AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Tariff Escalation and Invasive Species Risk

Anh Tu and John Beghin*

Iowa State University

Draft of 05-15-05

Selected Paper prepared for presentation at the 2005 American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005

Abstract

We investigate the interface between trade and invasive species (IS) risk, focusing on the existing tariff escalation in agricultural and food-processing markets and its implication IS risk. Tariff escalation in processed agro-forestry products exacerbates the risk of IS by biasing trade flows towards increased trade of primary commodity flows and against processed-product trade. We show that reductions of tariff escalation by reduction of the tariff on processed goods increase allocative efficiency and reduce 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.

*We thank GianCarlo Moschini, Estelle Gozlan, Harvey Lapan, and Denis Mcgee for comments and discussions. Estelle Gozlan and Denis Mcgee provided us with background information regarding pests associated with agricultural and wood products and tariff escalation in wood products.

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 of dirty activities. In a few cases trade is the direct vector of the environmental issue as emphasized in recent literature. The latter 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 to the economics of IS since trade is a major vector of propagation of these species, although not the only one. The current economic literature is mostly focused on the "right" criteria to use or the optimal environmental policy response to the hazard of IS (Binder; Sumner). A related debate evolves around quarantine as a legitimate policy response to phyto-sanitary risk (Anderson, McRae, and Wilson; Cook and Frazer; and Kim and Lewandrowski)

Agricultural and forestry imports have always been an important conduit for biological invasions. The agricultural tariff structure, because of its strong influence on trade flows, is therefore an important issue to understand the hazards of IS introductions. The literature is still limited. Using a 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 quantity of crops available for IS damage is reduced and so is the amount of land disturbed and thereby aiding the propagation of exotic species. Tu and Beghin extend this analysis to two-way trade and multilateral trade liberalization and trade integration, and show that the ambiguity of the Costello-McAusland results is much reduced in the latter context. Subsequently, McAusland and

Costello compare tariff (duties) and non-tariff (quarantine measures or port inspections) regulations aimed at monitoring the risks of biological invasions 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 such as Foot-and-Mouth Disease from imports to a tariff, so that the exporter of an infected product faces a higher tariff than would otherwise be the case.

Our paper departs from this limited literature and fills an important knowledge gap in policy analysis related to trade and IS. We investigate the interface between trade and IS risk, focusing on the existing tariff escalation in agricultural and food-processing markets and its impact on IS hazard and associated externalities. The paper addresses and analyzes 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 well established in processing sectors using agro-forestry raw inputs. Tariff escalation in processed agro-forestry products increases the risk of IS by biasing trade flows towards 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 commodity 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 weevils invasions related to rice imports could be negligible for milled rice as compared to 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 investigate 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, and operationalize and translate these conditions into practical policy guidance. Our specific objectives are to identify policy setting and reforms under which win-win situations arise (reduced trade distortions, reduced hazard and externalities).

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

2. Evidence on Tariff Escalation and IS

2.1. Tariff escalation

The economic 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 literature 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 a long-term feature of agricultural and food-processing trade according to more recent literature, (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 have been impeded by tariff escalation in the industrialized countries but also within 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 0% and 6% respectively (Aksoy). Japan and the US apply comparable tariff structures. Studies show that the proportion of processed products to the 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 being traded at zero or very low tariff while processed wood products faced much higher tariffs.

2.2. IS and associated externalities

The introduction of harmful exotic species into the 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 invasive species of plants, mammals, birds, amphibians, reptiles, fish, arthropods, and mollusks are established and cost the economy at least US$138 billion a year (Pimentel et al.). This estimate is much higher than data provided by The US Office of Technology Assessment (OTA), which mainly focused on crop damages (agriculture related costs represent over 90% of the OTA estimation, and over half of Pimentel's calculation). For agriculture, Perrault et al. range the costs and impacts from invasive species 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 is attributable to non-indigenous species. For example the rice weevil (*Sitophilus Oryzae*) is an important crop and stored-grain destroyer 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 in a new environment. Aggregate IS risk and externalities are conditioned by the existing trade distortion structure. The current trade distortions structure exacerbates this risk and 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 exclusion or eradication efforts.

3. The Model

We use a simple multimarket partial-equilibrium model combining input and output markets in a small open economy distorted by tariffs and an externality induced by IS.

3.1. Modeling tariff escalation

Suppose that domestic final good *DFG* is produced from input *D* and *I* with a Cobb Douglass technology, where *D* and *I* are perfect substitutes raw inputs and fixed factor $\bar{K}$. We denote

DI=*D*+*I*, the total use of raw input. The production function for the domestic final good is $DFG = DI^{\theta}\bar{K}^{1-\theta}$ with $\theta \in (0,1)$.

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

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

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 all other goods, *AOG*. This is expressed as U(*DFG*+*IFG*, *OAG*) with

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

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 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 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:

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

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

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

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

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

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 a condition for both domestic and imported input to be positive as the following:

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

Total welfare of the economy include the following components: the consumer surplus associated with *FG* consumption, the surplus from the derived demand of *DI* captured in the profit equivalent to 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 $t^N_{IFG} < t_{IFG}$ ($\tau^N_{IFG} < \tau_{IFG}$) and keeping t_I constant. The new equilibrium, denoted by the double asterisk (**), is:

$$FG^{**} = \tau_{IFG}^{N\ -\gamma}, \qquad (8)$$

$$DFG^{**} = \left[\frac{\tau_I}{\theta\tau^N_{IFG}}\right]^{\frac{\theta}{\theta-1}} \bar{K}, \qquad (9)$$

$$IFG^{**} = \tau_{IFG}^{N\ -\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}^N}\right]^{\frac{\theta}{\theta-1}}, \qquad (10)$$

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

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

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

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 a shift of the derived demand *DI* to the left in figure 1.b, a resulting decrease in imports of the input, and associated externality. 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 due to 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 is 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 supply of *D* when risks are associated with equilibrium import level

$P_D^{*}(D) = \alpha D + z_I I^{*}$, and $DI^{d}(\tau, \tau_{IFG}) = \left(\frac{\tau}{\theta \tau_{IFG}} \right)^{\frac{1}{\theta - 1}} \bar{K}$. 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 good 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 DI market before and after reforms, we have $PS^{**} > PS^{*}$ since by lemma 1, $D^{**} > D^{*}$ and $I^{**} < I^{*}$. Comparing deadweight loss associated with supply of DI, since $\tau^{N}_{IFG} < \tau_{IFG}$ and $\theta < 1$ we get 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 market increases after reforms. The IS risk and externality decrease 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 imported final good is lowered to any level below its initial level, hence when it is equal to 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 the tariff on the raw input in 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 the raw-input tariff is. Figure 2 illustrates the joint tariff reduction case with two policy shocks, i.e., both tariff factors fall. The processor 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 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 insure 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 $\tau \equiv \frac{\tau_{IFG}}{\tau_I}$ and measure deadweight loss, *DWL,* associated with *DI* in terms of the relative τ , we 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,

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

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

The last component to worry about 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 reduction of the raw-input tariff ($\tau_I^{NN} < \tau_I$) increases raw-product imports, 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 several 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 insures 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

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

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

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

$$(DI/(1-\theta))(d\ln\tau_{IFG} - d\ln\tau_I)] - (\tau_I/\alpha)d\ln\tau_I < 0,$$[4]

which after simplification leads to

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

A subset of the joint tariff reforms decreasing deadweight loss does not exacerbate the externality, 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 iff 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

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

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 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 processed goods are. Suppose the effects of z_I and z_{IFG} on the economy translate into an increase in the cost of production 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 invasive species risks associated with 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 :

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

[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 with no IS externality ($\beta=0$), the own-price elasticity of D^{ne}= 1, and $D^{ne}/DI < 1$.

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

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

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

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

How does the equilibrium look after the reform? We now reduce the tariff escalation by reducing t_{IFG} to $t_{IFG}^N < t_{IFG}$ 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 invasive species risks associated with imported processed good.

---

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

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)) if and only if 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} and D^e, I^e.

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

(ii) $DI^{ee} < DI^e$, $I^{ee} \underset{>}{\overset{<}{=}} I^e$ (and therefore $D^{ee} \underset{<}{\overset{>}{=}} D^e$) if and only if $\frac{z_I}{z_{IFG}} \underset{<}{\overset{>}{=}} \frac{IFG^{ee} - IFG^e}{DI^e - DI^{ee}}$. ■

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 then focus on sufficient conditions that guarantee that the externality from IS is not exacerbated by the reform but rather reduced.

Welfare in input market, except the transferable DI consumer surplus, is the D producer surplus subtracted by the deadweight loss associated with the DI demand:

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

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

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 invasive species 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 invasive species reduce. It also proves, together with $D^{ee} > D^e$ that the D producer surplus increases:

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

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 inequality

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

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 (-γ) and (θ/(1-θ)) 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 initial tariff escalation (τ_{IFG}/τ_I large) and the higher pest risk for the raw input relative to the processed final good (Z_I/Z_{IFG} large), the more likely 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 to relax 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.

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 toward primary commodity flows and against processed-product trade. We show that reductions

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

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 insure 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 calls for free trade and an additional targeted policy instrument to address the IS externality. In absence of such an instrument or if such an instrument is not set optimally, we show that the tariff structure can be changed to insure 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 decrease 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 the raw input import does, policy menus that reduce escalation and IS risk also exist but need to be designed to insure 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.

References

Aksoy, M.A. (2004).“Global Agricultural Trade Policies,” chapter 3 in M. A. Aksoy, and J. C. Beghin, eds. *Global Agricultural Trade and Developing Countries*. The World Bank: 37-53.

Anderson, K., C. McRae, and D. Wilson, Eds (2001). *The Economics of Quarantine and the SPS Agreement*, CIES and AFFA, Adelaide, Australia.

Binder, M. (2002). “The Role of Risk and Cost Benefit Analysis in Determining Quarantine measures,” Australia Productivity Commission Staff Research Paper, Canberra.

Cook, D.C., and R.W. Fraser (2002). “Exploring the regional Implications of interstate quarantine policies in Western Australia,” *Food Policy* 27: 143-157.

Costello, C. and C. McAusland (2003). “Protectionism, Trade, and Measures of Damage from Exotic Species Introductions,” *American Journal of Agricultural Economics* 84(5): 964-75.

Gallezot, J. (2003). “La progressivité tarifaire de l’UE vis à vis des produits agricoles et agroalimentaires.” Mimeo, Institut National de Recherche Agronomique, Unité Mixte de Recherche Économie Publique, Paris-Grignon, January.

Gibson, P., J. Wainio, D. Whitley, and M. Bohman. (2001). “Profile of Tariffs in Global Agricultural Markets,” AER-796, Economic Research Service, USDA Washington DC.

Golub, S., and J.M, Finger. (1979). “The Processing of Primary Commodities: Effects of Developed-Country Tariff Escalation and Developing Country Export Taxes,” *Journal of Political Economy* 83(3): 559-577.

Kim, C. S., and J. Lewandrowski. (2003). “Economics of Managing Invasive Pest Species: Exclusion and Control.” Selected paper of the American Agricultural Economics Association. Annual Meeting, July 27-30, Montreal, Canada.

Laird, S., and A.J. Yeats. (1987). “Empirical Evidence Concerning the Magnitude and Effects of Developing Country Tariff Escalation,” *Developing Economies* 25(2) (June): 99-123.

Lindland, J. (1997). “The Impact of the Uruguay Round on tariff escalation in agricultural products,” *Food Policy* 22: 487-500.

Lucas, E., and J. Riudavets (2000), “Lethal and Sublethal Effects of Rice Polishing Process on *Sitophilus oryzae,*” *Journal of Economic Entomology* 93(6): 1837-1841.

McAusland, C., and C. Costello. (2004). “Avoiding Invasives: Trade-related Policies for Controlling Unintentional Exotic Species Introductions,” *Journal of Environmental Economics and Management* September 48(2): 954-77.

Mumford, J.D. (2002). “Economic Issues Related to Quarantine in International Trade,” *European Review of Agricultural Economics* 29: 329-48.

Paarlberg, P., and J.G. Lee. (1998). “Import Restrictions in the Presence of a Health Risk: an Illustration Using FMD,” *American Journal of Agricultural Economics* 79: 175-183.

Perrault, A., M. Bennett, S. Burgiel, A. Delach, and C. Muffett. (2003). “Invasive species, agriculture and trade: case studies from the NAFTA context,” North American

Commission for Environmental Cooperation Working Paper.

Perrings, C., M.Williamson, and S. Dalmazzone (eds.) (2000). *The economics of biological invasions*. Edward Elgar Publishing, Cheltenham, UK.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. (2000). "Environmental and economic costs of non-indigenous species in the United States," *BioScience* 50: 56-65.

Rae, A., and T. Josling. (2003). "Processed food trade and developing countries: protection and trade liberalization," *Food Policy* 28:147-166.

Sumner, D.A. (2003) *Exotic Pest and Diseases: Biology, Economics, and Public Policy for Biosecurity*, Ames, IA: Iowa State press.

Tu, A.T., and J.C. Beghin. (2004). "Intra-Industry Trade, Imperfect Competition, Trade Integration and Invasive Species Risk," Selected Paper of the 2004 American Agricultural Economics Association Meetings, Denver August 1-4.

U.S. Office of Technology Assessment (OTA). (1993). Harmful non-indigenous species in the United States. US Congress, Washington DC, USA. ww.wws.princeton.edu/~ota/disk1/1993/9325.PDF

Wailes, E. J. (2004). "Global Trade, Protectionist Policies, and the Impact of Trade Liberalization," chapter 10 in M. A. Aksoy, and J. C. Beghin, eds. *Global Agricultural Trade and Developing Countries*. The World Bank: 177-193.

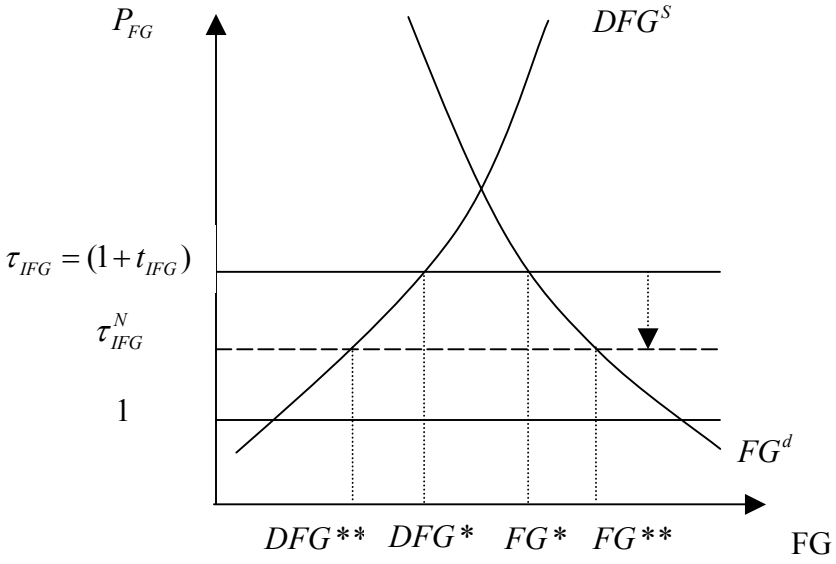
Windfuhr, M. (2002). Little progress for liberalised trade: the agricultural exports of developing countries are blocked. *Development and Cooperation* 6: 31-34.

Yeats, A.J. (1984). "On the Analysis of Tariff Escalation: Is There a Methodological Bias against the Interest of Developing Countries?" *Journal of Development Economics* 15(1,2,3): 77-88.

World Trade Organization. (1994). "Agreement on Agriculture." Final Act of the 1986-1994 Uruguay Round, WTO Agreements. http://www.wto.org/english/docs_e/legal_e/14-ag.pdf.

World Trade Organization. (2004). General Council. "Doha Work Programme, Decision Adopted by the General Council on 1 August 2004." Report of General Council. August 2. Document WT/L/579 http://www.wto.org/english/tratop_e/dda_e/ddadraft_31jul04_e.pdf

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



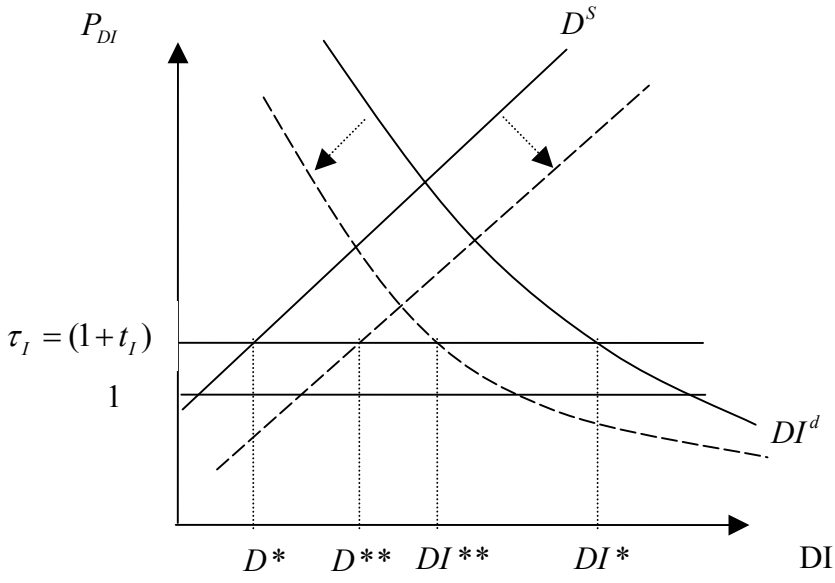
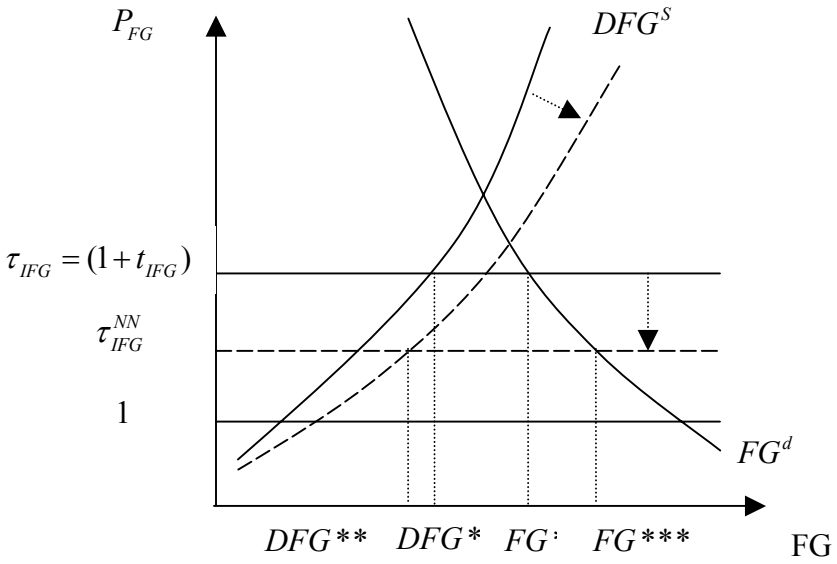
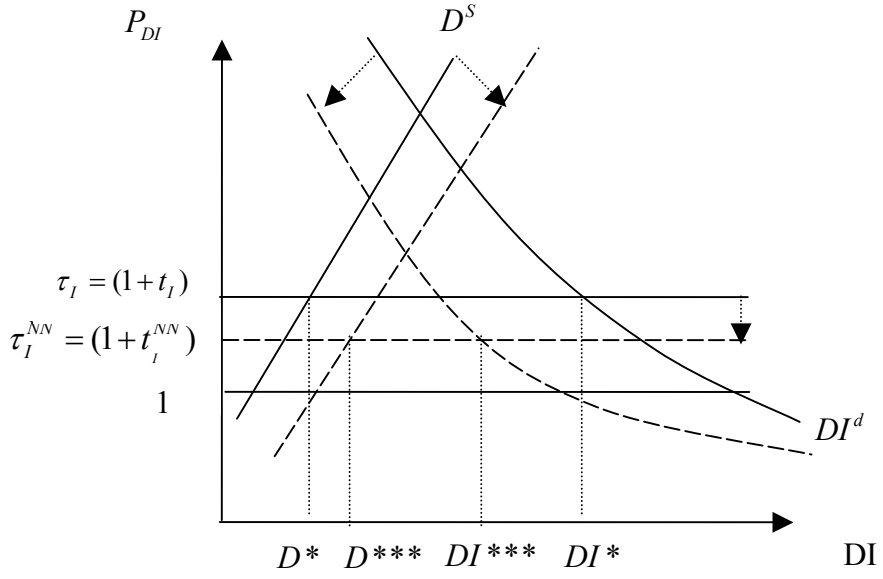



Figure 2a and 2b. Final good (2a) and input (2b) markets with both tariffs reduced.