left(\frac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}} \\
&\left(\frac{P_i}{1+t_{2i}}\right)^{\varepsilon_i} = \left(\frac{P_i}{P}\right)^{1-\sigma}\frac{P^{\eta+1}}{P_i} && \text{if} \quad P_i > (1+t_{2i})\left(\frac{QTA_i}{k_i}\right)^{\frac{1}{\varepsilon_i}}
\end{aligned}
$$

for i=1,...n.[7]

Integrating Vertical Linkages into the CES COMPAS model

Using the basis framework of the CES COMPAS model, the vertically linked version of the CES COMPAS model accounts for changes in the prices of upstream and downstream goods. The effects of changes in prices of downstream goods are accounted for through the aggregate demand function. An increase in the price of a downstream good increases aggregate demand for all of its inputs depending on the change in the general price level (as represented by its price index) of each downstream good (P_i^D) and their respective cross price aggregate demand elasticities (η_j) as below:

$$
(3') \qquad Y = kP^{\eta+1}\prod_{j=1}^{m} P_j^{D\eta_j} + g
$$

where k is a constant and j=1,..., m downstream goods.

The effects of changes in prices of upstream goods are accounted for through the supply function. An increase in the price of an upstream good increases costs for downstream goods it is used to produce depending on the change in the general price level in the industry (as represented by its price index) for

[7]In the case of a quota, (8) reduces to the first two equation with t_{2i} approaching positive infinity.

each upstream good (r_k) and their respective cross price supply elasticity (ε_{ik})as below:

(4'')
$$q_i = k_i \left(\frac{P_i}{1+t_i} \right)^{\varepsilon_i} \prod_{k=1}^{m'} r_k^{\varepsilon_{ik}} + g_i$$

for i=1,2,...,n countries and j=1, 2,...,m' upstream goods.

Calibrating as above and then combining (1) and (4''), substituting (3') into (1), and rearranging, we have the following equilibrium condition:

(5')
$$\left(\frac{P_i}{1+t_i} \right)^{\varepsilon_i} \prod_{k=1}^{m'} r_k^{\varepsilon_{ik}} + g_i = \left(\frac{P_i}{P} \right)^{1-\sigma} \frac{P^{\eta+1} \prod_{j=1}^{m} P_j^{D\eta_j} + g}{P_i}$$

Application of a tariff increases factor demand and decreases supply of downstream goods when these vertical linkages incorporated, increasing prices of both factors and downstream goods, while increasing shipments of factors of production and decreasing production of downstream goods.

Application of the President's safeguard measures to the U.S. flat rolled steel market

The vertically linked version of the CES COMPAS model was used to simultaneously model both the direct effect of safeguard tariffs and tariff rate quota imposed by the President on flat rolled steel on March 20, 2002.[8] The vertical linkages between these forms of flat-rolled steel are important to take into account because a large share of some forms of flat rolled steel are used to produce other flat-rolled products, and also make up a large share of their costs.

Figure 1 shows that about 90 percent of slab produced in the United States is used to produce hot-rolled steel (including coils), while the remaining 10 percent is used to produce cut-to-length plate.[9] Also, about 55 percent of hot-rolled steel produced in the United States is used to produce cold-rolled steel.

[8]The President placed 30 percent tariffs on cut-to-length plate, hot-rolled steel, cold-rolled steel, coated steel, and tin mill products and a 30 percent tariff on all imports of slab over 5.4 million short tons per year.

[9]The shares in figure 1are based on estimates provided by Karen Taylor, a steel industry analyst at the USITC, November 2001.

About 55 percent of cold-rolled steel is used to produce coated (galvanized) steel and about 10 percent of cold-rolled steel is used to produce tin mill products. Figure 2 shows that the upstream products also make up a sizable share of their costs of the downstream goods. Assuming that at least 90 percent of reported material costs are for the upstream steel product, the cost share of upstream steel products range from 33 percent to 49 percent.[10]

If the cost shares are the same for imported steel as they are for domestically produced forms of flat-rolled steel and they are unaffected by changes in prices or quantities for the goods in question, the domestic supply cross price elasticity between the downstream product and its corresponding upstream products should be the negative of the product of the domestic supply elasticity of the downstream good and the cost share $\left(csh_k\right)$ of the upstream good, k=1,..., m.

(6) $$\varepsilon_{1k} = -\varepsilon_1 * csh_k$$

Similarly, if this is also true for the share of upstream goods used to produce downstream goods, the aggregate demand cross price elasticity between the upstream product and each of its corresponding downstream products should be equal to the negative of the product of the aggregate demand elasticity of the downstream product and the usage share $\left(ush_j\right)$ of each upstream product, j=1,...m.

(7) $$\eta_j = -\eta \; * ush_j$$

As can be seen clearly in table 1, for the case of the U.S. market for forms of flat rolled steel, changes in price of upstream products will have more of an impact on downstream goods than vice versa

[10]Upstream steel costs are assumed to be 90 percent of the material cost for coated steel and tin mill products and 100 percent of the cost of other products. Estimates provided by Karen Taylor, a steel industry analyst at the USITC, November 2001. The share that raw materials make of cost of goods sold is based on data from USITC (2001c) Steel Volume II, pages Flat-25 to Flat-29.

since the supply elasticities are much larger in magnitude than the aggregate demand elasticities.[11]

Table 3 shows the estimated impact of the safeguard measures on all of the forms of flat rolled steel when they are modeled separately. As expected, prices for both the domestic shipments and imports subject to the safeguard measures increase while domestic shipments increase and imports subject to the remedy fall for all forms of flat rolled steel subject to tariffs. However, the estimated impact of the tariff rate quota on slab is no change in price or shipments from any source since the baseline level of imports subject to the remedy is less than quantity at which the 30 percent tariff is applied.

Table 4 shows the estimated impact of the safeguard measures on all of the forms of flat rolled steel when vertical linkages are accounted for. Comparing the tables 3 and 4, shows that when accounting for the vertical linkages the estimated impact of safeguard measures on domestic price and quantity increased or remained the same for all forms of flat-rolled steel. Accounting for the vertical linkages was most important when estimating impact on domestically produced slab since all forms of flat rolled steel produced from slab were subject to the tariffs resulting in the highest impact on their supply.

Conclusion

The vertically linked version of the CES COMPAS model accounts for vertical linkages between upstream and downstream products by treating the prices of upstream products as costs in the supply functions of downstream products and treating the prices of downstream products as demand shifters in aggregate demand function of upstream goods. As a result of introducing a trade restriction, factor demand will increase and downstream supply will decrease for forms of flat rolled steel subject to the safeguard measures.

In estimating the impact of the safeguard measures imposed on the flat rolled steel market in 2002, accounting for these linkages increases the estimated impact on domestic prices and slightly

[11]The substitution, aggregate demand and price elasticities of supply used in the model are the same used by the Office of Economics during the remedy phase of investigation TA-201-73 (Steel). An explanation of these estimates can be found on pages Flat-9 to Flat-11 of Office of Economics memorandum, EC-Y-046, November 21, 2001, public version.

increases the estimated impact on domestic quantity resulting from a tariff on all flat-rolled steel products. Accounting for the vertical linkages is most important when estimating the impact on domestically produced slab since all downstream products produced from slab were subject to the safeguard tariffs.

This approach can also be applied to other markets where the basic assumptions of the CES COMPAS model, the share of upstream goods and the cost share of downstream goods are all known. The approach could also be extended to include other non-CES models which specify supply and demand functions.

Table 1- Elasticity Assumptions

	Slab	Plate	Hot Rolled	Cold Rolled	Coated	Tin
Substitution	4 to 7	3 to 6	3 to 6	2.5 to 5	2 to 4	2 to 4
Aggregate demand	-0.2 to-0.6	-0.2 to-0.6	-0.25 to -0.75	-0.25 to -0.75	-0.25 to -0.75	-0.2 to -0.6
Domestic supply	2 to 4	4 to 7	3 to 5	2 to 4	3 to 5	4 to 6
Canadian imports supply	2 to 4	4 to 7	3 to 5	3 to 5	3 to 5	3 to 5
Mexican imports supply	2 to 4	4 to 7	4 to 6	3 to 5	4 to 6	5 to 7
All other imports supply	10 to 20	10 to 20	10 to 20	10 to 20	10 to 20	10 to 20
Cross demand of slab		0.02 to 0.06	0.18 to 0.54			
Cross demand of plate						
Cross demand of hot-rolled				0.14 to 0.41		
Cross demand of cold-rolled					0.14 to 0.41	0.03 to 0.08
Cross demand of coated						
Cross demand of tin						
Cross supply of slab						
Cross supply of plate	-1.96 to -3.43					
Cross supply of hot-rolled	-1.41 to -2.35					
Cross supply of cold-rolled			-0.74 to -1.48			
Cross supply of coated				-0.99 to -1.65		
Cross supply of tin				-1.44 to -2.16		

Table 2- Model Inputs

Value (thousands of $)	**Slab**	**Plate**	**Hot Rolled**	**Cold Rolled**	**Coated**	**Tin**
Domestic shipments	14,739,327	2,468,934	20,106,986	15,540,552	10,595,444	1,865,809
Covered country imports	1,124,974	274,364	1,345,908	1,006,883	780,464	281,899
Canadian imports	53,991	66,527	163,838	103,233	324,057	58,932
Mexican imports	381,793	80	110,621	74,674	170,047	34
Other exempt country imports	46,672	37,451	643,149	102,257	98,197	725
Quantity (short tons)						
Domestic shipments	67,180,508	6,156,068	67,632,964	37,217,653	19,881,429	3,163,331
Covered country imports	5,196,179	652,808	4,372,309	2,071,795	1,373,102	487,204
Canadian imports	221,355	167,712	459,954	219,104	583,794	91,570
Mexican imports	1,635,969	211	335,401	206,291	288,642	39
Other exempt country imports	206,310	130,036	2,291,980	266,584	213,791	1,383
Tariff and transportation						
Covered country imports	9.3%	11.5%	12.2%	10.8%	10.0%	11.9%
Canadian imports	5.3%	2.9%	2.6%	3.1%	2.9%	3.4%
Mexican imports	7.2%	6.8%	7.2%	6.6%	5.7%	1.7%
Other exempt country imports	9.3%	11.5%	12.2%	10.8%	10.0%	11.9%

Sources: Domestic shipments and values: USITC (2001c) Steel Volume II, pages Flat-16 to Flat-22; Import shipments and values: USITC (2001d) Steel Volume II, pages Flat-8 to Flat-14; Tariff and Transportation: Percent difference between landed duty paid and customs value for 2000 on USITC Dataweb.

Table 3-Impact of Safeguard Measures-CES COMPAS model

U.S. market effects (in percent unless otherwise noted)	Slab	Plate	Hot Rolled	Cold Rolled	Coated	Tin
Domestic:						
Price	-0.0 to -0.0	0.5 to 1.4	0.5 to 1.2	1.1 to 2.2	0.9 to 1.8	1.2 to 2.5
Quantity	0.0 to 0.0	3.1 to 6.8	2.4 to 4.3	1.7 to 3.8	0.6 to 3.2	2.2 to 6.9
Covered country imports:						
Price	-0.0 to -0.0	16.9 to 23.4	16.7 to 23.1	18.3 to 24.0	19.4 to 24.7	19.6 to 24.5
Quantity	-0.0 to 0.0	-63.8 to -39.2	-64.1 to -39.8	-58.3 to -34.8	-52.6 to -30.6	-49.9 to -28.5

Note: The safeguard measures instituted by the President on March 20, 2002 included a 30 percent tariff on cut-to-length plate, hot-rolled steel, cold-rolled steel, coated steel, and tin mill products and a 30 percent tariff on all imports of slab over 5.4 million short tons per year.

Table 4-Impact of Safeguard Measures-vertically linked version of CES COMPAS model

U.S. market effects (in percent unless otherwise noted)	**Slab**	**Plate**	**Hot Rolled**	**Cold Rolled**	**Coated**	**Tin**
Domestic:						
Price	0.1 to 0.4	0.6 to 1.5	0.6 to 1.3	1.1 to 2.2	0.9 to 1.8	1.2 to 2.5
Quantity	0.3 to 0.9	3.0 to 6.8	2.3 to 4.2	1.7 to 3.8	0.6 to 3.2	2.2 to 6.9
Covered country imports:						
Price	0.0 to 0.2	17.0 to 23.4	16.8 to 23.1	18.3 to 24.0	19.4 to 24.7	19.5 to 24.5
Quantity	0.5 to 2.2	-63.7 to -39.1	-64.0 to -39.7	-58.3 to -34.8	-52.6 to -30.6	-49.9 to -28.5

Note: The safeguard measures instituted by the President on March 20, 2002 included a 30 percent tariff on cut-to-length plate, hot-rolled steel, cold-rolled steel, coated steel, and tin mill products and a 30 percent tariff on all imports of slab over 5.4 million short tons per year.

Figure 1- Share of Upstream Products Used in Downstream Products

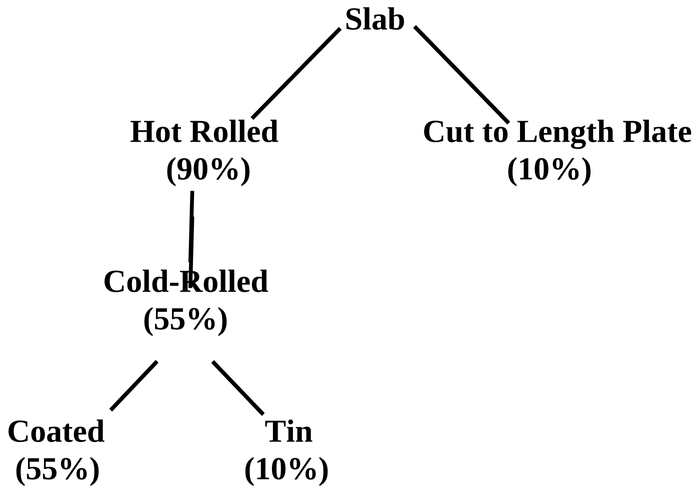
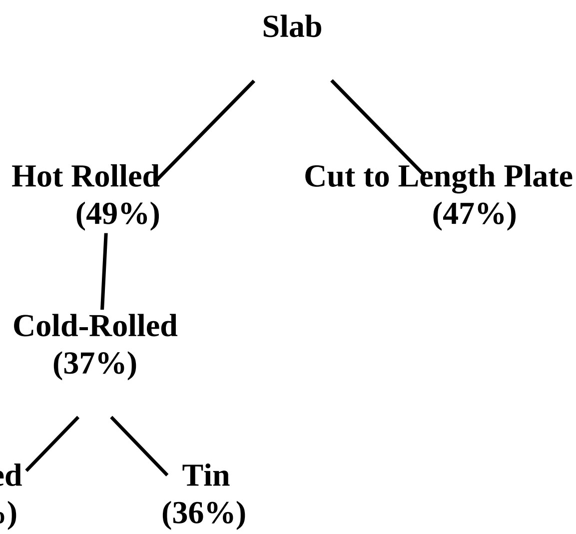


Figure 2- Cost Share of Upstream Products in Downstream Products



Source: USITC staff estimates and cost of goods sold data USITC (2001c) Steel Volume II, pages Flat-25 to Flat-29

Figure 3-Effects on subject import shipments and prices of placing a duty on subject imports

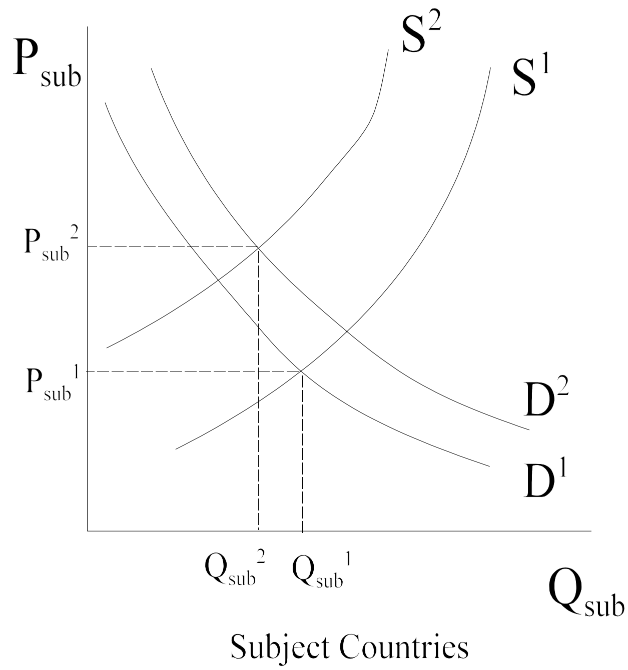


Figure 4-Effect on domestic and nonsubject shipments and prices of placing a duty on subject imports

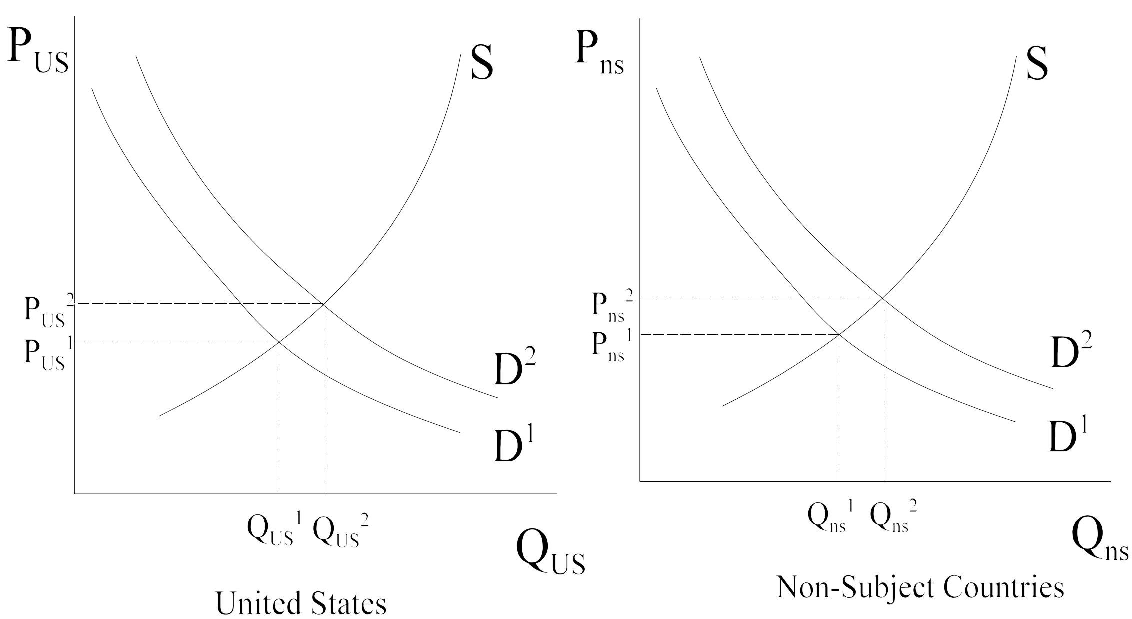


Figure 5-Effect on subject import shipments and prices accompanied by a decrease in aggregate demand of placing a duty on subject imports

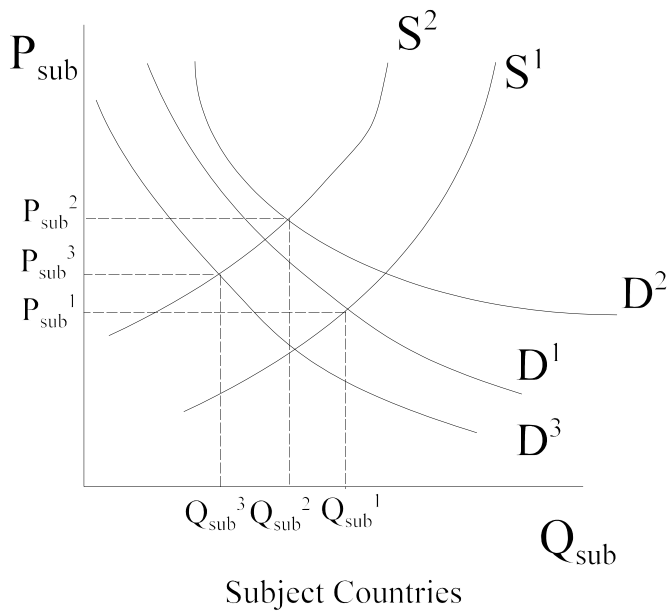
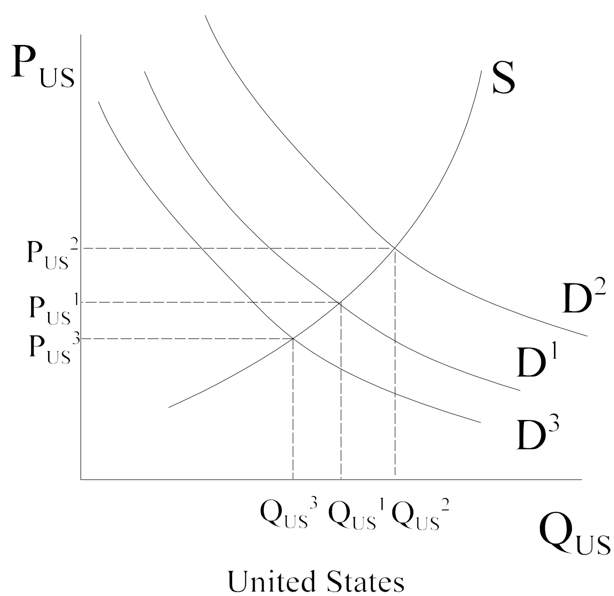


Figure 6-Effect on domestic shipments and prices accompanied by an exogenous decrease in aggregate demand of placing a duty on subject imports



Bibliography

Babula, Ronald, A.., Fry, John, Hall, H. Keith, and Jabara, Cathy L. "A Comparative Static Analysis of European Union Tariff and Support Policies for Canned Pears," Journal of International Food & Agribusiness Marketing, 13(2/3), 2003.

Ferrantino, Michael J. and Hall, H. Keith, "The Direct Effects of Trade Liberalization on Foreign Direct Investment: A Partial Equilibrium Analysis," Office of Economics Working Paper, USITC, October 2001.

Joseph F. Francois and Laura M. Baughman, "Estimated Economic Effects of Proposed Import Relief Remedies for Steel." Paper sponsored by the CITAC Foundation, Dec. 19, 2001.

Francois, Joseph F. and Hall, H. Keith., "Partial Equilibrium Modeling," In Applied Methods for Trade Policy Analysis, edited by Francois, Joseph F. and Reinert, Kenneth P. Cambridge University Press, Cambridge, 1997.

Gohin, Alexandre and Hertel, Thomas W., "A Note on the CES Functional Form and Its Use in the GTAP Model," undated.

Henderson, James M. and Quandt, Richard E.., Microeconomic Theory: A Mathematical Approach, McGraw-Hill Book Company, New York, 1958.

Hertel, Thomas W., "Partial vs. General Equilibrium Analysis of Trade Policy Reform," The Journal of Agricultural Economics Research, 44(3), 1992, pp. 3-15.

Office of Economics memorandum, EC-Y-046, Investigation No. TA-201-73: STEEL-Remedy Memorandum, November 21, 2001.

Kaplan, Seth T. and Riker, David A., "Flat-Rolled Steel Remedy Analysis," Charles Rivers Associates, Inc. Exhibit A, In Prehearing Brief of Bethlehem Steel Corporation, LTV Steel Corporation, Inc. National Steel Corporation, and United States Steel LLC with Respect to Carbon and Alloy Flat Steel Products, submitted by Dewey Ballantine LLC and Skadden, Arps, Slate, Meagher & Flom LLP, October 29, 2001.

Roningen, Vernon O., "Multi-Market, Multi-Region Partial Equilibrium Modeling," In Applied Methods for Trade Policy Analysis, edited by Francois, Joseph F. and Reinert, Kenneth P. Cambridge University Press, Cambridge, 1997.

Saudners, Caroline, Moxey, Andrew, and Roningen, Vernon O., "Trade and the Environment. Linking a partial equilibrium trade model with production systems and their environmental consequences," Paper presented to the Symposium on Trade in Livestock Products ITRAC, Aukland, January 2001.

U.S. International Trade Commission. September 2001. U.S.-Korea FTA: The Economic Impact of Establishing a Free Trade Agreement (FTA) Between the United States and the Republic of Korea. USITC Publication 3452, Washington DC.

U.S. International Trade Commission. October 2001. PROCESSED FOODS AND BEVERAGES: A Description of Tariff and Non-tariff Barriers for Major Products and Their Impact on Trade. USITC Publication 3455, Washington DC.

U.S. International Trade Commission. December 2001. Steel, Investigation No. TA-201-73. Volume I: DETERMINATIONS AND VIEWS OF THE COMMISSIONERS. USITC Publication 3479, Washington DC.

U.S. International Trade Commission. December 2001. Steel, Investigation No. TA-201-73. Volume II: INFORMATION OBTAINED IN THE INVESTIGATION (CARBON AND ALLOY STEEL FLAT, LONG, AND TUBULAR PRODUCTS). USITC Publication 3479, Washington DC.

U.S. International Trade Commission. September 2003. Steel-Consuming Industries: Competitive Conditions with Respect to Steel Safeguard Measures. Volume III: Executive Summaries and Investigation No. 332-452 (Report and Appendices). USITC Publication 3632, Washington DC.