Tariff Escalation and Invasive Species Risk

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Working Paper 05-WP 407
October 2005

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The authors thank Harvey Lapan, Denis Mcgee, Giancarlo Moschini, and participants at the 2005 Australian Agricultural and Resource Economic Society and American Agricultural Economics Association meetings for comments and discussions.

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Abstract

We investigate the interface between trade and invasive species (IS) risk, focusing on the existing tariff escalation in agro-forestry product markets and its implication for IS risk. Tariff escalation in processed agro-forestry products exacerbates the risk of IS by biasing trade flows toward increased trade of primary commodity flows and against processed-product trade. We show that reducing tariff escalation by lowering the tariff on processed goods increases allocative efficiency and reduces the IS externality, a win-win situation. We also identify policy menus for trade reforms involving tariffs on both raw input and processed goods, leading to win-win situations.

Keywords: agro-forestry products, exotic pest, international trade, invasive species, tariff escalation, trade flows.

TARIFF ESCALATION AND INVASIVE SPECIES RISK

1. Introduction

International trade can be an important driver of environmental change, although often indirectly through specialization and expansion or contraction of dirty activities (Beghin, Roland-Holst, and van der Mensbrugghe). In a few cases, trade is the direct vector of the environmental issue, as emphasized in recent literature. The literature has been focusing on accidental introductions of exotic or invasive species (IS) like pests, weeds, and viruses, by way of international transport of commodities, which is an important aspect of this complex nexus (Perrings, Williamson, and Dalmazzone; Mumford). The trade and environment interface is inherent in the economics of IS since trade is a major vector of propagation of these species. The current economic literature is mostly focused on the "right" criteria to use or the optimal environmental policy response to the hazard of IS (e.g., Binder; Sumner). A related debate revolves around quarantine as a legitimate policy response to phytosanitary risk (Anderson, McRae, and Wilson; Cook and Fraser; and Kim and Lewandrowski).

Agricultural and forestry imports have always been an important conduit for biological invasions. The agricultural tariff structure, with its strong influence on trade flows, is a determinant of IS. Identifying the linkages between tariff structure, trade, and IS is an important issue for understanding the risk of IS introduction. The trade and IS literature is still limited. Using a Heckscher-Ohlin-Samuelson (HOS) approach, Costello and McAusland show that lowering agricultural tariffs could potentially lower the damage from exotic species, even though the volume of trade rises. An increase in imports results in a reduced domestic agricultural output. Thus, the output available for IS damage is reduced and so is the amount of contaminated land, which mitigates the propagation of IS. Subsequently, McAusland and Costello compare tariff (duties) and non-tariff regulations (quarantine measures, port inspections) aimed at monitoring IS risks linked to commodity imports. Tariffs are found to be optimal (i.e., the optimal trade tax is positive and increasing with the risk of invasion), while inspections are not. Paarlberg and Lee have also investigated the role of trade policy as a tool for monitoring risks, linking infection risk from imports to a tariff, so that the exporter of an infected product faces a higher tariff than would otherwise be the case. Margolis, Shogren, and Fischer investigate IS hazards and trade barriers by introducing an IS externality in a political-economy model of tariff formation. The tariff set by a government caring both for general welfare and for lobbyists' donations is above the socially optimal level, internalizing the risk from IS. However, unless the damage function from IS is common knowledge, it is impossible to distinguish the protectionist component of the tariff.

Our paper departs from this limited literature and fills an important knowledge gap in policy analysis related to trade and IS. We investigate the trade-IS interface, focusing on the existing tariff escalation in agricultural and food-processing markets and its impact on IS hazard and associated externalities. The paper addresses an overlooked but important aspect of the trade-IS debate. Tariff escalation occurs when tariffs increase with stages of transformation/processing of products into value-added products (e.g., from primary agricultural commodities to food-processing goods). Tariff escalation is a well-established and lasting fact in processing sectors using agro-forestry raw inputs (see Aksoy; Gallezot; Lindland; and Rae and Josling for recent evidence). Tariff escalation in processed agro-forestry products increases the risk of IS by biasing trade flows toward primary commodity flows and against processed-product trade. Even though precise data on differential risk from agricultural to processed-good imports are limited, the risk of pest introduction appears much higher for non-processed commodities than for highly transformed products. Many nature-based, processed final goods are virtually IS free, whereas their raw input is a significant IS vector. For example, rice-processing practices such as polishing have a lethal effect on insects like rice weevils (Lucas and Riudavets). This suggests that the potential high risk of weevil invasions related to rice imports could be negligible for milled rice as compared with paddy rice imports. Similarly, invasive foreign insects in raw wood products such as the Asian longhorned beetle can be eliminated in final goods since finish milling and kiln drying will kill most wood organisms when done properly.

We explore the conjecture that many OECD countries could reduce or rebalance their trade of primary products (agricultural commodities, wood) by reducing tariffs on processed food and value-added wood products. The composition of their imports would change and the share of processed goods in imports would rise. Two welfare gains ensue. The first one is an allocative gain in markets. The second one refers to the reduction of IS hazard and associated externalities. We formalize this conjecture and establish conditions under which it arises. We translate these conditions into practical policy recommendations. Our specific objectives are to identify policy setting and reforms under which win-win situations arise (reduced trade distortions, reduced hazard and externalities).

In the following sections we discuss the evidence on tariff escalation, on IS, and on associated costs. Then we analytically formalize the conditions under which win-win outcomes arise. Finally, we provide conclusions and policy implications.

2. Evidence on Tariff Escalation and IS

2.1. Tariff escalation

The economics literature has long established the existence of tariff escalation in the protection structure of commodity and processed-product markets. Protection escalates with the level of processing, in almost all countries and across many products. This escalation hinders the exporter's diversification into value-added and processed products.

There is a well-established, older research track on tariff escalation from the late 1970s with the work of Yeats, Finger, and associates (Golub and Finger; Laird and Yeats; and Yeats). Tariff escalation is still an enduring feature of agricultural and food-processing trade according to more recent literature (Aksoy; Gibson et al.; Lindland; and Rae and Josling). It continues to be so despite the emergence of preferential agreements in the EU and the US (Gallezot). Rae and Josling find that export of processed food from developing economies has been impeded by tariff escalation in the industrialized countries but also within the developing countries themselves. These finding are based on an older dataset (GTAP 4). Aksoy and Gibson et al. find similar patterns with much more recent data.

Telling examples of tariff escalation abound for a wide range of products. Current EU tariffs on milled rice imports into the EU are 80% compared to only 46% for brown rice (Wailes). Within the EU raw cocoa has a tariff of 0%. At its first processing stage (cocoa butter) it is charged 9%, and at its second stage (cocoa paste) it attracts 21%. The figures for coffee are 4% for the raw product and 11% for its second processing stage, and for soybeans the figures are 0% and 6% respectively (Aksoy). Japan and the US apply comparable tariff structures. Studies show that the proportion of processed products to the least developed countries' (LDCs') total agricultural produce exports dropped from 27% to 16.9% from 1964 to 1994 while that of the developing countries as a whole during the same period increased from 41.7% to 54.1%. This, however, covers mostly only first-stage processing. If a further processing stage is taken into account, the proportions are much lower, at 8.4% and 16.6% respectively (Aksoy; Windfuhr).

Wood products show similar patterns, with logs traded at zero or a very low tariff while processed wood products faced much higher tariffs.

2.2. IS and associated externalities

The introduction of harmful exotic species into non-native environments has received heightened recognition because of the threats this biological pollution poses to agriculture, ecosystem health, endangered species, economic interests, and even public health. In the US alone, scientists estimate that about 7,000 IS of plants, mammals, birds, amphibians, reptiles, fish, arthropods, and mollusks are established and cost the economy between US$120 and $138 billion a year (Pimentel et al*.,* 2000 and 2005). The US Office of Technology Assessment (OTA) provides lower cost estimates, which mainly focus on crop damages caused by 79 species, as agriculture-related costs represent over 90% of the OTA estimation, whereas over half of Pimentel's calculation relates to agriculture.

For agriculture, Perrault et al. arrange the costs and impacts from IS into six broad categories (crop losses, rangeland value decline, water resource depletion, livestock disease, genetic contamination, and management and eradication costs), and estimate that 40% of all insect damages to crops in the US are attributable to non-indigenous species. For example, the rice weevil (*Sitophilus Oryzae*) is a significant destroyer of crop and stored-grain that originated in India. It attacks wheat, corn, oats, rye, barley, sorghum, buckwheat, dried beans, and cashew nuts. In sum, large externalities are generated when IS are introduced to a new environment. Aggregate IS risk and externalities are conditioned by the existing trade distortion structure. The current trade distortion structure exacerbates this risk and the costs by favoring imports with higher IS risk. A reduction in trade distortions will affect the IS risk level and the environmental policy response to address this risk, be it through exclusion or through eradication efforts. The appendix provides further details on IS associated with rice and wood products and associated tariff escalation.

3. The Model

We use a simple multimarket partial-equilibrium model combining input and output markets in a small, open economy distorted by tariffs in both markets and by an externality in the input market. The latter is induced by IS associated with imports.

3.1. Modeling tariff escalation

Suppose that domestic final good *DFG* is produced from inputs *D* and *I* with a Cobb-Douglas technology, where *D* and *I* are perfect substitutes for raw inputs and fixed factor $\overline{K}$. We denote *DI*=*D*+*I*, the total use of raw input. The production function for the domestic final good is $DFG = DI^{\theta}\overline{K}^{1-\theta}$ with $\theta \in (0,1)$.

Profit maximization leads to the derived input demand and supply of *DFG* as follows:

$$DI^{d} = \left(\frac{P_{DI}}{\theta P_{DFG}}\right)^{\frac{1}{\theta-1}}\overline{K}, \text{ and } DFG^{s} = \left(\frac{P_{DI}}{\theta P_{DFG}}\right)^{\frac{\theta}{\theta-1}}\overline{K},$$

where P_{DI} is the input price and P_{DFG} is price of *DFG*.

Turning to demand, the demand for the processed good comes from the consumer of the processed final products, *FG*. Domestic and imported processed goods, *DFG* and *IFG*, are assumed perfect substitutes for the consumer. For simplicity's sake we assume quasilinear preferences for the processed goods. The utility of the consumer is a function of these two goods and an aggregate of all other goods, *AOG*. This is expressed as U(*DFG*+*IFG*, *OAG*) with

$$U(FG, AOG) = AOG + \frac{\gamma}{\gamma-1}FG^{\frac{\gamma-1}{\gamma}} \text{ where } \gamma > 0, \text{ and } FG = DFG + IFG.$$

Utility maximization subject to a budget constraint, with *AOG* as numeraire, leads to the demand for processed goods as $FG = P_{FG}^{-\gamma}$ or the inverse demand $P_{FG} = FG^{-1/\gamma}$.

Suppose imported input I is subject to an ad valorem tariff t_I, that is, $P_I = WP_I(1+t_I)$, and imported processed good IFG is subject to an ad valorem tariff t_{IFG}, leading to $P_{IFG} = WP_{IFG}(1+t_{IFG})$. Suppose that, initially, tariff escalation is in place, i.e., $t_I < t_{IFG}$. By normalizing world prices equal to 1 without any loss of generality and using tariff factors denoted by τ we have $P_I = \tau_I = (1+t_I)$ and $P_{IFG} = \tau_{IFG} = (1+t_{IFG})$.

3.2. IS associated with imported input

Suppose input D is produced with an increasing marginal cost. Suppose that the frequency of IS occurrence associated with imported input is z_I per unit, and imported output does not bring any risk. Consistent with many cases of IS, suppose the effects of z_I on the economy translate into an increase in the cost of production of the domestic input D. The total cost function is written as

$$TC_D = FC + 0.5\alpha D^2 + \beta D,$$

where $\beta = z_I I$ reflects the IS externality and the cost of eradication associated with imports. The marginal cost is

$$MC_D = \alpha D + \beta .$$

Profit-maximizing behavior of *D* producer leads to marginal cost pricing behavior, which defines the supply of input *D:*

$$P_D = \alpha D + \beta .$$

Since *DFG* and *IFG* are homogenous commodities, in equilibrium, they face the same price in the domestic market:[1]

$$P_{DFG} = P_{IFG} = P_{FG} = WP_{IFG}(1+t_{IFG}) = \tau_{IFG},$$

and the same for *D* and *I*:

$$P_D = P_I = P_{DI} = WP_I(1+t_I) = \tau_I .$$

Initial equilibrium with tariff escalation

Denoting (*) for the equilibrium level, after some simple calculation, we get

$$FG^* = \tau_{IFG}{}^{-\gamma}, \qquad (1)$$

$$DFG^* = \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{\theta}{\theta-1}} \bar{K}, \qquad (2)$$

$$IFG^* = \tau_{IFG}{}^{-\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{\theta}{\theta-1}} \bar{K}, \text{ and} \qquad (3)$$

$$DI^* = \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}} \bar{K}. \qquad (4)$$

Since $P_D = \tau_I = \alpha D^{*(\alpha-1)} + z_I I^*$, and $D^*+I^*=DI^*$, we solve for D^* and I^*:

$$D^* = \frac{\tau_I}{\alpha - z_I} - \frac{z_I\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}}, \text{ and} \qquad (5)$$

$$I^* = \frac{\alpha\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}} - \frac{\tau_I}{\alpha - z_I}. \qquad (6)$$

Parameter z_I is assumed to be small enough so that $\alpha > z_I$. This leads to the following condition for both domestic and imported input to be positive:

$$z_I DI^* < P_I < \alpha DI^*, \text{ or } z_I\bar{K}\left[\theta\tau_{IFG}\right]^{\frac{1}{1-\theta}}\left[\tau_I\right]^{\frac{\theta}{1-\theta}} < 1 < \alpha\bar{K}\left[\theta\tau_{IFG}\right]^{\frac{1}{1-\theta}}\left[\tau_I\right]^{\frac{\theta}{1-\theta}}. \qquad (7)$$

[1] We assume that these tariffs are not prohibitive; i.e., imports take place at equilibrium.

Total welfare of the economy includes the following components: the consumer surplus associated with *FG* consumption, the surplus from the derived demand of *DI* captured in the producer surplus associated with the supply of *DFG*, the producer surplus associated with the supply of *D*, and the tax revenues generated by the imposition of τ_{IFG} and τ_I.

Reducing tariff escalation via a final-good tariff decrease

We now reduce the tariff escalation by reducing the tariff (and the associated factor) on the processed final good, t_{IFG}, to $t_{IFG}^N < t_{IFG}$ ($\tau_{IFG}^N < \tau_{IFG}$) and keeping t_I (or τ_I) constant. The new equilibrium, denoted by the double asterisk (**), is

$$FG^{**} = \tau_{IFG}^{N\ -\gamma}, \tag{8}$$

$$DFG^{**} = \left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{\theta}{\theta-1}} \bar{K}, \tag{9}$$

$$IFG^{**} = \tau_{IFG}^{N\ -\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{\theta}{\theta-1}} \bar{K}, \tag{10}$$

$$DI^{**} = \left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{1}{\theta-1}} \bar{K}, \tag{11}$$

$$D^{**} = \frac{\tau_I}{\alpha - z_I} - \frac{z_I\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{1}{\theta-1}}, \text{ and} \tag{12}$$

$$I^{**} = \frac{\alpha\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{1}{\theta-1}} - \frac{\tau_I}{\alpha - z_I}. \tag{13}$$

By using $\theta < 1, \gamma > 0, \tau_{IFG}^N < \tau_{IFG}$ and comparing directly the equilibrium levels before and after reforms, we get the following lemma.

Lemma 1*: Under assumptions of sections 3.1 and 3.2., a reduction in tariff escalation through a* *decrease in the tariff on the imported processed good and holding the tariff on imported raw input constant has the following impacts:*

(i) total final good consumed increases, domestic final good consumed decreases, and imported final good consumed increases;

(ii) total raw input used decreases, domestic input used increases, and imported input used decreases.

Lemma 1 is illustrated in figure 1. The policy shock is shown in figure 1a, which induces an immediate shift of the derived demand *DI* to the left in figure 1b, a resulting decrease in imports of the input, and, after stabilization, a decrease in the associated externality and eradication cost. The latter induces a shift of the domestic supply of the input *D* to the right.

To compare total welfare before and after reforms, we decompose welfare in terms of elements in final-good and input markets. First, welfare in the final-good market, the sum of consumer surplus, producer surplus, and tariff revenue, increases as the tariff on the final good falls and the two triangles of deadweight loss shrink. Next, in the input market, the triangle of deadweight loss associated with the domestic input supply *D* remains unchanged because of its linear specification and the parallel shift from the reduced externality. Note also that the changes in surplus from the derived demand *DI* and input tax revenues from τ_I are captured in changes in profit measured in the variation of the producer surplus in the supply *DFG*. Hence, two less obvious components of the welfare consequences of the lower tariff are the input producer surplus in *D* inclusive of the externality and the deadweight loss associated with the derived demand of *DI*. These two welfare components before reform are described as follows:

$$W_{DI}^{*} = PS* - DWL_{DI^d}^{*} = \left[D*\tau_I - \int_0^{D*} P_D^{*}(D)dD \right] - \left[\int_1^{\tau_I} DI^d(\tau)d\tau - DI* \right]$$

where P_D^* is the supply of *D* when risks are associated with equilibrium import level

$P_D^*(D) = \alpha D + z_I I^*$, and $DI^d(\tau, \tau_{IFG}) = \left(\dfrac{\tau}{\theta \tau_{IFG}}\right)^{\frac{1}{\theta-1}} \bar{K}$. For this cost specification, welfare in the input market is

$$W_{DI}^* = 0.5D^*\left[\tau_I - z_I I^*\right] - \left[\int_1^{\tau_I} DI^d(\tau, \tau_{IFG}) d\tau - DI^*\right]$$

$$= 0.5D^*\left[\tau_I - z_I I^*\right] - \bar{K}\left(\theta \tau_{IFG}\right)^{1/(1-\theta)}\left[\frac{1-\theta}{\theta} - \frac{1}{\theta}\tau_I^{\ \theta/(\theta-1)} + \tau_I^{\ 1/(\theta-1)}\right]. \qquad (14)$$

These two welfare components in the input market after reforms are

$$W_{DI}^{**} = 0.5D^{**}\left[\tau_I - z_I I^{**}\right] - \left[\int_1^{\tau_I} DI^d(\tau, \tau_{IFG}^N) d\tau - DI^{**}\right]$$

$$= 0.5D^{**}\left[\tau_I - z_I I^{**}\right] - \bar{K}\left(\theta \tau_{IFG}^N\right)^{1/(1-\theta)}\left[\frac{1-\theta}{\theta} - \frac{1}{\theta}\tau_I^{\ \theta/(\theta-1)} + \tau_I^{\ 1/(\theta-1)}\right]. \qquad (15)$$

Proposition 1*: Under assumptions of sections 3.1. and 3.2., a reduction in tariff escalation through a decrease in the tariff on imported processed goods and holding the tariff on imported raw input constant increases total welfare by increasing allocative efficiency and reducing IS risk and externality.*

Proof: Comparing producer surplus in the input market before and after reforms, we have $PS^{**} > PS^*$ since by lemma 1, $D^{**} > D^*$ and $I^{**} < I^*$. Comparing deadweight loss associated with the derived demand for DI since $\tau_{IFG}^N < \tau_{IFG}$ and $\theta < 1$ we find that $DWL_{DI^d}^{**} < DWL_{DI^d}^*$. We also know that welfare in the final-good market, which is the sum of consumer surplus, producer surplus, and tariff revenue, increases as the tariff on the final good falls. Therefore, total welfare, the sum of welfare in final-good and input markets, increases after reforms. Market efficiency improves and the IS externality decreases because of the reduction in imports of raw inputs I.■

Some interesting situations lead to special cases of proposition 1. The results stated in proposition 1 hold when the tariff on the imported final good is lowered to any level below its initial level, hence, when it is equal to the tariff on imported raw inputs or when it is removed.

Corollary 1*: Under assumptions of sections 3.1.and 3.2., starting from initial tariff escalation,*

(i) removing the tariff on the final good increases welfare and reduces IS risk.

(ii) a uniform tariff structure that equates tariff on processed good to tariff on raw input increases welfare and reduces IS risk.

Finally, we note the special case of a zero tariff on the raw input in the presence of tariff escalation. In the latter case, moving to free trade in all markets is welfare improving and reduces the externality from IS.

Reducing tariff escalation by joint tariff reduction

We now consider a second policy menu reducing the escalation by reducing both tariffs or equivalently both factors from τ_I , τ_{IFG} to τ_I^{NN} and τ_{IFG}^{NN}, respectively, such that $\frac{\tau_{IFG}^{NN}}{\tau_I^{NN}} < \frac{\tau_{IFG}}{\tau_I}$. This implies that the final-processed tariff is reduced faster than is the raw-input tariff. Figure 2 illustrates the joint tariff reduction case with two policy shocks; i.e., both tariff factors fall. The processor's supply DFG^s shifts moderately to the right as the input becomes cheaper. Her/his derived demand DI^d shifts much to the left as output price falls significantly with the reduction in escalation. Supply D^s shifts to the right as the externality decreases when input imports decrease.

This type of joint reduction menu is consistent with the spirit of tariff reforms the World Trade Organization (WTO) has put in place with the Uruguay Round Agreement on Agriculture (WTO 1994). The Doha agreement is also likely to continue this approach (WTO 2004). All tariffs will eventually fall but the highest tariffs will fall faster than the moderate ones. This approach raises some issues: How fast should the tariff on the processed final good fall relative to the fall of the tariff on the raw input, and what supply and demand conditions would ensure that such a reduction of escalation through joint tariff reduction would increase welfare without exacerbating the externality in the raw input market?

To derive sufficient conditions for welfare-improving joint tariff reduction, we consider change in deadweight loss before and after reforms and then the IS externality. There are three components of deadweight loss in the model: the deadweight loss associated with *D* supply, the deadweight loss associated with *DI* demand (or *DFG* supply), and the deadweight loss associated with *FG* demand. Since *D* and *FG* depend on one policy only, deadweight loss associated with either *D* or *FG* decreases when their respective tariff factors fall. The deadweight loss associated with *DI* (or equivalently *DFG* by integrability) could produce a second-best situation in which a reduction in one tariff could exacerbate the distortion created by the other. Focusing on *DI*, denote the relative tariff factor $\tau \equiv \dfrac{\tau_{IFG}}{\tau_I}$ and measure deadweight loss, *DWL,* associated with *DI* in terms of the relative factor τ ; we then have

$$DWL = (\tau - 1)\tau^{\frac{1}{1-\theta}} - \int_1^{\tau} x^{\frac{1}{1-\theta}} dx = \tau^{\frac{2-\theta}{1-\theta}} - \tau^{\frac{1}{1-\theta}} - \frac{1-\theta}{2-\theta}(\tau^{\frac{2-\theta}{1-\theta}} - 1) = \frac{1-\theta}{2-\theta} + \frac{1}{2-\theta}\tau^{\frac{2-\theta}{1-\theta}} - \tau^{\frac{1}{1-\theta}}.$$

Therefore,

$$\frac{\partial DWL}{\partial \tau} = \frac{1}{1-\theta}\tau^{\frac{1}{1-\theta}}(1 - 1/\tau) > 0.$$

Hence, any menu that decreases both policies so that the relative τ falls (toward 1) is welfare improving in terms of allocative efficiency and abstracting from the eternality.[2,3]

The last component of concern is the externality. The reduction in the final-good tariff ($\tau_{IFG}^{NN} < \tau_{IFG}$) works its way as in proposition 1 and reduces the externality. However, the

[2] A similar argument can be developed for the DWL associated with the supply DFG, which is also increasing in τ.
[3] This argument also holds for the single tariff reduction case considered previously.

reduction of the raw-input tariff ($\tau_I^{NN} < \tau_I$) increases raw-product imports and hence increases the IS risk and associated external cost *β*. Establishing sufficient conditions for a reduction in IS under joint tariff reform hinges upon having two offsetting effects on raw imports *I*, such that the IS externality is not exacerbated. There are a number of ways to do this. A sufficient condition is that the decrease in raw-input imports from the lower derived demand for *DI* caused by the lower τ_{IFG}^{NN} should at least offset the increase in raw-input imports caused by the lower τ_I^{NN}. This condition ensures that the marginal externality *β* does not increase with the joint reform or that $\frac{\partial \beta}{\partial \tau_I} d\tau_I + \frac{\partial \beta}{\partial \tau_{IFG}} d\tau_{IFG} \leq 0$. Next, we formalize these sufficient conditions linking tariff reductions and the marginal externality so that a win-win outcome arises. Noting that

$$dDI = (DI / (1-\theta))(d\ln \tau_{IFG} - d\ln \tau_I)]$$

and that

$$dD = (\tau_I / \alpha) d\ln \tau_I ,$$

we have

$$dI = (DI / (1-\theta))(d\ln \tau_{IFG} - d\ln \tau_I)] - (\tau_I / \alpha) d\ln \tau_I ,$$

which leads to the condition[4]

$$(DI / (1-\theta))(d\ln \tau_{IFG} - d\ln \tau_I)] - (\tau_I / \alpha) d\ln \tau_I < 0,$$

which after simplification leads to

$$\frac{d \ln \tau_{IFG}}{d \ln \tau_I} > 1 + \frac{(1-\theta)\tau_I}{DI}. \qquad (16)$$

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[4] In elasticity terms the condition is $\frac{d \ln \tau_{IFG}}{d \ln \tau_I} > 1 + \frac{s_D \varepsilon_{D P_D}}{\eta_{DI\, P_{FG}}}$, noting that $\eta_{DI\, P_{FG}} = -\eta_{DI\, P_D}$, $s_D = D / DI$, and $\frac{d \ln \tau_{IFG}}{d \ln \tau_I} > 1 + \frac{s_D \varepsilon_{D P_D} - \eta_{DI\, P_D}}{\eta_{DI\, P_{FG}}}$.

A subset of the joint tariff reforms decreasing deadweight loss does not exacerbate the externality, for which the relative tariff factor falls "strongly" enough. We formalize this result in the following proposition.

Proposition 2. *Under assumptions of sections 3.1. and 3.2., starting from an initial tariff escalation, reducing tariff escalation with a joint tariff reduction increases welfare and reduces IS risk i.f.f. the joint reduction satisfy the following condition:*

$$\frac{d\ln\tau_{IFG}}{d\ln\tau_I} > 1 + \frac{(1-\theta)\tau_I}{DI}.$$

The intuition of the condition is straightforward. The larger the elasticity of the derived demand *DI* is with respect to the processed output price, the larger is the decrease in *DI* and raw imports *I* in response to a decrease of the final-good tariff factor τ_{IFG}. The smaller the raw input supply response is or the own-price elasticity of derived demand is in absolute value, the smaller is the price response of import demand in absolute value, and the smaller is the export expansion as a result of the lower tariff factor τ_I . Given the assumptions we made on the supply of the raw input and the technology of the processed good, it is easy to show that if the final good tariff factor falls twice as fast as the raw-input tariff factor then the condition is satisfied.[5]

3.3. Extensions

IS associated with both imported input and imported processed good

Suppose that the frequency of occurrence associated with the imported processed good is z_{IFG} per unit, assumed negligible in the previous sections. We assume that $z_{IFG} < z_I$ to reflect the fact that input is much more likely to transfer risks into a country than are processed goods. Suppose the effects of z_I and z_{IFG} on the economy translate into an increase in the cost of production

[5] $1+ [\tau_I (1-\theta)/(\alpha DI))] = 1+ (1-\theta)(D^{ne}/DI)*1$, with D^{ne} being the prevailing level of domestic supply *D* in absence of IS externality (β=0), the own-price elasticity of D^{ne}= 1, and $D^{ne}/DI < 1$.

MC_D of the domestic input D as

$$p_D = MC_D = \alpha D + z_I I + z_{IFG} IFG .$$

First, we describe the initial equilibrium with tariff escalation. Denote this equilibrium by a superscript (^{e}). The equilibrium levels of FG^e, DFG^e, IFG^e, and DI^e remain the same as those in the initial equilibrium (*) in the situation with absence of IS risks associated with the imported processed good. Since $P_D = \tau_I = \alpha D^e + z_I I^e + z_{IFG} IFG^e$, and $D^e + I^e = DI^e$, we solve for D^e and I^e:

$$D^e = \frac{\tau_I}{\alpha - z_I} - \frac{z_{IPG}}{\alpha - z_I}\left[\tau_{IFG}{}^{-\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{\theta}{\theta-1}}\right] - \frac{z_I\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}} \text{, and} \tag{17}$$

$$I^e = \frac{\alpha\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}} + \frac{z_{IPG}}{\alpha - z_I}\left[\tau_{IFG}{}^{-\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{\theta}{\theta-1}}\right] - \frac{\tau_I}{\alpha - z_I}. \tag{18}$$ [6]

Parameter z_I is still assumed to be small enough such that $\alpha > z_I$. This leads to a condition for both domestic and imported input to be positive as follows:

$$z_I DI^e < \tau_I - z_{IFG} IFG^e < \alpha DI^e ,$$

where $DI^e = DI*$ and $IFG^e = IFG*$ as specified in the previous section. The latter condition defines some relation between tariff factors, frequency of occurrence, and cost parameters.

As in the previous case in section 3.2, the crux of the welfare analysis lies in the input market, as allocative efficiency increases unambiguously in the output market. The surplus from the derived demand *DI* can be measured in terms of the *DFG* producer surplus by integrability and can be abstracted from. Hence, welfare consequences in the input market hinge on the

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[6] We use $D^e = \dfrac{\tau_I - z_{IPG} IFG^e - z_I DI^e}{\alpha - z_I}$, and $I^e = \dfrac{\alpha DI^e + z_{IPG} IFG^e - \tau_I}{\alpha - z_I}$.

producer surplus for input *D* and the deadweight loss associated with the *DI* derived demand:

$$W_{DI}^{e} = 0.5D^{e}\left[\tau_I - z_I I^{e} - z_{IFG} IFG^{e}\right] - \left[\int_1^{\tau_I} DI^{d}(\tau, \tau_{IFG})d\tau - DI^{e}\right]$$

$$= 0.5D^{e}\left[\tau_I - z_I I^{e} - z_{IFG} IFG^{e}\right] - \bar{K}\left(\theta\tau_{IFG}\right)^{1/(1-\theta)}\left[\frac{1-\theta}{\theta} - \frac{1}{\theta}\tau_I^{\,\theta/(\theta-1)} + \tau_I^{\,1/(\theta-1)}\right]. \tag{19}$$

How does the equilibrium look after the reform? We now reduce the tariff escalation by reducing t_{IFG} to t_{IFG}^{N} with $t_{IFG}^{N} < t_{IFG}$ and keeping t_I constant. Denote the new equilibrium by a superscript (^{ee}). The equilibrium levels of FG^{ee}, DFG^{ee}, IFG^{ee}, and DI^{ee} remain the same as those in the initial equilibrium (**) in the situation with absence of IS risks associated with the imported processed good.

Since $P_D = \tau_I = \alpha D^{ee} + z_I I^{ee} + z_{IFG} IFG^{ee}$, and $D^{ee} + I^{ee} = DI^{ee}$, we solve for D^{ee} and I^{ee}:

$$D^{ee} = \frac{\tau_I}{\alpha - z_I} - \frac{z_{IPG}}{\alpha - z_I}\left[\tau_{IFG}^{N\ \gamma-1} - \left[\frac{\tau_I}{\theta\tau_{IFG}^{N}}\right]^{\frac{\theta}{\theta-1}}\right] - \frac{z_I\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}^{N}}\right]^{\frac{1}{\theta-1}} \text{, and} \tag{20}$$

$$I^{ee} = \frac{\alpha\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}^{N}}\right]^{\frac{1}{\theta-1}} + \frac{z_{IPG}}{\alpha - z_I}\left[\tau_{IFG}^{N\ \gamma-1} - \left[\frac{\tau_I}{\theta\tau_{IFG}^{N}}\right]^{\frac{\theta}{\theta-1}}\right] - \frac{\tau_I}{\alpha - z_I}. \tag{21}$$

Lemma 2*: Under the assumptions of sections 3.1. and 3.3., a reduction in tariff escalation through a decrease in the tariff on imported final good and holding the tariff on imported raw input constant has the following effects:*

(i) total final good consumption increases, domestic final good consumed decreases, and imported final good consumed increases;

(ii) total raw input use decreases, imported input use decreases (increases, and therefore domestic input used increases [decreases]) i.f.f. the relative frequency of occurrence between

risks coming with input imported and risks coming with final good imported is higher (lower) than the relative change in final good imported and the total input consumed.

Proof: These inequalities are obtained by using $\theta < 1, \gamma > 0, t_{IFG}^{N} < t_{IFG}$ and by comparing directly D^{ee}, I^{ee} with D^{e}, I^{e}, respectively.

(i) $FG^{ee} > FG^{e}, DFG^{ee} < DFG^{e}$, $IFG^{ee} > IFG^{e}$; and

(ii) $DI^{ee} < DI^{e}$, $I^{ee} \underset{>}{\overset{\leq}{-}} I^{e}$ (and therefore $D^{ee} \underset{<}{\overset{\geq}{-}} D^{e}$) i.f.f. $\dfrac{z_I}{z_{IFG}} \underset{<}{\overset{>}{-}} \dfrac{IFG^{ee} - IFG^{e}}{DI^{e} - DI^{ee}}$. ■

Part (ii) of lemma 2 states a relationship between prices, demand and cost parameters, and frequency of IS occurrence for the imported input to decrease (or increase).

We are interested in a win-win situation, which is a sufficient condition for welfare improvement since IS risk decreases with a reduction of tariff escalation. Since a reduction in tariff escalation has ambiguous impacts on changes in the distribution of imported inputs and domestic input use, we focus on sufficient conditions that guarantee that the externality from IS is not exacerbated by the reform but rather reduced.

Welfare in the input market is the producer surplus for *D* subtracted by the deadweight loss associated with the *DI* demand and the transferable surplus associated with the derived demand *DI.* The latter is already accounted for in the producer surplus for *DFG*. Hence, welfare is

$$W_{DI}^{ee} = 0.5D^{ee}\left[\tau_I - z_I I^{ee} - z_{IFG} IFG^{ee}\right] - \left[\int_1^{\tau_I} DI^{d}(\tau, \tau_{IFG})d\tau - DI^{ee}\right]$$

$$= 0.5D^{ee}\left[\tau_I - z_I I^{ee} - z_{IFG} IFG^{ee}\right] - \bar{K}\left(\theta \tau_{IFG}^{N}\right)^{1/(1-\theta)}\left[\frac{1-\theta}{\theta} - \frac{1}{\theta}\tau_I^{\,\theta/(\theta-1)} + \tau_I^{\,1/(\theta-1)}\right]. \qquad (22)$$

Proposition 3: *Under assumptions of sections 3.1. and 3.3., reducing tariff escalation by reducing the tariff on the imported final good and keeping the tariff on imported raw input constant increases total welfare and reduces IS risks if* $\frac{z_I}{z_{IFG}} > \frac{IFG^{ee} - IFG^{e}}{DI^{e} - DI^{ee}}$.

Proofs: By lemma 2(ii), $\frac{z_I}{z_{IFG}} > \frac{IFG^{ee} - IFG^{e}}{DI^{e} - DI^{ee}}$ means that $I^{ee} < I^{e}$ and $D^{ee} > D^{e}$.

Moreover, given that $I^{ee} < I^{e}$, we have $\frac{IFG^{ee} - IFG^{e}}{DI^{e} - DI^{ee}} > \frac{IFG^{ee} - IFG^{e}}{I^{e} - I^{ee}}$. Hence

$\frac{z_I}{z_{IFG}} > \frac{IFG^{ee} - IFG^{e}}{I^{e} - I^{ee}}$, or $z_I I^{ee} + z_{IFG} IFG^{ee} < z_I I^{e} + z_{IFG} IFG^{e}$. This proves that the IS reduce. It also proves, together with $D^{ee} > D^{e}$, that the D producer surplus increases:

$0.5 D^{ee}\left[\tau_I - (z_I I^{ee} + z_{IFG} IFG^{ee})\right] > 0.5 D^{e}\left[\tau_I - (z_I I^{e} + z_{IFG} IFG^{e})\right]$.

Comparing deadweight loss associated with demand of DI, since $\tau_{IFG}^{N} < \tau_{IFG}$ and $\theta < 1$, we get that $DWL_{DI^d}^{ee} < DWL_{DI^d}^{e}$. We also know that welfare in the final good market only, which is the sum of consumer surplus, producer surplus, and tariff revenue, increases as the tariff on the final good falls. Therefore, total welfare, which is the sum of welfare in the final-good and input markets, increases after reforms. ■

To express the local inequality $\frac{z_I}{z_{IFG}} > -\frac{dIFG}{dDI}$ in terms of underlying parameters, we first take the log differential of *IFG* and *DI* with respect to the natural logarithm of the tariff factor τ_{IFG}, which leads to

$$\frac{d \ln IFG}{d \ln \tau_{IFG}} = -\left[\frac{s_{DFG}\theta}{1-\theta} + \gamma\right] / (1 - s_{DFG}) \text{ and } \frac{d \ln DI}{d \ln \tau_{IFG}} = \frac{1}{1-\theta}.$$

These expressions are substituted into the local inequality to yield

$$-\frac{d\ln IFG / d\ln \tau_{IFG}}{d\ln DI / d\ln \tau_{IFG}}\frac{IFG}{DI} = -\frac{dIFG}{dDI},$$

therefore

$$-\frac{d\ln IFG / d\ln \tau_{IFG}}{d\ln DI / d\ln \tau_{IFG}}\frac{IFG}{DI} < \frac{z_I}{z_{IFG}},$$

which after simplification leads to

$$\frac{\tau_{IFG}}{\tau_I}\frac{z_I}{z_{IFG}} > 1 + \frac{\gamma(1-\theta)}{s_{DFG}\theta}. \qquad (23)$$

This sufficient condition for welfare improvement is expressed locally in terms of underlying parameters, where ($-\gamma$) and ($\theta/(1-\theta)$) are the own-price elasticity of demand and domestic supply of the final good, and s_{DFG} is the share of the final good consumption sourced domestically (*DFG/FG*). This local condition is intuitive. As demand elasticity gets smaller in absolute value (lower γ), the expansion of FG and IFG induced by the lower tariff is moderated. As parameter θ gets larger, the decrease of the derived demand for *DI* induced by the lower tariff gets larger in absolute value, and so does the decrease in *I* and its IS externality. A large share s_{DFG} means that *IFG* is small relative to *DFG* and also that *DI* and *I* are large other things being equal. Hence, the contribution of *IFG* to the externality gets smaller relative to the contribution of *I* as the share s_{DFG} gets larger. The larger the initial tariff escalation (τ_{IFG}/τ_I large) and the higher the pest risk for the raw input relative to the processed final good (Z_I/Z_{IFG} large), the more likely it is that the condition will be satisfied and welfare will be improved by a decrease in tariff escalation.

Other extensions

The argument of Costello and McAusland on ambiguous effects of unilateral trade liberalization could be the basis for relaxing the sufficient conditions underlying propositions 2 and 3. The basic argument is that the externality may not increase when imports increase because the higher IS risk is applied to a lower land base corresponding to a lower D. This argument could be applied in our context of tariff escalation. Sufficient conditions established in propositions 2 and 3 could be relaxed somewhat to account for the decrease in D induced by a lower tariff on raw inputs. The potentially higher β is applied to a lower basis and may reduce the total externality if the decrease in D offsets the impact of higher raw imports on the externality.

Another extension would be to refine the modeling of the damage function from IS. In many cases the consequences of introductions go beyond an increase of the costs in agricultural input supply, and the welfare analysis should include an evaluation of environmental impacts. However it would only reinforce the case for reduction in tariff escalation, provided it does not result in an increase in raw product imports.

The analysis provided in this paper would also hold with some IS-related environmental policies initially in place as long as the policies are not optimal, that is, a cost in the production of D is not internalized. Parameter z_I can be policy dependent and as long as it is not equal to zero, the cost is not fully internalized or the pest associated with imports is not fully eliminated.[7]

4. Conclusions

Our paper investigated the interface between trade and IS risk and the impact of tariff escalation in agricultural and food-processing markets on IS hazard and associated externalities. Tariff escalation in processed agro-forestry products increases the risk of IS by biasing trade flows

[7] Having z_I =0 does not invalidate our results but makes them a mute point focusing exclusively on tariff escalation.

toward primary commodity flows and against processed-product trade. We show that reductions of tariff escalation by reduction of the tariff on processed goods increases allocative efficiency and reduces the IS externality, a win-win situation. This finding has obvious implications for many exporters of raw and processed commodities. For example, several countries that are members of the Association of Southeast Asian Nations (ASEAN) are major exporters of forestry products, both raw and processed. A reduction in the tariff escalation faced by forestry exports from ASEAN countries would produce a global win-win outcome: both economic efficiency and environmental sustainability would be enhanced in all countries involved. This implication is particularly relevant in the context of sustainable trade. Reductions in tariff escalation as designed in our analysis ensure an expansion of value-added activities and exports by developing countries while mitigating environmental externalities directly associated with trade.

It is well known that a first-best policy menu typically calls for free trade and an additional targeted policy instrument to address the IS externality. However, Margolis, Shogren, and Fischer recall that IS are "among a small group of market failures," the source of which is trade itself, and that often in these cases, reducing trade is the solution closest to the source of the failure, unless it is possible to monitor the harmful activity itself and sort out harmful imports by inspection. In the absence of such an instrument or if such an instrument is not set optimally, we show that the tariff structure can be changed to ensure that allocative efficiency improves while keeping the IS risk in check or even reducing it. If the IS risk is contained to the raw input market, any reduction of the tariff on the final good leads to a desirable outcome. We also show that both tariffs can be decreased in an orderly fashion such that the risk of IS is not increased while deadweight loss in both markets can be reduced. Finally, we also show that if the processed final good carries some moderate IS risk that is smaller than that of the raw input import, policy menus that reduce escalation and IS risk also exist but need to be designed to ensure that the IS risk is kept in check. In the latter, win-win situations are characterized by a price-elastic supply of the processed good, a price-inelastic demand for the processed good, a predominant domestic supply of the processed good, and a high initial tariff escalation.

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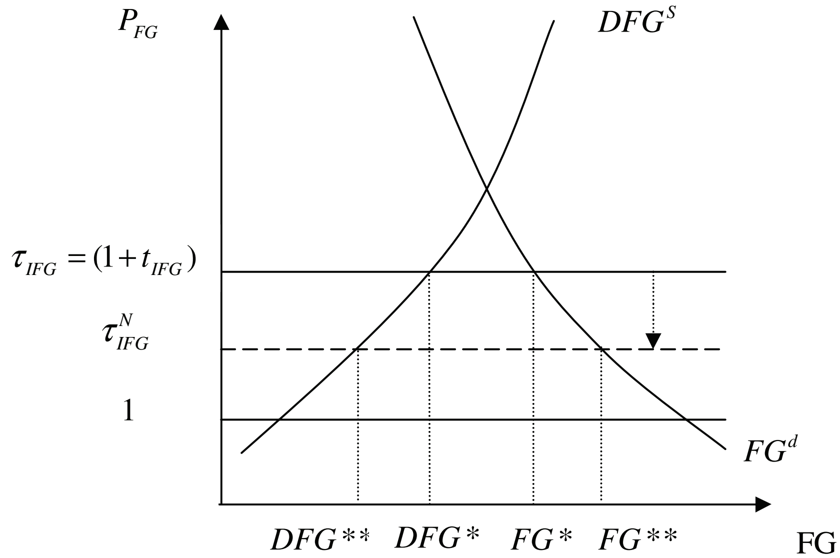
Figure 1a and 1b. Final good (1a) and input (1b) markets with τ_{IFG} reduced.



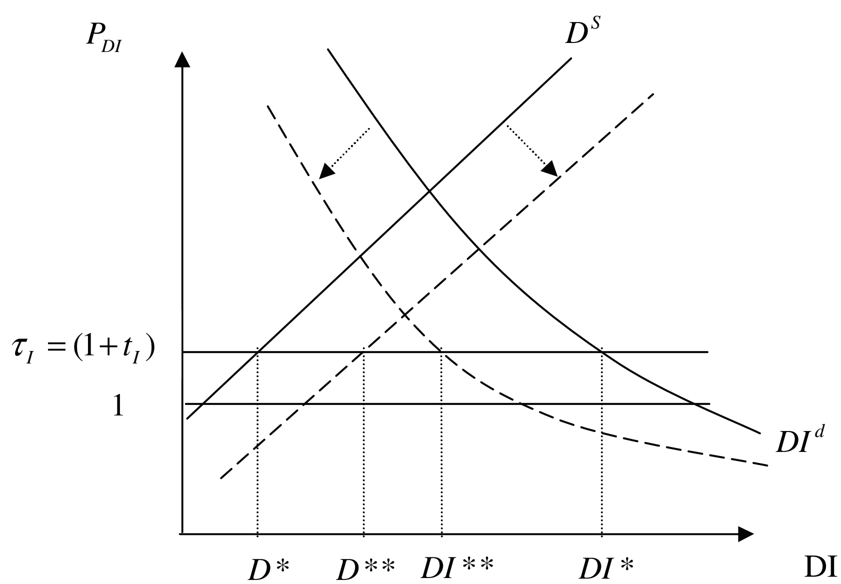
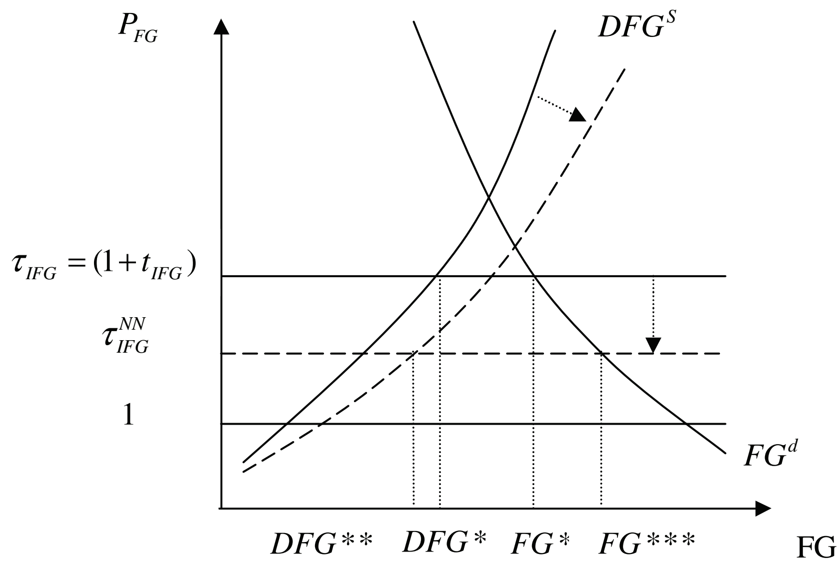
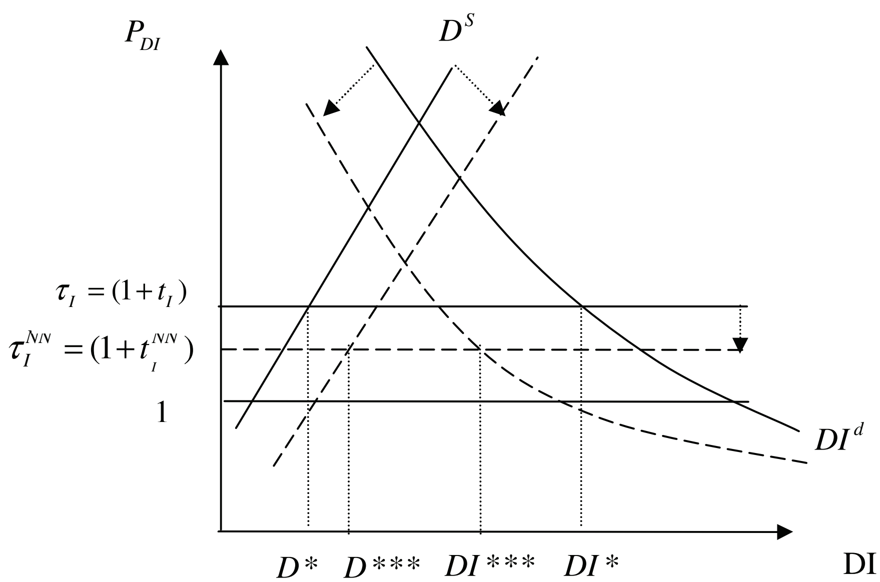


Figure 2a and 2b. Final good (2a) and input (2b) markets with both tariffs reduced.





Appendix

Tariff Escalation and Invasive Species Risk

Tariff escalation and IS hazard in the rice market

The rice weevil (*Sitophilus Oryzae*) is a significant crop- and stored-grain destroyer. This pest originated in India and has been spread worldwide by commerce. In the southern United States, adult rice weevils fly from the stored grain to the crop in the field, which in turn goes into storage, continuing the infestation. They attack wheat, corn, oats, rye, barley, sorghum, buckwheat, dried beans, and cashew nuts. The most important aspect of control is location of the source of the infestation.

Thailand is one of the largest rice growing countries in the world (annual production is 19.5 million tons). The percentage of losses due to insect infestation is difficult to determine (there is no official report) and the figures vary from 1% to as much as 25%. The ASEAN stated that its member nations lost about 25% of their paddy crop during harvesting and other post-harvest practices including storage and transportation. Presently, quantity loss is not as important a factor as the loss of goodwill in international trade. The loss of goodwill between traders and farmers, or between importers and exporters in the international markets, could be a serious matter in future marketing. In the past, major exporters experienced the embarrassment of some shipments being declared distressed cargoes. This was because of the presence of some banned insecticide on grain, which may cause health hazards to human beings. Commercial losses can also occur from the reduction of quality through adulteration or insect attacks (Sukprakarn).

Recent entomologic studies have shown that rice processing practices, e.g., rice polishing, have a lethal effect on insects such as rice weevils (Lucas and Riudavets). This suggests that the risk of weevil invasions related to rice imports could be much lower for milled rice than for paddy imports. Indeed, an escalated tariff structure could result in increased environmental hazards of pest introduction. Note that for the considered case, phytosanitary barriers to trade might be ineffective since Rice weevil is not a quarantine insect.

Wailes documents tariff escalation by milling stage in rice. Tariff escalation occurs in many nations that desire protection of their rice milling sectors. Tariffs that are higher on processed rice distort rice trade and milling activities. Tariff escalation is especially prevalent in Central and South American nations and the European Union. Under the Uruguay Round agreement, the EU agreed to convert variable levies to fixed tariffs and reduce them by 26% by 2000. However escalation is still present. Tariffs on milled rice are higher than for brown or paddy rice. Current tariff levels are 211 euros per ton for paddy, 264 euros per ton for brown rice, and 416 euros per ton for milled rice. Tariff escalation by degree of milling makes the tariff on milled rice prohibitive. Tariffs on milled rice imports into the EU are 80% compared to only 46% for brown rice.

In Mexico, paddy rice imports are assessed a 10% tariff while brown and milled have a 20% tariff. The effect of tariff escalation is seen in the trade flows of milled high-quality long grain. Most of this trade goes to nations with low tariffs. Most of the trade in brown and paddy rice, however, goes to nations that have high tariffs on brown and paddy rice but even higher tariffs on milled rice. The trade-weighted average tariffs by degree of milling for high-quality, long grain rice is estimated to be 31.4% for brown and 16.9% for paddy rice. Table 1 summarizes import protection on rice in countries exhibiting tariff escalation.

Table A.1. Tariff protection in rice processing.

Country/Region	Long Grain				Medium/Short	
	Milled		Brown	Paddy	Milled	**Brown**
	Non-fragrant	Fragrant				
Brazil	15.0%	15.0%	13.0%	13.0%	15.0%	13.0%
Costa Rica	35.0%	35.0%	35.0%	20.0%	35.0%	35.0%
Côte d'Ivoire	32.0%	32.0%	12.0%	7.0%	32.0%	12.0%
EU Union	80.0%	71.0%	46.0%	146.0%	75.0%	64.3%
Mexico	20.0%	20.0%	20.0%	10.0%	20.0%	20.0%
Other Europe	25.0%	25.0%	10.0%	10.0%	25.0%	10.0%
Sierra Leone	32.0%	7.0%	12.0%	7.0%	32.0%	12.0%
Taiwan	0.0%	210.0%	0.0%	0.0%	210.0%	229.4%
Turkey	35.0%	27.0%	35.0%	27.0%	35.0%	35.0%
US ($/ton)	14	14	21	18	14	21

Sources: Wailes (2004) based on AMAD (Agricultural Market Access Database), USDA, FAS GAIN reports.

Tariff escalation and IS hazard in wood-product markets

The United States is the world's largest importer of forest products. Wood imports have grown from less than 13% of volume consumed in 1965 to more than 25% of volume consumed in 1999 (Howard). Wood is a plant material, whether in the form of logs, unfinished lumber, chips, shipping, or packing materials, and it has in it and on it larvae and adult wood-boring insects, fungi, and numerous other organisms from its native forest. Logs present the greatest risk of transporting pests. Among the major forest pests in the United States, introduced exotic species such as chestnut blight (*Cryphonectria parasitica*), Dutch elm disease (*Ophiostoma ulmi*), white

pine blister rust (*Cronartium ribicola*), the European gypsy moth (*Lymantria dispar*), the balsam woolly adelgid (*Adelges piceae*), the Formosan termite (*Coptotermes formosanus*), the pine shoot beetle (*Tomicus piniperda*), and the Asian longhorned beetle (*Anoplophora glabripennis*), have caused some of the most devastating losses in productivity and species displacement.
The US is also an important producer both of raw wood and processed wood products. There are about 200 million hectares of commercial timberland in the United States. Dubensky et al. state that many forest industries are looking at ways to increase yields on less land. Invasive forest pests conveyed by large volumes of imported logs, chips, and other unprocessed wood products to manufacturing facilities in the United States could jeopardize this strategy.

Finish milling and kiln drying will kill wood organisms before they are imported if the procedures are done according to strict standards in the country of origin. While imports of lumber probably present a smaller risk than imports of logs, pests can still be transported by this pathway. Pests—especially fungi and nematodes—can travel in shipments of wood chips. While Canada is the principal and the safest source of foreign wood supplies (because its forests are contiguous with US forests and are unlikely to harbor insects and pathogens to which US forests are not adapted), other suppliers such as Chile and China are also increasing market penetration.[8] Unprocessed wood imported from all other temperate countries carries a significant risk of transporting pests that could threaten forests in the continental United States. If just 3% of logs imported from non-Canadian sources in 2000 harbored exotic pests, at least 1,941 pests would arrive in America through this pathway (Americanland.org). For example, Russian forest pests and pathogens that can be transported on logs and pose significant risks to North American forests include the Asian gypsy moth (*Lymantria dispar*), nun moth (*Lymantria monacha*), spruce bark beetle (*Ips typographus*), pine wood nematodes (*Bursaphelenchus* spp.), larch canker (*Lachnellula willkommii*), and root rot (*Heterobasidion* spp.). Takcz recalls that the potential economic costs associated with the introduction of these forest pests and pathogens from Russia are high (Table 2). "Costs would result from potentially reduced yields caused by growth loss, increased mortality, defects in the host species, and increased management costs. The introduction of these exotic pest organisms from Russia and their subsequent establishment in North American forests could result in significant changes in forest ecosystems, such as tree

[8] Softwood imports from countries other than Canada jumped by over 41%.

species conversion, deforestation, wildlife habitat destruction, degradation of riparian communities, increased fuel loading, and loss of biodiversity."

Table A.2. Potential economic losses from the introduction of selected Russian forest pests (US Department of Agriculture 1991).

Pest	Best Case Scenario (x $1 million)	Worst Case Scenario (x $1 million)
Defoliators (*Lymantria* spp.)	35,049	58,410
Nematodes (*Bursaphelenchus* spp.)	33	1,670
Spruce beetle (*Ips typographus*)	210	1,500
Root rot (*Heterobasidion* spp.)	84	344
Larch canker (*Lachnellula willkommii*)	25	240

Environmental activists complain that US timber companies and sawmills process foreign wood in the US to replace domestic logs they cannot obtain because of over-logging and export. The US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) adopted phytosanitary regulations governing imports of wood,[9] including logs, lumber, railroad ties, chips, and solid wood packing material, with a new standard for treating non-manufactured packing material as well. Wood packing material made entirely of processed manufactured wood (plywood, particle board, oriented strand board, veneer) is exempt from the standard. However these regulations have several limitations, both with the feasible enforcement issue and with the efficiency in reliably killing all pests.

[9] "APHIS" wood import regulation was based, in part, upon the results of risk assessments, careful analysis of available mitigation measures, consideration of comments from the public and industry, and the results of an environmental impact statement (EIS) that was completed in 1994 pursuant to the National Environmental Policy Act (NEPA). The regulation became effective in August 1995 and was subsequently challenged by the Oregon Natural Resources Council (ONRC) and two California environmental groups (CATS) in federal court, in part, on grounds that the NEPA component of the rulemaking was deficient. The US District Court of Northern California agreed that the EIS was lacking in certain respects and, on June 5, 1997, enjoined the issuance of new import permits for the importation of certain unfinished nontropical wood articles under the 1995 regulation, pending the correction of deficiencies in the EIS. APHIS challenged the injunction and, in response, submitted a Supplemental EIS in May 1998. The judge ruled that the SEIS satisfied deficiencies in the original EIS and lifted the injunction on log import permits in January 1999. The plaintiffs appealed the ruling to the 9th Circuit Court, which recently upheld the earlier decision (USDA, APHIS 1998a)." From Dubensky et al., see http://www.apsnet.org/online/exoticpest/Papers/dubensky.htm.

The Asian longhorned beetle (*Anoplophora glabripennis*) is a wood-boring insect with a lethal appetite for deciduous trees. It thrives inside hardwood trees such as maple, elm, locust, and horse chestnut. It came into New York and Chicago in the 1990s in wooden packing materials imported from China and has turned up at more than 30 locations around the United States—and has also been detected in Great Britain and recently in France. The beetles are virtually undetectable until they kill a tree from the inside and then fly on to the next one. The only known way to eradicate this pest is to cut every tree suspected of harboring it, chip all the wood, and burn all the chips.

The government has felled and burned more than 10,000 trees so far in a still-unsuccessful attempt to eliminate the beetle. Now the US Department of Agriculture (USDA APHIS) has proposed a $365 million plan to try to wipe out the beetle. Left unchecked, the beetle could destroy approximately one-third of all urban shade trees in the country over a couple of decades. The consequences of a wood-boring insect's invasion could also be dramatic for the timber industry. In 1986, timber was the most important agricultural crop in the US in terms of dollar value of production, surpassing corn, soybeans, and hay. The APHIS estimates that if the Asian longhorned beetle were to expand beyond the current quarantined areas of New York, Illinois, and New Jersey, it could wreak havoc nationwide, affecting such industries as lumber, maple syrup, nurseries, and tourism and accumulating more than $41 billion in losses.

Tariff escalation is predominant in wood products. Data for wood were obtained from the New Zealand Ministry of Foreign Affairs and Trade. The technical data are shown in Table 3. The values are expressed in US dollars, but the same final outcome is valid for any other currency units. Let us look at the example of moldings in Table 3. Wood costs at $220 per cubic meter are the main costs, with energy etc (i.e., all non-labor costs of processing) at $21 and labor at $99 per cubic meter. This gives an end value of $340 per cubic meter for moldings, with added value past the log stage of $120. It is this $340 (plus freight difference, discussed below) that the final tariff is levied on, and not the value-added of $120.

Table A.3. Technical coefficients for wood processing (US$ per cubic meter).

HS	Product	Wood	Energy Etc	Labor	Added Value	Final Value
4403	Logs*					
4407108	Clear wood	70	25	17	42	112
440910	Moldings	220	21	99	120	340
9403	Furniture	220	25	199	224	444
440810	Veneers	300	22	202	224	524
441219	Plywood	40	56	45	101	141
44112/3	Fiberboard	20	76	15	91	111
44103	Particleboard	10	61	38	99	109
4701	Mechanical pulp	63	106	22	128	191

Source: Jaakko Poyry Report.

Logs are introduced into the table because they represent the raw material. Freight is another complicating factor. Logs are exported as a bulk commodity and as such face low per unit freight costs. Processed products require more sophisticated and therefore more costly handling than logs. An accurate assessment of the full impact of freight costs would require a detailed analysis of the differences in these costs by product to each individual market, whereas the costs in Table 3 are invariant as to destination. The freight costs will therefore increase the effective tariff rates (ETR), and the values seen below in Table 4 are an under-estimate. Tariffs for the main forestry products are shown in Table 4. These are the applied tariffs, and they are sourced from the relevant country's tariff schedules.

Table A.4. Applied tariff rates (ad valorem).

	Korea	US	China	Japan	Malay	Indon	Phil	Thai
Product								
Logs	2	0	0	0	0	0	0	10
Clear wood	5	0	0	4.8	0	0	10	10
Moldings	8	0.3	9.4	5	20	0	7	20
Furniture	8	0.5	11	0	30	15	20	20
Veneers	5	0	4	5	20	5	10	20
Plywood	8	10.4	8.4	15	35	15	20	20
Fiberboard	8	6	7.5	2.6	20	5	20	20
Particleboard	8	8	9.6	5	20	5	20	20
Mechan pulp	0	0	0	0	0	5	3	5

Table 5 combines Tables A.3 and A.4 to produce the ETR for the main forestry products. Some of these ASEAN countries are major exporters of forestry products. A reduction in the ETRs for forestry exports to ASEAN would produce a global win-win outcome: both economic efficiency and environment sustainability would be enhanced.

Table A.5. Effective tariff rates (ETR), ad valorem or percentage rates.

	Korea	US	China	Japan	Malay	Indon	Phil	Thai
Product								
Clear wood	10.0	0	0	12.8	0	0	26.7	10.0
Moldings	19.0	0.85	26.6	14.2	56.7	0	19.8	38.3
Furniture	13.9	1.0	21.8	0	59.5	29.7	39.6	29.8
Veneers	9.0	0	9.4	11.7	46.8	11.7	23.4	33.4
Plywood	10.4	14.5	11.7	20.9	48.9	20.9	27.9	24.0
Fiberboard	9.3	7.3	9.2	3.2	24.4	6.1	24.5	22.2
Particleboard	8.6	8.8	10.6	5.5	22.0	5.5	22.0	21.0
Mechan pulp	-2.0	0	0	0	0	7.5	4.5	2.5

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