2005

Essays on international trade, endogenous quality and invasive species risk

Anh Thuy Tu
Iowa State University

Essays on international trade, endogenous quality and invasive species risk

by

Anh Thuy Tu

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Program of Study Committee:
John Beghin, Co-major Professor
Harvey Lapan, Co-major Professor
GianCarlo Moschini
Rajesh Singh
Denis McGee

Iowa State University

Ames, Iowa

2005

Graduate College
Iowa State University

This is to certify that the doctoral dissertation of

Anh Thuy Tu

has met the dissertation requirements of Iowa State University

Signature was redacted for privacy.

Co-major Professor

Signature was redacted for privacy.

Co-major Professor

Signature was redacted for privacy.

For the Major Program

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I thank my mom and my husband for their unconditional support and continuous encouragement during my years of graduate school. Thanks also go to my sisters, brothers, extended family, and friends.

I would also like to thank my major professors, John Beghin and Harvey Lapan, for their immense patience, dedication, and their always helpful suggestions, comments, and advice.

Last but not least, I would like to thank my Committee Members, and the faculty and staff of the Center for Agricultural and Rural Development and the Economics Department for the help I received during my graduate studies.

CHAPTER 1. GENERAL INTRODUCTION

1. Introduction

Trade is considered as a powerful engine of economic growth. International trade flows have tripled in the last twenty years. This dissertation takes a close look at the relation between international trade and two issues that have become among the active fields of economic research: (1) the quality decisions in firms' behavior and (2) the invasive species risk.

On the quality choice, the dissertation focuses on a specific trade policy called Voluntary Import Expansions (VIEs) and the effects of this policy on firms' quality decisions. A Voluntary Import Expansion is an agreement to increase the quantity of imports of a product over a specified period of time. VIEs are used to correct trade imbalances, specifically imbalances between the United States and Japan. In the late 1980s, VIEs were suggested by the US as a way of expanding U.S. exports to Japan. Under the assumption that Japan maintained barriers to trade that restricted the entry of U.S. exports, Japan was asked to increase its volume of imports on specified products including semiconductors, automobiles, and auto parts. The intention was that VIEs would force a pattern of trade to be closer to replicate the free trade level. VIEs have become the latest weapon in the arsenal of U.S. trade policies to "open" foreign markets that are considered closed because of alleged discriminatory practices and other hidden barriers to trade. VIEs are a special results-oriented trade policy that focuses on specific, concrete outcomes rather than on what proponents dismiss as free trade principles that rely on ineffective rules.

VIEs are the import counterpart to Voluntary Export Restraints (VERs): VERs set a quantitative ceiling on a country's imports of a given product to another country, while VIEs set a quantitative floor on a country's exports of a given good to another country. Although VERs are generally considered harmful to the economic welfare of the importing country because of restricting trade, VIEs are more difficult to judge because their ostensible purpose is to expand trade in the face of alleged foreign trade barriers. The first part of this dissertation studies the endogenous quality effects of VIEs.

The links between international trade and the environment are multiple, complex and have been a topic of continuing heated debate. In the second part of the dissertation, the confluence of international trade and the environment, especially the invasive species risk is explored.

Ever since humans began to travel over sea, land and air they have deliberately, or inadvertently, brought along livestock, crops, plants, pets, and even pests, introducing them into new environments. Many of these alien species did not survive, but many others thrived. Some of these species did so well that they crowded out native species and modified their surroundings. Such species are described as invasive. They can threaten biodiversity as well as imposing significant economic hardship on society. Global trade, which carries millions of tons of goods around the world every year, provides numerous modes of transportation for would-be invaders. Food and waterborne disease organisms, agricultural pests and weeds, as well as other alien species will move to new lands and areas aboard ships, aircraft, trains and trucks; stowing away in shipping containers and packing materials; or riding along with plant nursery stock, and in unprocessed logs, fruits, vegetables and seeds.

Formally, an invasive species is defined as a species that is (i) non-native (or alien) to the ecosystem under consideration, and (ii) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (definition derived from Executive Order 13112 issued February 3, 1999, http://www.invasivespecies.gov/). Invasive species are also known as introduced species or pest species, sometimes called invasive alien species. Invasive species are now a leading cause of global biodiversity loss, environmental change, and economic damages. For instance, the cost to the US is estimated at $137 billion each year (Pimentel 2000). The cost to Canada of only 18 species is over $13 billion each year (McGill School of Environment Community, Invasive Species Risk Assessment Project).

In this dissertation, we address and analyze two important issues about the linkage between international trade and IS risk. The first issue is about the link between intra-industry trade, multilateral trade integration and the invasive species risk. The second one is about the effects of tariff escalation on invasive species risk.

2. Dissertation organization

In this section I provide a brief outline of the chapters that follow. Chapter 2 focuses on the impact of VIEs on quality decisions of firms' behavior. I model a vertically differentiated international duopoly, with one firm in each country. A domestic (say Japanese) and an exporting (say American) firms choose the quality of their goods and then compete in the domestic market. Both quantity and price conjectures are considered. The paper investigates the case where the government of the exporting country imposes a market share VIE before firms' quality decision. I show that the market share VIE is a powerful protection to the exporting firm not only at the quantity or price competition stage but also when the impacts of VIE on quality choice are taken into account. I also find that the market share VIE can affect the equilibrium even though it may not bind at the original equilibrium. It is possible that a VIE below the laissez faire solution binds. The VIE appears not to be "voluntary" since the welfare of the importing country is lower than the laissez faire solution in the presence of the policy, no matter the firms' quality choice.

Chapter 3 analyzes the linkage between protectionism and invasive species hazard in the context of two-way trade and multilateral trade liberalization, the major actual features of agricultural trade and policies in the real world. In a perfectly competitive two way trade model, I show that the multilateral trade integration is much more likely to increase the damage from invasive species than predicted by unilateral trade liberalization under the classical Heckscher-Ohlin-Samuelson framework. I also find that market structure does not affect the qualitative results. I illustrate the analytical results with a stylized model of the world wheat market.

Chapter 4 investigates the interface between trade and invasive species risk, focusing on the existing tariff escalation in agricultural and food-processing markets and its implication on 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. I 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. I also identify policy menus for trade reforms involving tariffs on both raw input and processed goods leading to win-win situations.

Chapter 5 finalizes the dissertation with some conclusion remarks.

CHAPTER 2. VOLUNTARY IMPORT EXPANSIONS AND ENDOGENOUS QUALITY CHOICE

1. Introduction

Together with Voluntary Export Restraints (VERs), Voluntary Import Expansions (VIEs) have become another new protective trade policy since the 1980s. VIEs mandate that a country imports a specific quantity of foreign goods in a specific industry, usually by setting a minimum import market share and often backed by the threat of tariff retaliation (Irwin, 1994). VIEs are most well-known in Japanese-US trade relations. VIEs were initiated with the semiconductor import agreement between these two countries in 1986 (Irwin, 1996). There are also such agreements on automobile parts and automobiles between the two countries. More details about VIEs and its practices are provided in the appendix.

In the academic literature, the research on VIEs is much less than that on VERs. VIEs are often viewed as anticompetitive. It is also believed that, given a choice, the government of the importing country would prefer a rules-oriented policy because of the verification obligations under a VIE. However, more favorable arguments have been offered. Krishna and Morgan (1998) consider an imperfectly competitive model in which the VIE is enforced by the threat of a tariff in the final goods market, while Krishna et al (1998) consider perfectly competitive markets where a VIE on the intermediate good is shown to lower the marginal cost of the final goods. Krishna et al. (2001) show the possibility of procompetitive VIEs in the absence of related market effects. By focusing on subsidies that are paid only when the requirement is met, they show that a VIE can increase aggregate output relative to free trade provided that the right set of firms is targeted.

The issue of quality choice under the effects of trade policy has received considerable attention in international trade and industrial organization. Theoretical models of quality choice can be classified into two categories, simultaneous and sequential. In the international trade literature, most of the theoretical models of endogenous quality fall into the category of simultaneous choice (see, e.g. Falvey 1979, Santoni and Van Cott (1980), Das and Donnenfeld (1987, 1989) among others). In these models quality choice is a short-run variable (Feenstra, 1988) in the sense that quality costs are borne during the market competition stage. These models predict policy induced quality upgrading under perfect competition. There are also some sequential choice models in which firms invest in quality before they compete in the market in prices or quantities. Quality costs are sunk once the market competition stage is reached. In this sense investment in quality is considered a long-run variable. Such models have been developed by Gabszewicz and Thisse (1980, 1986), Shaked and Sutton (1982, 1983, 1984), Sutton (1992), Motta (1993) and Herguera et al. (2000, 2002), Lutz (1997, 2002) among others.

To the best of our knowledge, although there has been an increasing amount of interest in endogenous quality choice and in results-oriented trade policy, the effects of VIE on firms' quality choice have never been considered in the literature. The purpose of this paper is to fill this important knowledge gap and analyze firms' quality choice in the presence of a market share VIE.[1]

The two most relevant papers in providing background for VIE enforcement are Harris (1985) and Krishna (1989) which compare VERs to import tariffs. The two papers differ in the timing of firms' decisions under a VER. Harris assumes that a VER enables the home firm to become an industry price-leader. Krishna however maintains simultaneity in the timing of the firms' decisions. In spite of this difference, the two papers, using a model of price competing firms producing non-perfect substitute goods, arrive to the same conclusion, concluding that a VER set close to the free trade level of imports results in higher prices and profits for both firms than those resulting under an equivalent tariff. We study the effects of VIE on quality choice, adopting Krishna's approach, since it would be more natural to think that implementing a VIE does not change the timing of firms' decisions.

This paper studies the effect of a VIE in a vertically differentiated industry in which a domestic firm competes against an exporting firm of another country in the same market. In the first stage, firms simultaneously choose the quality of their goods before competing in the

---

[1] Qiu and Spencer (2001) divided VIE into three types: content VIE, market share VIE and total value VIE. In the case of automobiles, they are explained as follows: the content VIE requires that autos produced in Home achieve at least some specified foreign content par auto. The market share VIE requires auto to meet a market share target of imported parts and the total value VIE requires that Home imports a given total value of Foreign parts. Alternatively, Ishikawa (1999) separated VIE into the quantity VIE and market share VIE. However, the market share VIE is the most popular among these.

market in the second stage. We consider both possibilities of quantity and price conjectures. In our set-up, firms' actions are preceded by government's announcement of a market share target. Due to the complexity of the analysis, we rely on numerical simulations to derive the results. In accordance with most of the findings in the literature on export targets, we find that the VIEs are anticompetitive in all of our scenarios. As a result, they decrease the importing country's welfare.

One of the contributions of this paper is about the methodology of solving sequential quality choice model in the presence of government intervention. In the previous papers which dealt with tariffs or quantitative restrictions such as quotas or VERs, the authors always divided the quality space into two halves: upper half space and lower half space. In other words, the case where the exporting firm produces high-quality products is considered separate from the low quality product case. This solving methodology is somehow misleading in the sense that, given one firm's quality, the other firm should rather be free to choose to either produce goods at a higher or a lower quality. It should not have to be constrained to being either a low- (or high-) quality producer. This paper is innovative because it provides an avenue to examine the case where the two half spaces are jointly considered, and hence each firm has the freedom of choosing the quality at the level it wants, given the other firm's quality choice.

The remainder of the paper is organized as follows. Section 2 presents the basic structure of the model. Sections 3 and 4 deal with the quantity and price conjectures, respectively. Concluding remarks are in section 5.

2. Basic framework

In the following, we shall model demand for vertically differentiated products along the lines of Mussa and Rosen (1978). We consider the simple case of two countries, referred to as A (for the US) and J (for Japan). There are two firms, one located in each country, producing a vertically differentiated good and selling in the J market. Firms located in country A and J are denoted as firms A and J respectively. High quality is indexed as s_1 and low quality as s_2, with $s_1 > s_2$. There is a continuum of consumers in market J, each is identified by his taste parameter θ, where θ is uniformly distributed over the interval $[0, \Theta]$, $\Theta > 0$ with density

1. The parameter Θ is interpreted as the size of the market. A consumer θ has unit demand for the good and his preferences are represented by a quasi-linear (indirect) utility function:

$$U = \begin{cases} \theta s_i - p_i & \text{if he buys one unit of the good of quality } s_i \text{ at a price } p_i, \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

Total costs are $C(s_i, q_i) = s_i^2 / 2,\ i = 1,2$. The marginal cost of production is 0, independently of the quality level and quality costs are fixed. Quality costs that are borne in the first stage are treated as being sunk in the production stage as in Sutton (1992).

The timing of events of the game is as follows. Country A's government imposes a market share VIE first. Then firms simultaneously choose their qualities. Finally, firms compete in quantity or in price in the J market. The game is solved by appealing to the sub-game perfection solution concept.

Firms' demand functions are derived as follows. Define the taste parameter of the consumer indifferent between buying the high or the low-quality good as $\theta_{12} = \Delta p / \Delta s$ where $\Delta p = p_1 - p_2$ and $\Delta s = s_1 - s_2$, and that of the consumer indifferent between buying the low-quality good and not buying at all is $\theta_{02} = p_2 / s_2$. Hence, the market demand is divided into three segments: non-purchasers for whom $\theta < \theta_{02}$, purchasers of the low-quality good for whom $\theta \in [\theta_{02}, \theta_{12}]$ and purchasers of the high-quality goods for whom $\theta \in [\theta_{12}, \Theta]$. As θ is uniformly distributed on $[0, \Theta]$, we derive the demands for the high and low quality good as

$$q_1(p_1, p_2) = \Theta - \frac{p_1 - p_2}{s_1 - s_2} \text{ and } q_2(p_1, p_2) = \frac{p_1 - p_2}{s_1 - s_2} - \frac{p_2}{s_2}. \quad (2)$$

The inverse demands are

$$p_1(q_1, q_2) = \Theta s_1 - s_1 q_1 - s_2 q_2 \text{ and } p_2(q_1, q_2) = (\Theta - q_1 - q_2) s_2. \quad (3)$$

3. Cournot competition

3.1. Free trade outcomes

Assume that firms compete in quantity in the last stage of the game. We first study quality choice under free trade. Following Motta (1993), for any given pair of qualities (s_1, s_2), firm i chooses its quantities to maximize its (gross) profits, $p_i(q_i, q_j)q_i$, given the quantity of its rival q_j as:

$$\pi_1^g = q_1(\Theta s_1 - s_1 q_1 - s_2 q_2) \text{ and } \pi_2^g = s_2 q_2(\Theta - q_1 - q_2)$$

where g stands for gross. The quantity reaction functions of the firms are

$$BR_1^c(q_2) = 0.5\Theta - q_2 s_2 / 2s_1 \text{ and } BR_2^c(q_1) = 0.5\Theta - 0.5q_1. \tag{4}$$

The resulting equilibrium quantities are

$$q_1^c = \Theta(2s_1 - s_2)/(4s_1 - s_2) \text{ and } q_2^c = \Theta s_1 /(4s_1 - s_2). \tag{5}$$

In the second stage, firm i anticipates the equilibrium quantities of the continuation game obtained as in (5) and chooses its quality s_i to maximizes its reduced-form profit $\pi_i^c(s_i, s_j)$ as:

$$\pi_1 = \frac{\Theta^2 s_1 (2s_1 - s_2)^2}{(4s_1 - s_2)^2} - \frac{s_1^2}{2} \text{ and } \pi_2 = \frac{\Theta^2 s_1^2 s_2}{(4s_1 - s_2)^2} - \frac{s_2^2}{2}.$$

The first order conditions that define firms' best quality level are:

$$\frac{\partial \pi_1}{\partial s_1} = \frac{\Theta^2 (2s_1 - s_2)(8s_1^2 - 2s_1 s_2 + s_2^2)}{(4s_1 - s_2)^3} - s_1 \text{ and } \frac{\partial \pi_2}{\partial s_2} = \frac{\Theta^2 s_1^2 (4s_1 + s_2)}{(4s_1 - s_2)^3} - s_2.$$

We proceed to find firms' quality best response. Denote $\rho = s_2 / s_1$, we have:

$$\pi_1 = \frac{\Theta^2 s_1 (2 - \rho)^2}{(4 - \rho)^2} - \frac{s_1^2}{2} \text{ and } \pi_2 = \frac{\Theta^2 s_2}{(4 - \rho)^2} - \frac{s_2^2}{2}; \text{ and}$$

$$\frac{\partial \pi_1}{\partial s_1} = \frac{\Theta^2 (2 - \rho)(8 - 2\rho + \rho^2)}{(4 - \rho)^3} - s_1 \text{ and } \frac{\partial \pi_2}{\partial s_2} = \frac{\Theta^2 (4 + \rho)}{(4 - \rho)^3} - s_2. \tag{6}$$

In (s_A, s_J) space, define domain I as the area where $s_A \geq s_J$, and domain II as the area where $s_A \leq s_J$. Given s_J, firm A's reduced profits are:

$$\pi_A = \begin{cases} \pi_1(s_1 = s_A, s_2 = s_J) = \pi_A^{\mathrm{I}} \text{ for } s_A \geq s_J \\ \pi_2(s_1 = s_J, s_2 = s_A) = \pi_A^{\mathrm{II}} \text{ for } s_A \leq s_J \end{cases}.$$

Therefore, firm A's best response is:

$$s_A^{BR} = \begin{cases} s_1^{BR}(s_2 = s_J) = s_A^{BR'} \text{ for } s_A \geq s_J \\ s_2^{BR}(s_1 = s_J) = s_A^{BR''} \text{ for } s_A \leq s_J \end{cases}.$$

In domain II, since $\lim_{s_A \to s_J^-} \frac{\partial \pi_A}{\partial s_A} = \lim_{s_A \to s_J^-} \frac{\partial \pi_2}{\partial s_2}\Big|_{s_2 = s_A, s_1 = s_J} = \frac{5}{27} - s_J$, if $s_J \leq \frac{5}{27}$, then there is no local best response because firm A is always better off by increasing its quality. The local best response only exists for $s_J \geq \frac{5}{27}$. Furthermore, in this domain, $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A}{\partial s_A}\right) = -\frac{2\Theta^2 s_A s_J (s_A + 8 s_J)}{(4 s_J - s_A)^4} < 0$ which leads to $\frac{\partial s_A^{BR''}}{\partial s_J} < 0$.

Similarly, in domain I, since $\lim_{s_A \to s_J^+} \frac{\partial \pi_A}{\partial s_A} = \lim_{s_A \to s_J^+} \frac{\partial \pi_1}{\partial s_1}\Big|_{s_1 = s_A, s_2 = s_J} = \frac{7}{27} - s_J$, firm A's best response only exists for $s_J \leq \frac{7}{27}$. Also, $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A}{\partial s_A}\right) = \frac{8\Theta^2 s_A s_J (s_A - s_J)}{(4 s_A - s_J)^4} > 0$ implies that $\frac{\partial s_A^{BR'}}{\partial s_J} > 0$ in this domain.

By simulation, the exact shapes of firm A's quality best responses in the two domains are obtained as follows.

Figure 1a: $s_A^{BR^I}$ and the 45^0 line against s_J in domain I, i.e. for $s_A \geq s_J$.

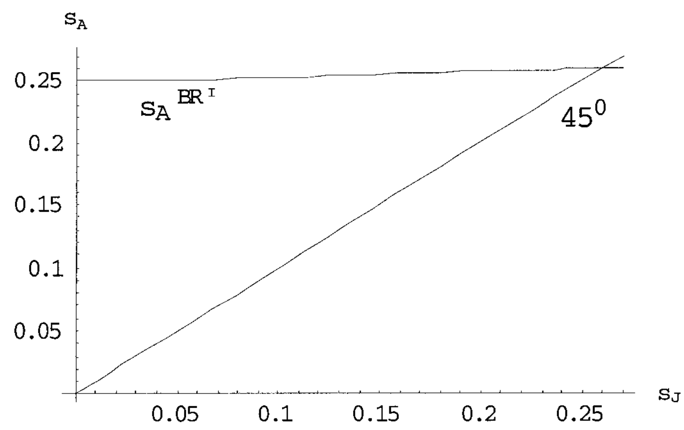
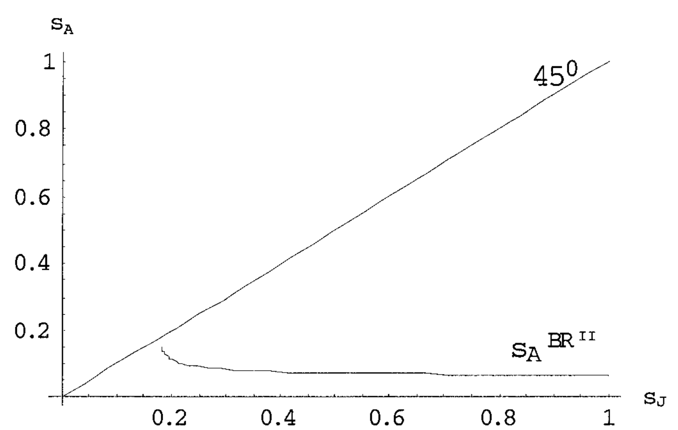
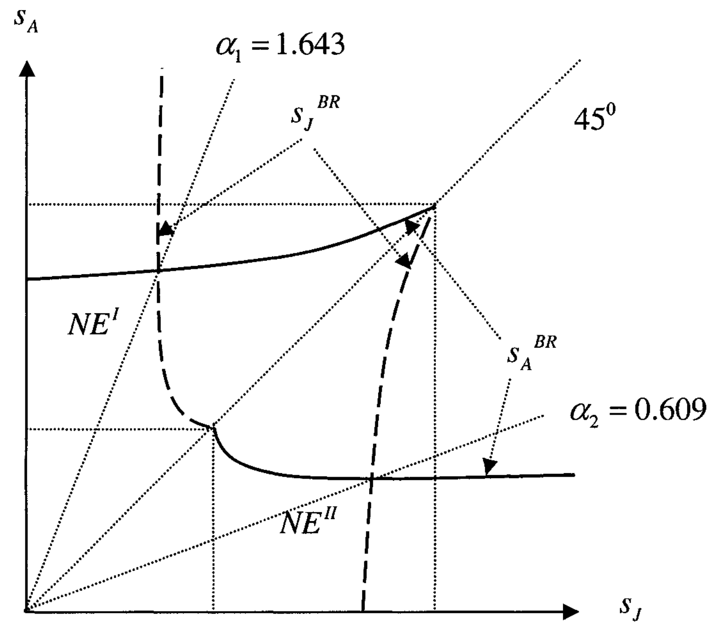


Figure 1b: $s_A^{BR^{II}}$ and the 45^0 line against s_J in domain II, i.e. for $s_A \leq s_J$.



Similar argument holds for firm J's quality best response. Therefore, we have 2 local equilibria which are represented graphically as the following:

Figure 2: Equilibrium in the unconstrained Cournot game.



Similar to Herguera et al. (2000), the two symmetric equilibria are characterized as follows, where if A=1 and J=2 then it is the NE^I, and if A=2 and J=1 then it is the NE^{II} :

$$s_1^c = 0.252\Theta^2,\ s_2^c = 0.09\Theta^2,\ q_1^c = 0.451\Theta,\ q_2^c = 0.275\Theta,\ \pi_1^c = 0.02\Theta^4,\ \pi_2^c = 0.003\Theta^4,$$

$$s_{av}^c \equiv \frac{q_1^c s_1^c + q_2^c s_2^c}{q_1^c + q_2^c} = 0.191,\ \rho^c = \frac{s_2^c}{s_1^c} = 0.357,\ \alpha_1^c = \frac{q_1^c}{q_2^c} = 1.643,\ \alpha_2^c = \frac{q_2^c}{q_1^c} = 0.609$$

where s_{av} is the average (quantity-weighted) quality in the market, ρ is the quality gap, α_i is firm i's market share in equilibrium for i=1,2.[2] The parameter ρ can also be interpreted as the degree of product differentiation between the two variants.

The domestic welfare is the sum of consumer gains and home firm profit:

---

[2] This market share represents the underlying VIEs as being discussed in the constrained game. α_i is interpreted as firm A's market share in free trade if firm A produces high quality good (for i=1) and low quality good (for i=2). These market shares will be used as the benchmark in the discussion in the constrained game.

$$W_J = \pi_J^* + \int_{\theta_{02}^*}^{\theta_{12}^*}(zs_2^* - p_2^*)dz + \int_{\theta_{12}^*}^{1}(zs_1^* - p_1^*)dz\,.$$

where the underscript $J = \{1,2\}$ depending on whether firm J produces the high- or the low-quality good and a star indicates the equilibrium level of the corresponding variable. The potential welfare of country J at the free trade equilibrium are $W_1 = 0.06\Theta^4$ and $W_2 = 0.043\Theta^4$ for the situation where firm J produces the high- or the low-quality good.

We need to verify whether these two local equilibria are global equilibria. Assume that $\Theta = 1$. For NE^I, given $s_J^{NE^I} = 0.09$, firm A does not want to deviate to domain II. However, given $s_A^{NE^I} = 0.252$, firm J may want to deviate and play its best response in domain II depending on profits. It firm J deviates, it gets profits $\pi_J^{II,NE^I} = \pi_1(s_1 = s_J, s_2 = s_A) = \pi_1\left(s_1 = s_J^{BR^{II}}\left(s_A = s_A^{NE^I}\right), s_2 = s_A^{NE^I}\right) = -0.004$ which is lower than the profits from not deviating which are 0.003. Therefore, firm J has no incentive to deviate and NE^1 is a global equilibrium.

By symmetry, NE^2 is also a global equilibrium. Hence the unconstrained model has two pure strategy symmetric global equilibria.

3.2. Effects of a VIE

Assume that in the first stage, country A's government implements a market share target α of firm A in market J so that q_A and q_J must satisfy $q_A / q_J \geq \alpha$.[3] It attempts to do this via a VIE scheme (α,V) where α is the minimum market share target that it wants to achieve and V is a penalty cost the government J credibly commits to as a threat on firm J if the target α is not effectively implemented. The threat in reality can be based upon various retaliatory trade measures (closure of one's own domestic market to the other's exports, tariffs, quotas, etc.) imposed by country A related to country J or firm J.

---

[3] In reality, market share targets are imposed in the form of firm A's quantity over the total quantity sold in market J, that is $q_A /(q_A + q_J) \geq r$. Since there is one to one relation between r and α, that is $r = \alpha/(1+\alpha)$, we use the share α instead of r for the sake of simplicity.

We proceed to find the firms' best responses in the presence of the sales target. Relating to firm A's response function, a VIE does not affect its best response function since the penalty, if imposed on firm J, does not alter the profit function of that firm, nor the timing of its pricing (or quantity) decision.

Turning to firm J, it faces two possibilities: either the minimum market share r is satisfied and the profit function is $\pi_J(q_A,q_J)$, or it is not and the penalty cost V is applied, hence the profit function is $\pi_J(q_A,q_J)-V$.

When the export target is satisfied, the optimal point for firm J is $q_0 = BR_J^c$ as determined in equations (4). This is the case when $q_A/q_J \geq \alpha$, i.e. when firm A's quantity is large enough, and firm J's quantity that makes the constraints bind is larger than q_0, such as q_I in figure 1. For this to be the case, the following must hold:

$$q_A/\alpha > BR_J^c(q_A) \Leftrightarrow q_A > q_A^*. \qquad (7)$$

If firm J's quantity required to meet the target is q_{II}, for example, then the firm will choose to meet the target. This is the case when

$$\pi^J(q_A,q_A/\alpha) \geq \pi^J(q_A,BR_J^c(q_A)) - V \Leftrightarrow q_A \in \left[\hat{q}_A, q_A^*\right]. \qquad (8)$$

If firm J's quantity required to meet the target is q_{III}, for example, then the firm will choose to violate the constraint. This holds when

$$\pi^J(q_A,q_A/\alpha) < \pi^J(q_A,BR_J^c(q_A)) - V \Leftrightarrow q_A < \hat{q}_A. \qquad (9)$$

The threshold quantities q_A^* and $\hat{q}_A$ are shown in figure 2. Therefore, firm J's best response in the presence of the export target is derived and depicted in bold type in this figure.

One could see that, since the target is set above firm A's share in the free trade equilibrium, q_A^* is always higher than q_A^C. However, $\hat{q}_A$ can be higher or lower than q_A^C depending on whether the penalty V is low or high. The case as drawn in figure 2 happens when the penalty is high enough. In consequence, the equilibrium under a VIE is a pair of quantities $\left(q_A^{VIE}, q_J^{VIE}\right)$ as shown in the same figure.

We focus on the size of the penalty cost V so that the VIE binds. That is, the V that makes $\hat{q}_A \leq q_A^C$. The analytical expression of q_A^* and $\hat{q}_A$ can be derived assuming that the foreign firm produces the high- or low- quality products. They will depend on (s_A, s_J).

We assume, similar to Krishna (1989) and Greaney (1996), that the impostition of a restrictive VIE does not change the nature of competition of the game: both firms still move simultaneously under the VIE. It will be shown that it is possible to have multiple equilibria of the game. Also in the scope of this study, we focus only on pure strategy equilibria.

Figure 3a: Domestic firm's profit.

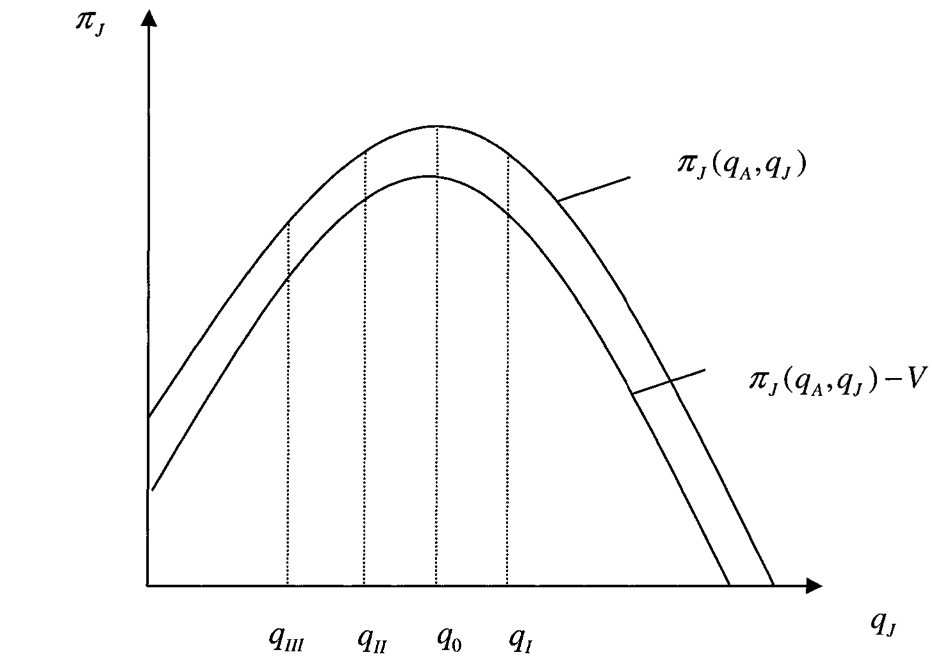
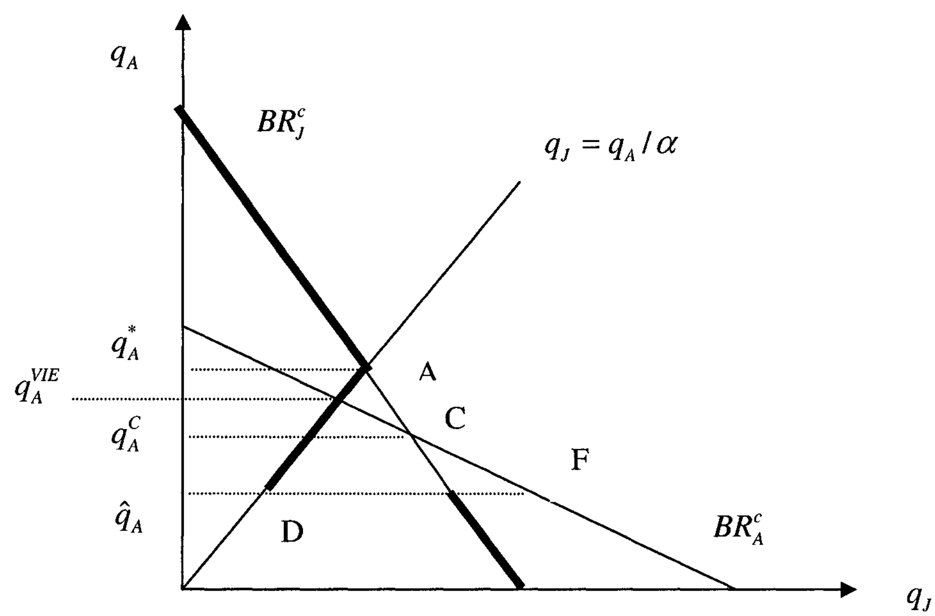


Figure 3b: Firms' quantity best responses in The Cournot game.



3.2.1. Effects of a low market share target

Assume that V is large enough such that the constraints bind, that is $q_A / q_J \geq \alpha$, and $\alpha \in [1/2,1]$. Given the quality choice, we need to know when the constraints bind.

For $s_A > s_J$, the constraints never bind since $\frac{q_A}{q_J} = 2 - \frac{s_J}{s_A} > \alpha$ for all $\alpha \in [1/2,1]$. This is still domain I, and the usual net profits also hold where

$$\pi_A{}^I = \frac{s_A(2-\rho)^2}{(4-\rho)^2} - \frac{s_A{}^2}{2} = \pi_1(s_1 = s_A, s_2 = s_J) \text{ and}$$

$$\pi_J{}^I = \frac{s_J}{(4-\rho)^2} - \frac{s_J{}^2}{2} = \pi_2(s_1 = s_A, s_2 = s_J). \tag{10}$$

The quality best responses are $s_A{}^{BR^I}(s_J) = s_1{}^{BR}(s_2 = s_J)$, $s_J{}^{BR^I}(s_A) = s_2{}^{BR}(s_1 = s_A)$.

For $s_A < s_J$, if $\frac{q_A}{q_J} = \frac{1}{2-\rho} \geq \alpha \Leftrightarrow \rho \geq \frac{2\alpha - 1}{\alpha} \equiv \hat{\rho}$, again the constraints do not bind. This is a part of the region that we defined in the previous section as domain II. The usual net profits hold where

$$\pi_J{}^{II} = \frac{s_J(2-\rho)^2}{(4-\rho)^2} - \frac{s_J{}^2}{2} = \pi_1(s_1 = s_J, s_2 = s_A) \text{ and}$$

$$\pi_A{}^{II} = \frac{s_A}{(4-\rho)^2} - \frac{s_A{}^2}{2} = \pi_2(s_1 = s_J, s_2 = s_A). \tag{11}$$

The quality best responses are $s_J{}^{BR^{II}}(s_A) = s_1{}^{BR}(s_2 = s_A)$, $s_A{}^{BR}(s_J) = s_2{}^{BR^{II}}(s_1 = s_J)$.

If $\rho \leq \frac{2\alpha - 1}{\alpha} \equiv \hat{\rho}$ then the constraint binds. Define this region as domain III. In this domain, firm A's quantity reaction function $q_A{}^{BR}$ remains the same as in (4): $q_A{}^{BR} = 0.5 - 0.5 q_J$, while firm J's quantity is such that the constraint just binds, that is $q_A / q_J = \alpha$. Therefore, the last stage equilibrium quantities are

$$q_A = \frac{\alpha}{1+2\alpha} \text{ and } q_J = \frac{1}{1+2\alpha}. \qquad (12)$$

In the second stage, firms simultaneously choose their quality level by maximizing net profits, given the firms' quantity strategies and hence price choice at the last stage. The net profits are:

$$\pi_J^{III} = \frac{\alpha(2-\rho)}{(1+2\alpha)^2} - \frac{s_J^{\ 2}}{2} \text{ and } \pi_A^{III} = \frac{\alpha^2 s_A}{(1+2\alpha)^2} - \frac{s_A^{\ 2}}{2}. \qquad (13)$$

Quality best responses are:

$$s_J^{\ BR^{III}} = \frac{2\alpha}{(1+2\alpha)^2} = s_J^{\ NE^{III}} \text{ and } s_A^{\ BR^{III}} = \frac{\alpha^2}{(1+2\alpha)^2} = s_A^{\ NE^{III}}. \qquad (14)$$

For consistency, a local equilibrium exists in domain III only if:

$$\frac{s_A *}{s_J *} \le \frac{2\alpha - 1}{\alpha} \Rightarrow \frac{\alpha}{2} \le \frac{2\alpha-1}{\alpha} \Rightarrow 0.586 \le \alpha \le 1.$$

Other characteristics of NE^{III} are as follows:

$$s_{ave}^{\ NE^{III}} = \frac{\alpha(2+\alpha^2)}{(1+\alpha)(1+2\alpha)^2},\ p_A^{\ NE^{III}} = \frac{\alpha^3}{(1+2\alpha)^3},\ p_J^{\ NE^{III}} = \frac{(4-\alpha)\alpha^2}{(1+2\alpha)^2},\ \pi_A^{\ NE^{III}} = \frac{\alpha^4}{2(1+2\alpha)^4},$$

$$\pi_J^{\ NE^{III}} = \frac{\alpha^2(2+15\alpha+40\alpha^2+40\alpha^3-16\alpha^5)}{(1+2\alpha)^8}, \text{ and}$$

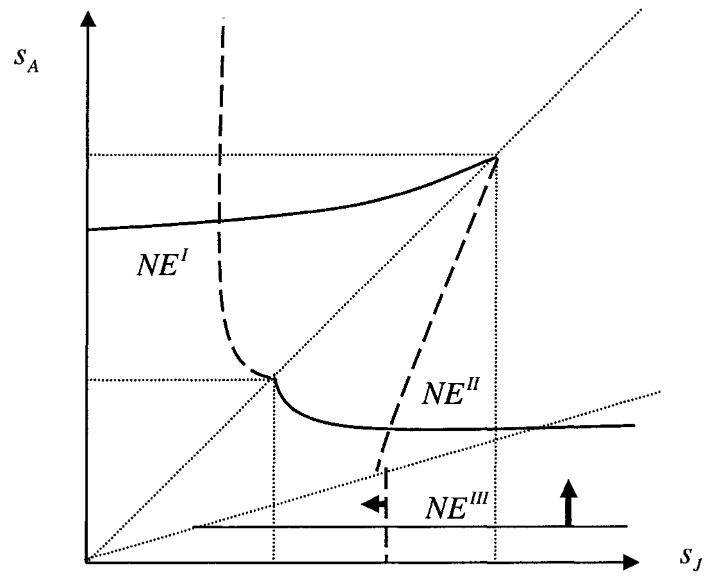
$$CS^{NE^{III}} = \frac{2.\,\alpha\,(2.3593+\alpha)\,(0.847708-0.359304\,\alpha+\alpha^2)\,(0.249951+0.999902\,\alpha+\alpha^2)\,(0.250049+1.0001\,\alpha+\alpha^2)}{(0.5+\alpha)^2\,(1+2\,\alpha)^2\,(1.+2.\,\alpha)^4}. \qquad (15)$$

The quality best responses in three domains are plotted in figure 4, assuming that three local equilibria exist in three domains. The bold arrows show the shift of the best responses in domain III when the share target increases.[4]

---

[4] It will be shown that figure 4 holds for $\alpha \in [0.586, 0.609]$.

Figure 4: Local equilibrium of the constrained Cournot game for $\alpha \in [0.5,1]$.



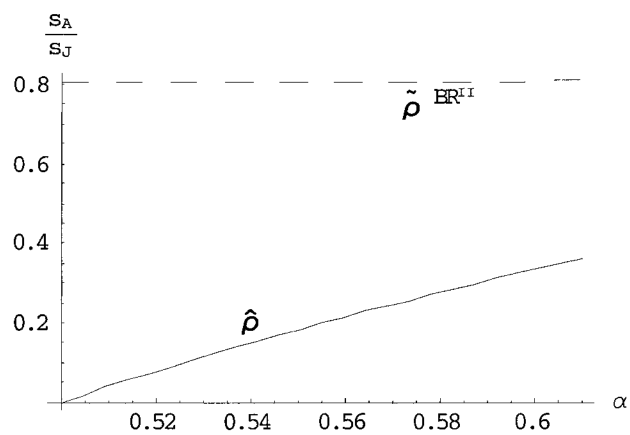
For this to happen, the quality gap in equilibrium $\rho^{NE^{II}} = \frac{s_A^{NE^{II}}}{s_J^{NE^{II}}}$ must be bigger than $\hat{\rho} = \frac{2\alpha - 1}{\alpha}$, that is $\hat{\rho} = \frac{2\alpha-1}{\alpha} \geq \frac{0.09}{0.252} \Rightarrow \alpha \leq 0.609$. Note that $\alpha = 0.609$ is the laissez-faire market share where firm A is low-quality producer. So, NE^{II} exists only when the share target is lower than the laissez-faire share. Additionally, to get figure 4, ones knows that $s_A^{NE^{III}} < s_A^{NE^{II}} = 0.09$ if NE^{II} exists, $s_A^{NE^{III}} < 5/27$ for all $\alpha \in [0.5,1]$; and $s_J^{NE^{III}} < s_J^{NE^{II}} = 0.252$ if NE^{II} exists, and $5/27 < s_A^{NE^{III}} < 7/27$ for all $\alpha \in [0.5,1]$. Finally, $\lim_{\frac{s_A}{s_J} \to \hat{\rho}} s_J^{BR^{II}}$ is compared to $s_J^{NE^{III}}$.[5] Since the limit cannot be evaluated directly, $s_J^{BR^{II}}(s_A)$ is rewritten in the form of s_A in terms of s_J and is denoted as $\tilde{s}_J^{BR^{II}}(s_J)$. Next, $\tilde{s}_J^{BR^{II}}(s_J)$ is evaluated at $s_J = s_J^{NE^{III}}$, and $\tilde{\rho}^{BR^{II}} = \tilde{s}_J^{BR^{II}}(s_J = s_J^{NE^{III}}) / s_J^{NE^{III}}$ is computed. $\tilde{\rho}^{BR^{II}}$ is then

---

[5] If $\lim_{\frac{s_A}{s_J} \to \hat{\rho}} s_J^{BR^{II}} > s_J^{NE^{III}}$ then a portion of firm J's best response would coincide with the ray $\hat{\rho} = \frac{2\alpha - 1}{\alpha}$.

compared to $\hat{\rho}$. If $\tilde{\rho}^{BR^{II}} \begin{smallmatrix} < \\ - \\ > \end{smallmatrix} \hat{\rho}$ then $\lim_{\frac{s_A}{s_J}\to\hat{\rho}} s_J^{BR^{II}} \begin{smallmatrix} > \\ - \\ < \end{smallmatrix} s_J^{NE^{III}}$. Plotting $\tilde{\rho}^{BR^{II}}$ and $\hat{\rho}$ against $\alpha \in [0.5, 0.61]$ in figure 5, it is obvious that $\tilde{\rho}^{BR^{II}} > \hat{\rho}$ for all $\alpha \in [0.5, 0.61]$. Hence $\lim_{\frac{s_A}{s_J}\to\hat{\rho}} s_J^{BR^{II}} < s_J^{NE^{III}}$.

Figure 5: Quality gap versus α.



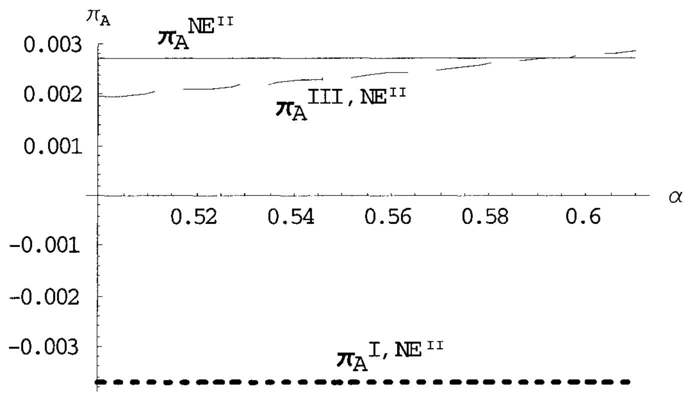
In summary, the local equilibrium of the constrained Cournot game is as follows: if $\alpha \in [0.5, 0.586]$, then there are two local equilibria: NE^I, NE^{II}, the same as in the unconstrained case; if $\alpha \in [0.586, 0.609]$, then there are three local equilibria: NE^I, NE^{II}, NE^{III}; if $\alpha \in [0.609, 1]$, then there are two local equilibria: NE^I, NE^{III}. We will verify whether the local equilibria are global equilibria.

For NE^I, from the previous section and with the description of the best responses, it is evident that neither firm wants to deviate given the other firm's choice of quality. Therefore, NE^I is a global equilibrium for all $\alpha \in [0.5, 1]$.

For NE^{II} which exists for $\alpha \in [0.5, 0.609]$, given $s_A^{NE^{II}} = 0.09$, firm J does not want to deviate. For firm A, its profits from not deviating are $\pi_A^{NE^{II}} = 0.00275$ while its profits from deviating to domain I are $\pi_A^{I,NE^{II}} = -0.004$. On the other hand, firm A's profits from deviating to domain III are $\pi_A^{III,NE^{II}}\left(s_J = s_J^{NE^{II}}, s_A = s_A^{BR^{III}}(s_J = s_J^{NE^{II}})\right) = \dfrac{\alpha^4}{2(1+2\alpha)^4}$.

Plotting the profits from three scenarios in figure 6, it is clear that firm A's profits from not deviating $\pi_A^{NE^{II}}$ are the highest profits for $\alpha \in [0.5, 0.596]$. Hence, NE^{II} **is a global equilibrium for** $\alpha \in [0.5, 0.596]$.

Figure 6: Firm A's profits versus α.



To understand why a region II equilibrium may be knocked out, $\lim\limits_{s_A/s_j \to \hat{\rho}^+} \dfrac{\partial \pi_A^{II}}{\partial s_A}$ is compared to $\lim\limits_{s_A/s_j \to \hat{\rho}^-} \dfrac{\partial \pi_A^{III}}{\partial s_A}$. By equations (6) and (12), we have:

$$\lim_{s_A/s_j \to \hat{\rho}^+} \frac{\partial \pi_A^{II}}{\partial s_A} = \frac{(4+\hat{\rho})}{(4-\hat{\rho})^3} - \hat{\rho} s_J \text{, and}$$

$$\lim_{s_A/s_j \to \hat{\rho}^-} \frac{\partial \pi_A^{III}}{\partial s_A} = \frac{\alpha^2}{(1+2\alpha)^2} - \hat{\rho} s_J = \frac{1}{(4-\hat{\rho})^2} - \hat{\rho} s_J .^{6}$$

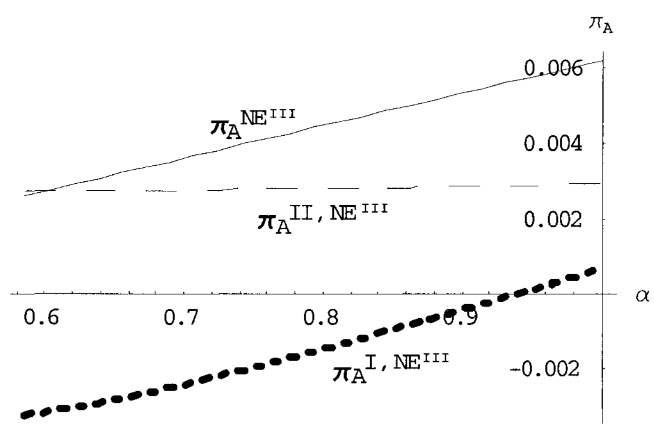
Hence $\lim\limits_{s_A/s_j \to \hat{\rho}^-} \dfrac{\partial \pi_A^{III}}{\partial s_A} < \lim\limits_{s_A/s_j \to \hat{\rho}^+} \dfrac{\partial \pi_A^{II}}{\partial s_A}$. The comparison suggests that, starting at NE^{II}, given $s_J^{NE^{II}}$, in domain II, when firm A decreases s_A, π_A decreases. However, when the transition

[6] Since $\hat{\rho} = \dfrac{2\alpha - 1}{\alpha}$.

to domain III occurs, decreases in s_A increase π_A. Hence the local equilibrium NE^{II} may be knocked out by a deviation to domain III.

For NE^{III}, it is unambiguous that given $s_A^{NE^{III}} = \dfrac{\alpha^2}{(1+2\alpha)^2}$, firm J does not want to deviate. For firm A, given $s_J^{NE^{III}} = \dfrac{2\alpha}{(1+2\alpha)^2}$, its profits from not deviating are $\pi_A^{NE^{III}}\left(s_A = s_A^{NE^{III}}, s_J = s_J^{NE^{III}}\right)$. In addition, that firm's profits from deviating to domain II and choosing $s_A = s_A^{BR^{II}}(s_A = s_A^{NE^{III}})$ are $\pi_A^{II,NE^{III}}\left(s_A = s_A^{BR^{II}}(s_A = s_A^{NE^{III}}), s_J = s_J^{NE^{III}}\right)$. On the other hand, its profits from deviating to domain I and choosing $s_A = s_A^{BR^{I}}(s_A = s_A^{NE^{III}})$ are $\pi_A^{I,NE^{III}}\left(s_A = s_A^{BR^{I}}(s_A = s_A^{NE^{III}}), s_J = s_J^{NE^{III}}\right)$. The profits from three scenarios $\pi_A^{NE^{III}}$, $\pi_A^{II,NE^{III}}$ and $\pi_A^{I,NE^{III}}$ are plotted against $\alpha \in [0.586,1]$ in figure 7. It is clear that the profits from not deviating are the highest for $\alpha \in [0.599,1]$.

Figure 7: Firm A's profit versus α.



Hence, NE^{III} **is a global equilibrium for** $\alpha \in [0.599,1]$. It has just been shown that a region III equilibrium can exist for the market share slightly below the laissez faire solution. This happens because the constraints give firm A an incentive to decrease the quality since a market share target is guaranteed for that firm. Hence, compared to laissez faire solution, firm A can respect the constraints and suffer some revenue loss but lower the quality and hence save on quality costs. This explanation is reinforced when we examined the comparative statics in result 2.

3.2.2. Effects of a high market share target

Suppose $\alpha > 1$. Given the quality choice, we need to know when the constraints bind.

For $s_A < s_J$, the constraints always bind since $q_A / q_J < \alpha$. This property was described previously as in **domain III** which now is the whole area under the 45^0 line. Profit functions and reaction functions remain as derived earlier. Profits are:

$$\pi_J^{III} = \frac{\alpha(2s_J - s_A)}{(1+2\alpha)^2} - \frac{s_J^{\ 2}}{2} \text{ and } \pi_A^{III} = \frac{\alpha^2 s_A}{(1+2\alpha)^2} - \frac{s_A^{\ 2}}{2}.$$

And the quality best responses are:

$$s_J^{\ BR^{III}} = \frac{2\alpha}{(1+2\alpha)^2} = s_J^{\ NE^{III}} \text{ and } s_A^{\ BR^{III}} = \frac{\alpha^2}{(1+2\alpha)^2} = s_A^{\ NE^{III}}.$$

For $s_A > s_J$, denote $\rho = s_A / s_J > 1$, if $\frac{q_A}{q_J} = \frac{2s_A - s_J}{s_A} = \frac{2\rho - 1}{\rho} \geq \alpha \Leftrightarrow \rho \geq \frac{1}{2-\alpha}$ then the constraints do not bind and the unconstrained reaction functions and profit functions hold. In the quality space, this area is a part of the domain which we defined previously as **domain I** (refer to figure 9 in page 25 for the new domain I). Hence, profit functions in this domain are:

$$\pi_A^{\ I} = \frac{s_A(2s_A - s_J)^2}{(4s_A - s_J)^2} - \frac{s_A^{\ 2}}{2} = \frac{s_A(2\rho-1)^2}{(4\rho-1)^2} - \frac{s_A^{\ 2}}{2} \text{ and } \pi_J^{\ I} = \frac{s_A^{\ 2} s_J}{(4s_A - s_J)^2} - \frac{s_J^{\ 2}}{2} = \frac{\rho^2 s_J}{(4\rho-1)^2} - \frac{s_J^{\ 2}}{2}.$$

The first order conditions that define the quality best responses are:

$$\frac{\partial \pi_A^{\ I}}{\partial s_A} = \frac{(2s_A - s_J)(8s_A^{\ 2} - 2s_A s_J + s_J^{\ 2})}{(4s_A - s_J)^3} - s_A = \frac{(2\rho-1)(8\rho^2 - 2\rho + 1)}{(4\rho-1)^3} - s_A \text{ and}$$

$$\frac{\partial \pi_J^{\ I}}{\partial s_J} = \frac{s_A^{\ 2}(4s_A + s_J)}{(4s_A - s_J)^3} - s_J = \frac{\rho^2(4\rho+1)}{(4\rho-1)^3} - s_J. \qquad (16)$$

Also, $s_A^{\ BR^I}(s_J) = s_1^{\ BR}(s_2 = s_J)$ and $s_J^{\ BR^I}(s_A) = s_2^{\ BR}(s_1 = s_A)$ are the quality best responses. We need to know whether there exists a local equilibrium in domain I. If it exists then the quality gap in equilibrium $\rho^{NE^I} = \frac{s_A{}^{NE^I}}{s_J{}^{NE^I}} = \frac{0.252}{0.09}$ must be bigger than $\hat{\rho} = \frac{1}{2-\alpha}$, or $\alpha \in [1, 1.643]$. Recall that the laissez-faire market share where firm A is the high-quality producer is 1.643. So it is logical that NE^I locally exists only when the share target is lower than the free trade share.

On the other hand, also for $s_A > s_J$, if $\frac{q_A}{q_J} \leq \alpha \Leftrightarrow 1 < \rho \leq \frac{1}{2-\alpha}$ then the constraints bind. Define this area as **domain IV** (refer to figure 9 to view this domain). This holds for $\alpha \in [1, 2]$. This is the meaningful domain of α for the high market share target case. We restrict our analysis in this domain of α. Assume that the punishment V is designed to be large enough so that the constraints bind, then $q_A / q_J = \alpha$, and $q_A{}^{BR}$ remains the same as in (4): $q_A{}^{BR} = 0.5 - 0.5 q_J s_J / s_A$. Therefore, the last stage equilibrium quantities are:

$$q_A = \frac{\alpha s_A}{s_J + 2\alpha s_A} = \frac{\alpha\rho}{1+2\alpha\rho} \text{ and } q_J = \frac{s_A}{s_J + 2\alpha s_A} = \frac{\rho}{1+2\alpha\rho}. \quad (17)$$

In the second stage, firms simultaneously choose their quality level by maximizing net profits, given the firms' quantity strategies and hence price choice at the last stage. The net profits are:

$$\pi_A^{IV} = \frac{\alpha^2 s_A{}^3}{(s_J + 2\alpha s_A)^2} - \frac{s_A{}^2}{2} = \frac{\alpha^2 \rho^2 s_A}{(1+2\alpha\rho)^2} - \frac{s_A{}^2}{2} \text{ and}$$

$$\pi_J^{IV} = \frac{s_A s_J [(\alpha-1)s_A + s_J]}{(s_J + 2\alpha s_A)^2} - \frac{s_J{}^2}{2} = \frac{s_J [1+\rho(\alpha-1)]}{(1+2\alpha\rho)^2} - \frac{s_J{}^2}{2}. \quad (18)$$

The first order conditions that define the quality best responses are:

$$\frac{\partial \pi_A^{IV}}{\partial s_A} = \frac{\alpha^2 s_A{}^2 (3 s_J + 2\alpha s_A)}{(s_J + 2\alpha s_A)^3} - s_A = \frac{\alpha^2 \rho^2 (3 + 2\alpha\rho)}{(1+2\alpha\rho)^3} - s_A \text{ and}$$

$$\frac{\partial \pi_J^{IV}}{\partial s_J} = \frac{s_A{}^2 [(\alpha-1)2\alpha s_A + (3\alpha+1)s_J]}{(s_J + 2\alpha s_A)^3} - s_J = \frac{\rho^2 [(\alpha-1)2\alpha\rho + (3\alpha+1)]}{(1+2\alpha\rho)^3} - s_J. \quad (19)$$

Since $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A^{IV}}{\partial s_A}\right) = -\frac{6\alpha^2 s_A{}^2 s_J}{(s_J + 2\alpha s_A)^4} < 0$, it follows that $\frac{\partial s_A{}^{BR^{IV}}}{\partial s_J} < 0$. Similarly,

$\frac{\partial}{\partial s_A}\left(\frac{\partial \pi_J^{IV}}{\partial s_J}\right) = -\frac{2s_A s_J\,[(\alpha s_A - s_J) + 3\alpha(s_A - s_J)]}{(s_J + 2\alpha s_A)^3} < 0$ leads to $\frac{\partial s_J{}^{BR^{IV}}}{\partial s_A} < 0$.

The exact shapes of the quality best responses in domain IV are obtained by simulation as below.

Figure 8a: $s_A{}^{BR^{IV}}$, the 45^0 line and $\frac{2\alpha - 1}{\alpha} s_J$ w.r.t. s_J for $\alpha = 1.6$

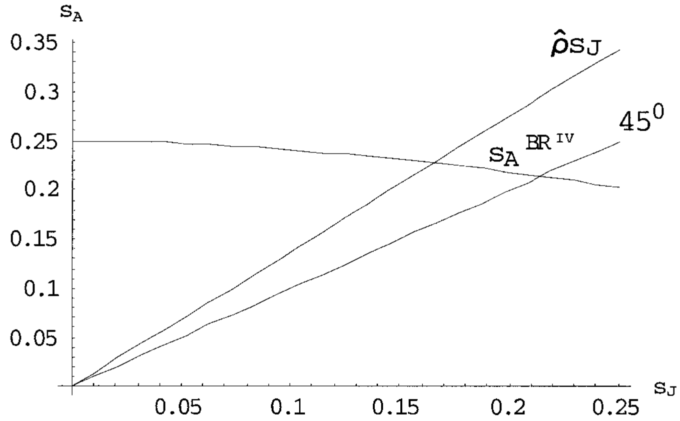
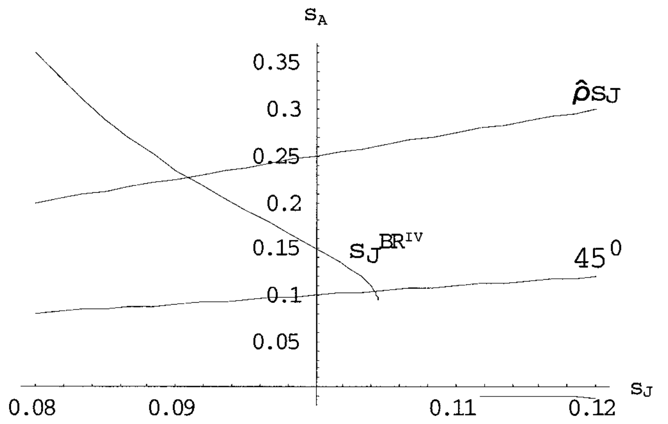
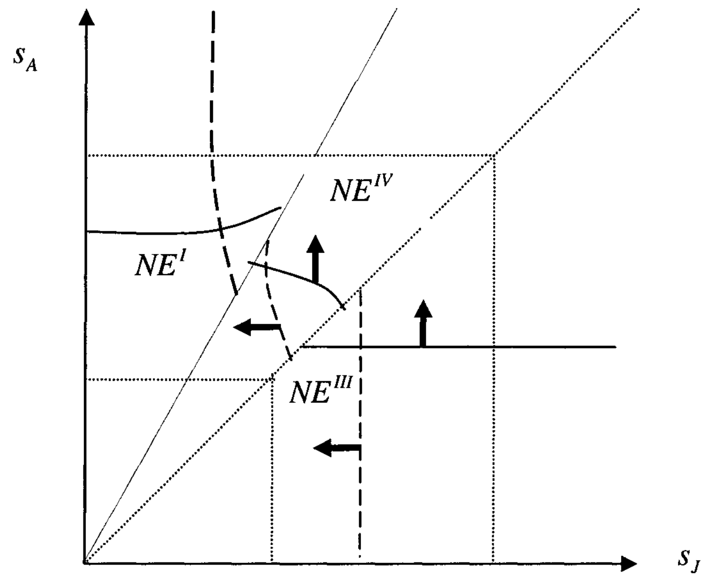


Figure 8b: $s_J{}^{BR^{IV}}$, the 45^0 line and $\frac{2\alpha - 1}{\alpha} s_J$ w.r.t. s_J for $\alpha = 1.6$



The quality best responses in the three domains are plotted in figure 9, assuming that all three local equilibria NE^{I}, NE^{III}, and NE^{IV} exist.[7] The bold arrows show how the best responses shift as the market share target increases.

Figure 9: Local equilibrium of the constrained Cournot game for $\alpha \in [1,2]$.



We need to know that when a local equilibrium exists in domain IV. If it exists then the quality gap in equilibrium $\rho^{NE^{IV}} = \frac{s_A^{NE^{IV}}}{s_J^{NE^{IV}}}$ must lie between 1 and $\hat{\rho} = \frac{1}{2-\alpha}$. The quality gap in equilibrium are calculated as $\rho^{NE^{IV}} = \frac{\alpha\left(2+\alpha+\sqrt{25\alpha^2+12\alpha+4}\right)}{2(1+3\alpha)}$.[8] It can be shown

---

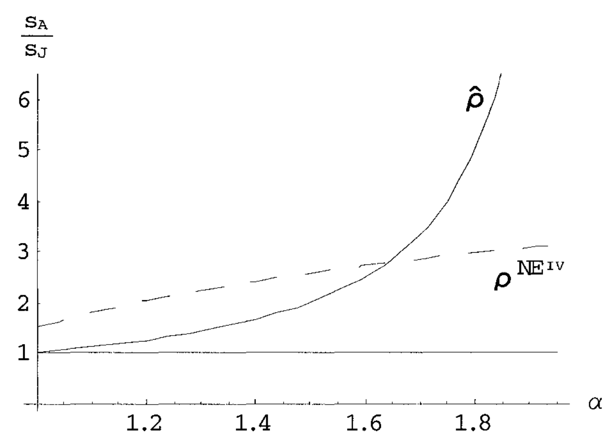
[7] It will be shown in a moment that figure 9 holds for $\alpha \in [1.639, 1.643]$

[8] To do this, from $\pi_A^{IV} = \frac{\alpha^2\rho^2 s_A}{(1+2\alpha\rho)^2} - \frac{s_A^{\ 2}}{2}$ and $\pi_J^{IV} = \frac{s_J[1+\rho(\alpha-1)]}{(1+2\alpha\rho)^2} - \frac{s_J^{\ 2}}{2}$, we take

$$\frac{\partial}{\partial s_A}\left[\frac{\alpha^2\rho^2 s_A}{(1+2\alpha\rho)^2}\right] / \frac{\partial}{\partial s_J}\left[\frac{s_J[1+\rho(\alpha-1)]}{(1+2\alpha\rho)^2}\right] = \rho$$ and solve for $\rho^{NE^{IV}}$.

mathematically that $\hat{\rho} > \rho^{NE^{IV}} > 1$ for $\alpha \in [1.639, 2]$. Figure 10 shows the graph of $\rho^{NE^{IV}}, \hat{\rho}$ and 1 with respect to $\alpha \in [1, 2]$. From this figure, it is evident that a local equilibrium NE^{IV} exists in domain IV for $\alpha \in [1.639, 2]$, otherwise it does not. Recall that the laissez faire market share of firm A when that firm is the high quality producer is 1.643. Hence the local NE^{IV} exists even when the constraint is set at a lightly lower level then the free trade solution.

Figure 10: Quality gap versus α.



Therfore, figure 9 holds for $\alpha \in [1.639, 1.643]$. We want to verify whether the local equilibria are global equilibria. Since the best responses in domain IV are complex, the following strategy is used to verify: for each equilibrium, assume that each firm may want to deviate to domain IV. Then, the quality gap ρ at the deviating point in the best responses in domain IV is computed. If $\rho \notin \left[1, \hat{\rho} = \dfrac{1}{2-\alpha}\right]$, then that firm does not deviate to domain IV. However, that firm may deviate to domain IV if $\rho \in \left[1, \hat{\rho} = \dfrac{1}{2-\alpha}\right]$ depending on profits. The profits from the two scenarios are subsequently calculated. If deviating to domain IV yields higher profits for a firm, then that firm has an incentive to deviate. Otherwise it does not deviate. The same strategy can also be used to verify whether a firm has any incentive to deviate to domain I due to the complexity of the best responses in this domain.

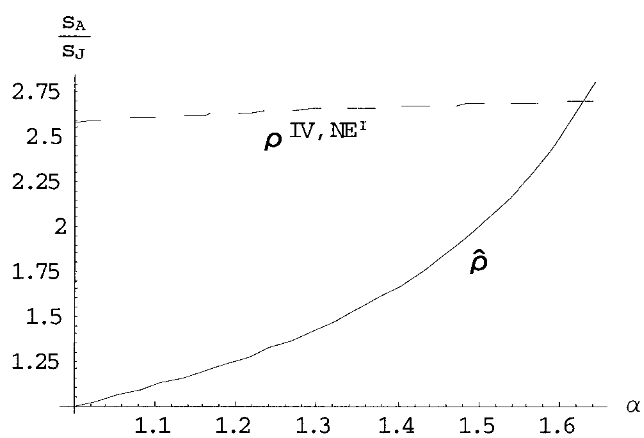
3.2.2.1. NE^I: local or global equilibrium

We start the verifying process with NE^I, which exists for the market shares that are not higher than the laissez-faire level $\alpha \in [1, 1.643]$.

Firm A's deviation

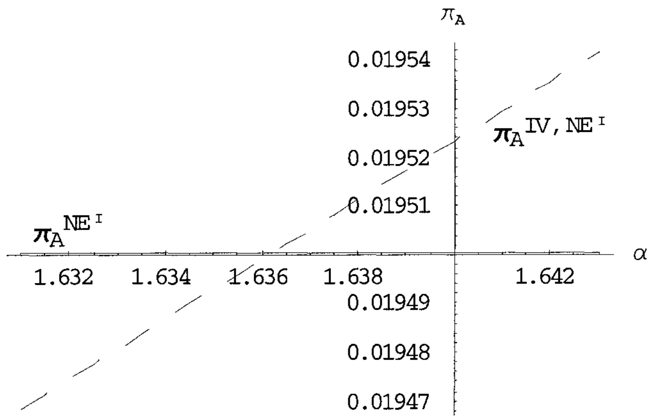
Given $s_J^{NE^I}$, it is apparent that firm A does not want to deviate to **domain III** since $s_J^{NE^I} = 0.09 < s_A^{NE^{III}}$. Suppose that firm A wants to deviate to **domain IV** by choosing $s_A^{IV,NE^I} = s_A^{BR^{IV}}(s_J = s_J^{NE^I})$. The resulting quality gap is $\rho^{IV,NE^I} = s_A^{IV,NE^I} / s_J^{NE^I}$. Plot ρ^{IV,NE^I}, $\hat{\rho} = \dfrac{1}{2-\alpha}$ and 1 as the reference level in figure 11a, it is obvious that $\rho^{IV,NE^I} \notin [1, \hat{\rho}]$ for $\alpha \in [1, 1.631]$. Therefore, firm A does not want to deviate to domain IV in this range of α.

Figure 11a: Quality gap versus α.



However, $\rho^{IV,NE^I} \in [1, \hat{\rho}]$ for $\alpha \in [1.631, 1.643]$. The latter suggests that firm A may deviate and play its best response in domain IV depending on profits. Plotting in figure 11b the profits from not deviating $\pi_A^{NE^I}(s_A = s_A^{NE^I}, s_J = s_J^{NE^I}) = 0.0195$ and the profits from deviating $\pi_A^{IV,NE^I}(s_A = s_A^{BR^{IV}}(s_J = s_J^{NE^I}), s_J = s_J^{NE^I})$ against $\alpha \in [1.631, 1.643]$, it is evident that the profits from deviating are higher for $\alpha \in [1.636, 1.643]$. Hence, firm A does not deviate if $\alpha \in [1, 1.636]$, and it deviates if $\alpha \in [1.636, 1.643]$.

Figure 11b: Firm A's profits versus α.



To understand why there may not be a region I equilibrium, $\lim_{s_A/s_j \to \hat{\rho}^+} \frac{\partial \pi_A^I}{\partial s_A}$ is compared to $\lim_{s_A/s_j \to \hat{\rho}^-} \frac{\partial \pi_A^{IV}}{\partial s_A}$. By equations (16) and (19), we have:

$$\lim_{s_A/s_j \to \hat{\rho}^+} \frac{\partial \pi_A^I}{\partial s_A} = \frac{(2\hat{\rho}-1)(8\hat{\rho}^2 - 2\hat{\rho}+1)}{(4\hat{\rho}-1)^3} - \hat{\rho} s_J \text{, and}$$

$$\lim_{s_A/s_j \to \hat{\rho}^-} \frac{\partial \pi_A^{IV}}{\partial s_A} = \frac{\alpha^2 \hat{\rho}^2 (3+2\alpha\hat{\rho})}{(1+2\alpha\hat{\rho})^3} - \hat{\rho} s_J = \frac{(2\hat{\rho}-1)^2(4\hat{\rho}+1)}{(4\hat{\rho}-1)^3} - \hat{\rho} s_J \text{.}$$ [9]

Hence $\lim_{s_A/s_j \to \hat{\rho}^-} \frac{\partial \pi_A^{IV}}{\partial s_A} < \lim_{s_A/s_j \to \hat{\rho}^+} \frac{\partial \pi_A^I}{\partial s_A}$. This comparison suggests that, starting at NE^I, given $s_J^{NE^I}$, in domain I, when firm A decreases s_A, π_A decreases. However, when the transition to domain IV occurs, decreases in s_A increase π_A. Hence the local equilibrium NE^I may be a global one, or it can be knocked out by a deviation to domain IV.

In addition, in domain I, firm A's decreases in s_A decrease q_A (by the envelope theorem) but increase q_J.[10] On the other hand, when the transition to domain IV occurs, because firm J's

---

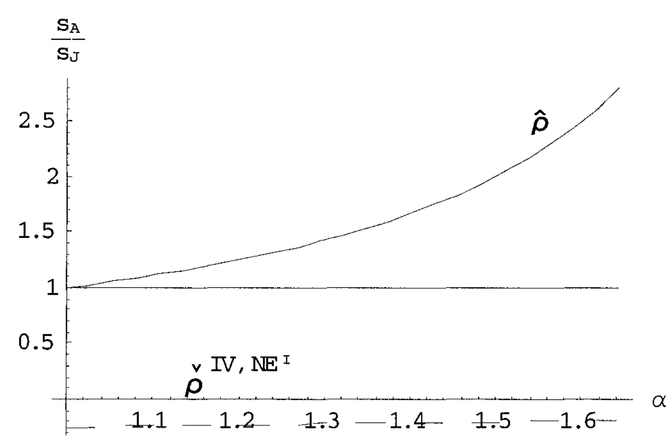
[9] Since $\hat{\rho} = \frac{1}{2-\alpha}$, or $\alpha\hat{\rho} = 2\hat{\rho}-1$, we have $\lim_{s_A/s_j \to \hat{\rho}^-} \frac{\partial \pi_A^{IV}}{\partial s_A} = \frac{(2\hat{\rho}-1)^2[3+2(2\hat{\rho}-1)]}{[1+2(2\hat{\rho}-1)]^3} - \hat{\rho} s_J$.

output is below that which it wants to produce, as s_A decreases, not only q_A decreases, but so does q_J.[11] Hence, the overall benefit of decreased quality in domain IV for firm A increases due to its impact on q_J and hence price. Therefore, there may not be a region I equilibrium for all α below the laissez faire solution. In fact, when α is approaching the laissez faire solution from below, there is no region I equilibrium.

Firm J's deviation

For firm J, given $s_A^{NE^I}$, it is clear that firm J does not want to deviate to **domain III** since $s_J^{NE^{III}} = \dfrac{2\alpha}{(1+2\alpha)^2} < s_A^{NE^I}$ for all $\alpha \in [1, 1.643]$. Suppose that firm J wants to deviate to **domain IV** by choosing $s_J^{IV,NE^I} = s_J^{BR^{IV}}(s_A = s_A^{NE^I})$. The resulting quality gap is $\breve{\rho}^{IV,NE^I} = s_A^{NE^I} / s_J^{IV,NE^I}$. Plotting $\breve{\rho}^{IV,NE^I}$, $\hat{\rho}$ and 1 in figure 11c, it is seen that $\breve{\rho}^{IV,NE^I} \notin [1, \hat{\rho}]$. Therefore, firm J does not want to deviate to domain IV for all $\alpha \in [1, 1.643]$.

Figure 11c: Quality gap versus α.



Hence NE^I ***is a global equilibrium when*** $\alpha \in [1, 1.636]$***, and it is not when the imposed target approaches the laissez-faire market share*** $\alpha \in [1.636, 1.643]$.

---

[10] By equation (5), $\partial q_J^{Domain\,I} / \partial s_A = -s_J / (4 s_A - s_J)^2 < 0$.

[11] By equation (17), $\partial q_J^{Domain\,IV} / \partial s_A = s_J / (2\alpha s_A + s_J)^2 > 0$.

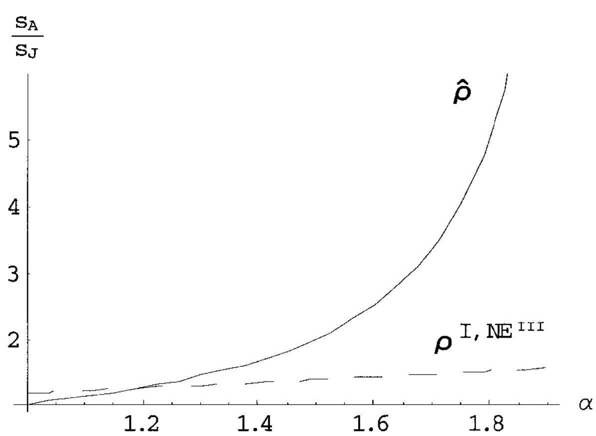
3.2.2.2. NE^{III} : local or global equilibrium

We turn to verify whether NE^{III}, which exists for all $\alpha \in [1,2]$, is a global equilibrium. To do so, we want to see whether firms have any incentive to deviate from NE^{III} to either domain I or domain IV.

Firm A's deviation to domain I

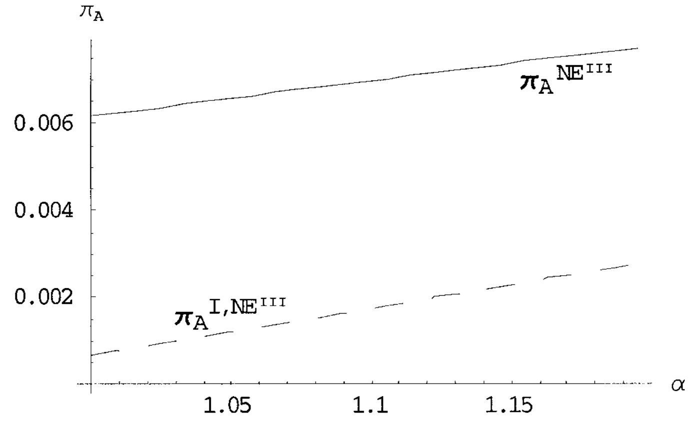
Given $s_J^{NE^{III}}$, suppose that firm A wants to deviate to domain I by choosing $s_A^{I,NE^{III}} = s_A^{BR^I}(s_J = s_J^{NE^{III}})$. The resulting quality gap is $\rho^{I,NE^{III}} = s_A^{I,NE^{III}} / s_J^{NE^{III}}$. If $\rho^{I,NE^{III}} \geq \hat{\rho} = \dfrac{1}{2-\alpha}$ then the deviating point lies in domain 1. Plotting $\rho^{I,NE^{III}}$ and $\hat{\rho}$ in figure 12a, it is concluded that firm A does not deviate to domain I if $\alpha \in [1.195, 2]$ since $\rho^{I,NE^{III}} \leq \hat{\rho}$.

Figure 12a: Quality gap versus α.



However, for $\alpha \in [1, 1.195]$, since $\rho^{I,NE^{III}} \geq \hat{\rho}$, firm A deviates to domain I if it gets higher profits. The profits from not deviating $\pi_A^{NE^{III}}$ and the profits from deviating $\pi_A^{I,NE^{III}} = \pi_A(s_A = s_A^{I,NE^{III}}, s_J = s_J^{NE^{III}})$ are computed and plotted against $\alpha \in [1, 1.195]$ in figure 12b. It is obvious that the profits from deviating are always lower than the profits from not deviating. Therefore, firm A does not want to deviate to domain I.

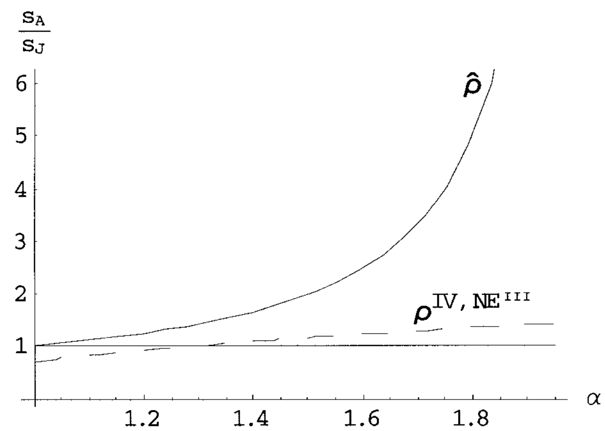
Figure 12b: Firm A's profits versus $\alpha \in [1, 1.195]$.



Firm A's deviation to domain IV

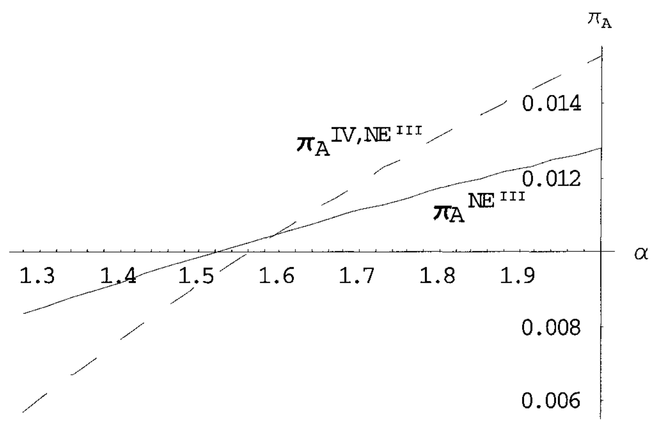
Suppose for now that firm A wants to deviate to domain IV by choosing $s_A^{IV,NE^{III}} = s_A^{BR^{IV}}(s_J = s_J^{NE^{III}})$. The resulting quality gap is $\rho^{IV,NE^{III}} = s_A^{IV,NE^{III}} / s_J^{NE^{III}}$. Plotting $\rho^{IV,NE^{III}}$, $\hat{\rho}$ and 1 in figure 12c, it is evident that firm A does not deviate to domain IV for $\alpha \in [1, 1.28]$ since $\rho^{IV,NE^{III}} \notin [1, \hat{\rho}]$.

Figure 12c: Quality gap versus α.



However, for $\alpha \in [1.28, 2]$, since $\rho^{IV,NE^{III}} \in [1, \hat{\rho}]$, firm A deviates to domain IV if the resulting profits are higher. The profits from the two scenarios are then calculated and plotted together in figure 12d. It is apparent that the profits from deviating $\pi_A^{IV,NE^{III}}$ are higher than the profits from not deviating $\pi_A^{NE^{III}}$ for $\alpha \in [1.595, 2]$. Hence firm A deviates to domain IV if $\alpha \in [1.595, 2]$, and it does not deviate otherwise.

Figure 12d: Firm A's profits versus α.



Firm J's deviation to domain I

For firm J, given $s_A^{NE^{III}}$, suppose that firm J wants to deviate to domain I by choosing $s_J^{I,NE^{III}} = s_J^{BR^I}(s_A = s_A^{NE^{III}})$. The resulting quality gap is $\widehat{\rho}^{I,NE^{III}} = s_A^{NE^{III}} / s_J^{I,NE^{III}}$ which is indeterminate[12] for $\alpha \in [1,2]$. Therefore firm J does not deviate to domain I.

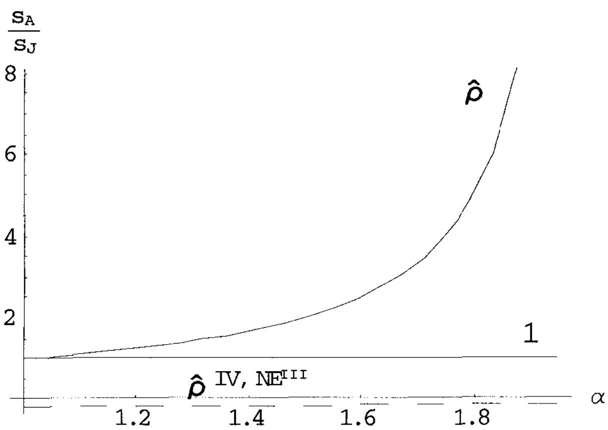
Firm J's deviation to domain IV

Suppose that, given $s_A^{NE^{III}}$, firm J wants to deviate to domain IV by choosing $s_J^{IV,NE^{III}} = s_J^{BR^{IV}}(s_A = s_A^{NE^{III}})$. The resulting quality gap is $\widehat{\rho}^{IV,NE^{III}} = s_A^{NE^{III}} / s_J^{IV,NE^{III}}$. Plotting $\widehat{\rho}^{IV,NE^{III}}$, $\hat{\rho}$ and 1 in figure 12e, it is seen that $\widehat{\rho}^{IV,NE^{III}} \notin [1, \hat{\rho}]$. Therefore, firm J does not want to deviate to domain IV.

---

[12] Numerical simulation shows that $\widehat{\rho}^{I,NE^{III}}$ is not a real number for any $\alpha \in [1,2]$.

Figure 12e: Quality gap versus α.



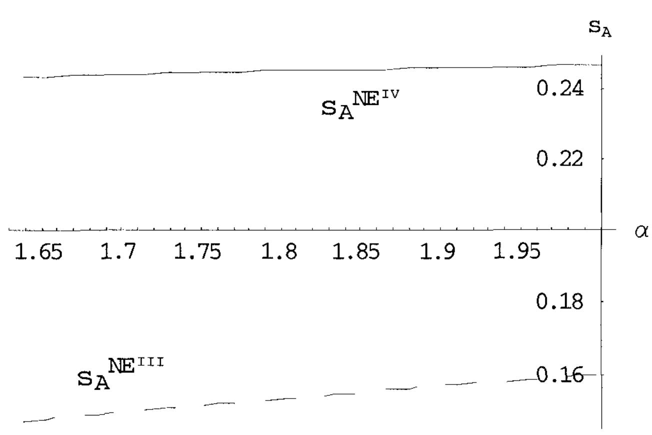
Hence NE^{III} is a global equilibrium for $\alpha \in [1, 1.595]$. NE^{III} is not a global equilibrium for $\alpha \in [1.595, 2]$.

3.2.2.3. NE^{IV}: local or global equilibrium

Firm A's deviation

For NE^{IV} which exists for $\alpha \in [1.639, 2]$, given $s_J^{NE^{IV}}$, firm A does not want to deviate to **domain III** since, as appeared in figure 13a, $s_A^{NE^{IV}} > s_A^{NE^{III}}$ for all $\alpha \in [1.639, 2]$.

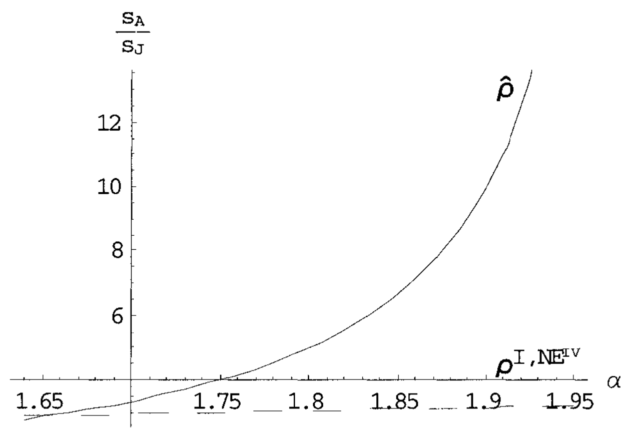
Figure 13a: $s_A^{NE^{IV}}$ and $s_A^{NE^{III}}$ versus α.



Assume that given $s_J^{NE^{IV}}$, firm A wants to deviate to **domain I** by choosing $s_A^{I,NE^{IV}} = s_A^{BR^I}(s_J = s_J^{NE^{IV}})$. The resulting quality gap is $\rho^{I,NE^{IV}} = s_A^{I,NE^{IV}} / s_J^{NE^{IV}}$. Plotting

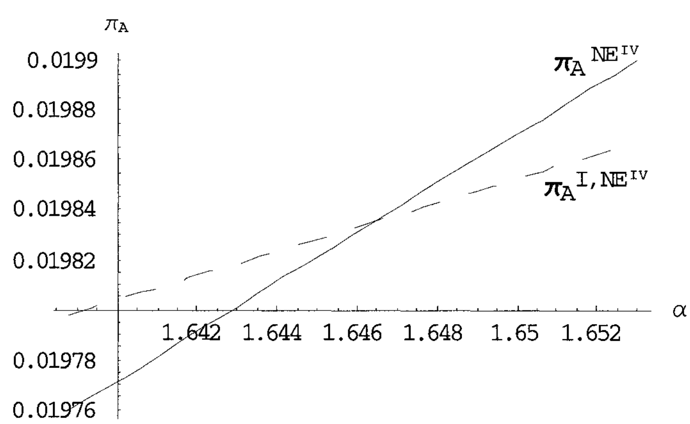
$\rho^{I,NE^{IV}}$ and $\hat{\rho} = \dfrac{1}{2-\alpha}$ in figure 13b, it is clear that $\rho^{I,NE^{IV}} \geq \hat{\rho}$ for $\alpha \in [1.639, 1.653]$, and $\rho^{I,NE^{IV}} \leq \hat{\rho}$ otherwise. Hence firm A does not deviate to domain I if $\alpha \in [1.653, 2]$. However, for $\alpha \in [1.639, 1.653]$, firm A may deviate to domain I depending on profits.

Figure 13b: Quality gap versus α.



Plotting the profits from not deviating $\pi_A^{NE^{IV}}(s_A = s_A^{NE^{IV}}, s_J = s_J^{NE^{IV}})$ and the profits from deviating $\pi_A^{I,NE^{IV}}(s_A = s_A^{BR^I}(s_J = s_J^{NE^{IV}}), s_J = s_J^{NE^{IV}})$ against $\alpha \in [1.639, 1.653]$ in figure 13c, it is evident that $\pi_A^{I,NE^{IV}}$ are higher than $\pi_A^{NE^{IV}}$ for $\alpha \in [1.639, 1.646]$. Hence, firm A deviates if $\alpha \in [1.639, 1.646]$, and it does not if $\alpha \in [1.646, 1.653]$.

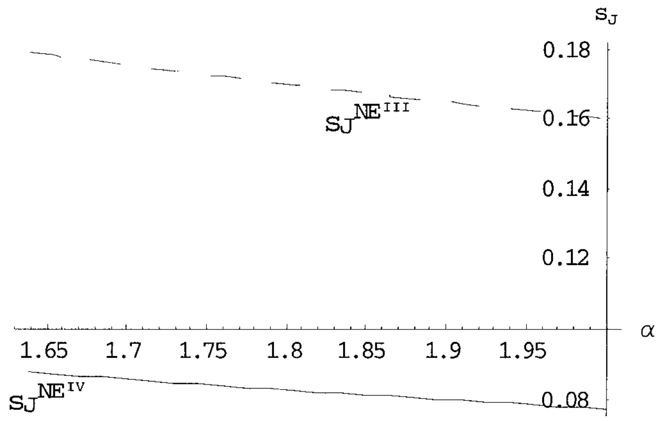
Figure 13c: $\pi_A^{NE^{IV}}$ and $\pi_A^{I,NE^{IV}}$ against $\alpha \in [1.639, 1.653]$



Firm J's deviation

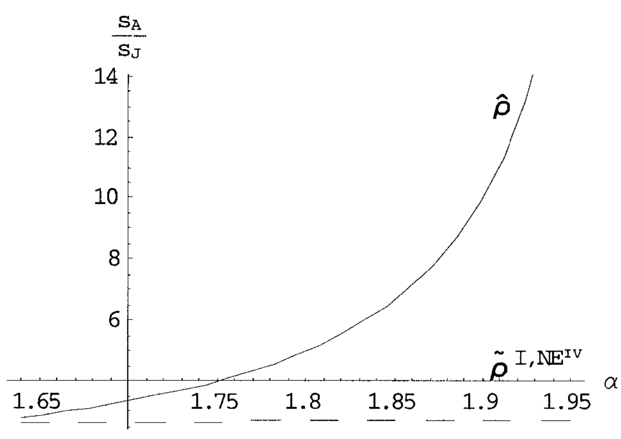
For firm J, given $s_A^{NE^{IV}}$, it is unambiguous that firm J does not want to deviate to **domain III** since, as appeared in figure 13d, $s_J^{NE^{IV}} < s_J^{NE^{III}}$ for all $\alpha \in [1.639, 2]$.

Figure 13d: $s_J^{NE^{IV}}$ and $s_J^{NE^{III}}$ versus α.



Suppose that firm J want to deviate to **domain I** by choosing $s_J^{I,NE^{IV}} = s_J^{BR^I}(s_A = s_A^{NE^{IV}})$. The resulting quality gap is $\tilde{\rho}^{I,NE^{IV}} = s_A^{NE^{IV}} / s_J^{III,NE^{IV}}$. Plotting $\tilde{\rho}^{I,NE^{IV}}$ and $\hat{\rho}$ in figure 13e, it is clear that $\tilde{\rho}^{I,NE^{IV}} \leq \hat{\rho}$ for all $\alpha \in [1.639, 2]$. Hence, firm A does not deviate to domain I.

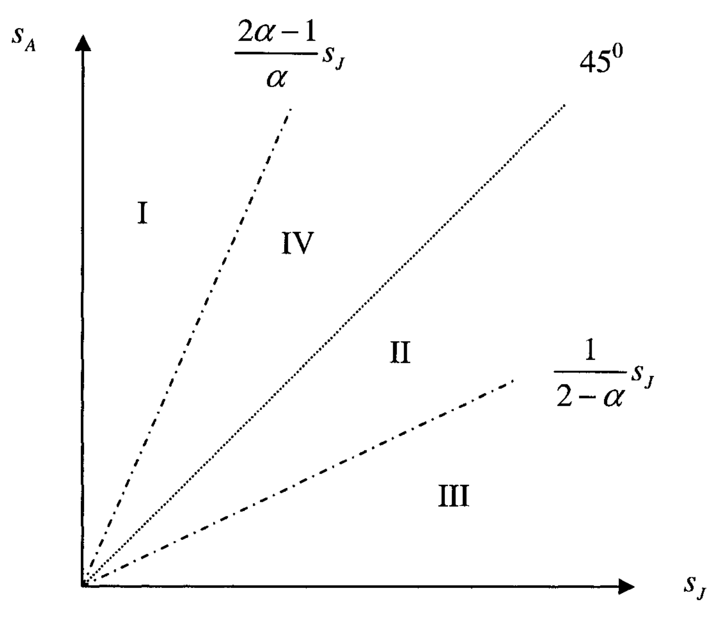
Figure 13e: Quality gap versus α.



In conclusion, NE^{IV} **is a global equilibrium only for** $\alpha \in [1.646, 2]$. In domain IV, because in the quantity game firm J's output is below that which it wants to produce, as s_A increases, not only q_A increases, but so does q_J.[13] Hence, the overall benefit of increased quality for firm A is reduced due to its impact on q_J and hence price. On the other hand, when the transition to region I occurs, increases in s_A increase q_A (by the envelope theorem) but decrease q_J.[14] Hence, in region IV, from A's perspective, the strategic impact of s_A is negative - that is, the impact on q_J adversely affects A, whereas in region I this strategic impact is positive. Therefore, when α is above the laissez faire solution, a region I equilibrium is (by construction) not feasible, but there may also not be a region IV equilibrium. This in fact is true for $\alpha \in [1.643, 1.646]$.

In contrary, when α is below the laissez faire solution, that is $\alpha \in [1.639, 1.643]$, in domain IV, both firms' outputs are below that which they want to produce. If firm A deviates to play the unconstrained best response, it will get higher revenues. If firm A respects the constraints, it will save some quality costs. Firm A's resulting overall benefits are higher if it deviates. Hence there is not a region IV equilibrium.

Figure 14a: Four regions of the Cournot game.



[13] See footnote (10).
[14] See footnote (9).

Figure 14a provides a recall of the four domains defined in the quantity game. All findings of the Cournot game are summarized in result 1.

Result 1: *Assume that firms compete in quantities at the last stage of the game;* NE^{I} *and* NE^{II} *are the two symmetric equilibria where firm A produces the high- or the low-quality products in free trade,* NE^{III} *and* NE^{IV} *are two local equilibria where the constraints bind and firm A is the low- or high- quality producer.*

i) If $\alpha \in [0.5, 0.596]$*, then the game has two global equilibria:* NE^{I}, NE^{II}.

ii) If $\alpha \in [0.596, 0.599]$*, then it has only one global equilibrium:* NE^{I}.

iii) If $\alpha \in [0.599, 1.595]$*, then it has two global equilibria:* NE^{I}, NE^{III}.

iv) If $\alpha \in [1.595, 1.636]$*, then it has only one global equilibrium:* NE^{I}.

v) If $\alpha \in [1.636, 1.646]$ *then it has no equilibrium.*

vi) If $\alpha \in [1.646, 2]$*, then it has only one global equilibrium:* NE^{IV}.

Recall that we focus only on pure strategy in this paper. The mixed strategy global equilibria are possible, especially for the share target that generates only one pure-strategy global equilibrium, or none of them.

Coming back to expressions reported in (12), (14) and (15), part (a) of result 2 is obtained by taking derivative with respect to α.[15] Due to the complexity of the underlying variables in equilibrium at NE^{IV}, part (b) of result 2 is found by numerical calculations.

Result 2:

(a) Comparative statics of qualities, prices, quantities and welfare at NE^{III} *are as the following:*

i) $\partial s_A^{NE^{III}} / \partial \alpha > 0, \partial s_J^{NE^{III}} / \partial \alpha < 0, \partial s_{av}^{NE^{III}} / \partial \alpha < 0, \partial \rho^{NE^{III}} / \partial \alpha > 0,$

[15] A few variables are not listed in these equations, but can be computed easily.

ii) $\partial p_A{}^{NE^{III}} / \partial \alpha > 0, \partial p_J{}^{NE^{III}} / \partial \alpha < 0$,

iii) $\partial q_A{}^{NE^{III}} / \partial \alpha > 0, \partial q_J{}^{NE^{III}} / \partial \alpha < 0, \partial q_{total}{}^{NE^{III}} / \partial \alpha < 0, q_{total}{}^{NE^{III}} < q_{free-trade}$,

iv) $\partial \pi_A{}^{NE^{III}} / \partial \alpha > 0, \partial W_J{}^{NE^{III}} / \partial \alpha < 0, \partial CS^{NE^{III}} / \partial \alpha < 0, \partial W_{world}{}^{NE^{III}} / \partial \alpha < 0$,

(b) Comparative statics of qualities, prices, quantities and welfare at NE^{IV} *are as the following:*

i) $\partial s_A{}^{NE^{IV}} / \partial \alpha > 0, \partial s_J{}^{NE^{IV}} / \partial \alpha < 0, \partial s_{av}{}^{NE^{IV}} / \partial \alpha > 0, \partial \rho^{NE^{IV}} / \partial \alpha > 0$,

ii) $\partial p_A{}^{NE^{IV}} / \partial \alpha > 0, \partial p_J{}^{NE^{IV}} / \partial \alpha < 0$,

iii) $\partial q_A{}^{NE^{IV}} / \partial \alpha > 0, \partial q_J{}^{NE^{IV}} / \partial \alpha < 0, \partial q_{total}{}^{NE^{IV}} / \partial \alpha < 0, q_{total}{}^{NE^{IV}} < q_{free-trade}$,

iv) $\partial \pi_A{}^{NE^{IV}} / \partial \alpha > 0, \partial W_J{}^{NE^{IV}} / \partial \alpha < 0, \partial W_{world}{}^{NE^{IV}} / \partial \alpha < 0$.

So, in the Cournot game, regardless of the firm's identity and as the share target gets larger, firm A always increases the quality of its products to raise its sales. At the same time, it also exploits high market share and enjoys higher profits. The opposite is true for firm J. In addition, as the share target increases, the average quality decreases (increases) if firm A is low- (high-) quality producer, but the quality gap, or the degree of product differentiation increases unambiguously.

We are also interested in the global effects of VIE on firms' quality. Firms' quality choices in equilibrium versus α are plotted in the two figures that follow. Noting that the free trade market share targets are 1.643 and 0.609 for the case where firm A is the high- and low-quality producer respectively. Figure 14b(iii) shows that VIE has important effects on firm A's quality in equilibrium. Considering the discrete jump in s_A from NE^{II} to NE^{III}, since the constraints are a guaranteed market share for firm A, that firm can produce goods at low quality and still enjoy the guaranteed market shares. This is also the reason why NE^{III} exists even for the market share below the laissez faire solution. The market share target must be large enough (0.75) so that s_A gets back to the laissez faire solution. Turning to firm A's quality choice at NE^{IV}, even though s_A increases with α, s_A is always lower than the laissez faire solution (that is s_A at NE^{I}), given that firm A is the high-quality producer. Therefore, the global effects of VIE on firm A's quality can be seen somehow as negative.

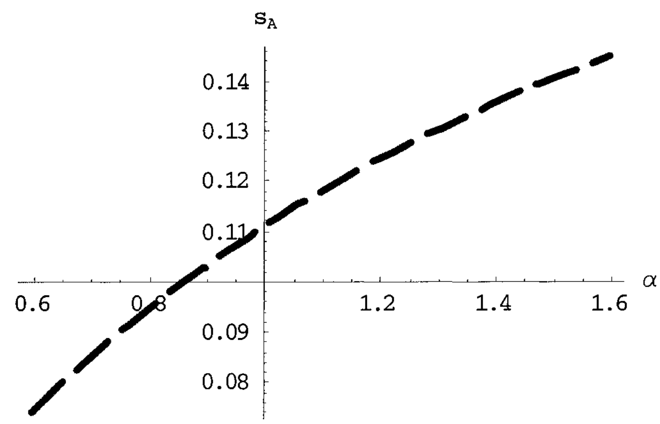
In terms of welfare analysis, in the quantity game, VIE is always anti-competitive. It is a beneficial mechanism only for country A since firm A's profits increase monotonically. Furthermore, it is a rather unbeneficial mechanism for country J as well as for the world as a whole since the consumer surplus, firm J's profits and the total welfare of the world decrease unambiguously.

We contrast our results with the previous findings in the literature. Herguera et al. (2000) use a similar Cournot competition model and find that, as a quota or a Voluntary Export Expansion (VER) becomes more restrictive,[16] the following happens: firm A decreases the quality while firm J upgrades it; total output decreases; firm J's profit increases; country J's welfare is lower (higher) than under free trade for sufficiently restrictive quota and average quality decreases (increases) if firm A is the high- (low-) quality producer. Since VIE can be considered as the import side of a VER, our results provide the outcomes generated by a VIE and are relatively consistent with that of Herguera et al., except for country J's welfare. In Herguera et al., they found that country J prefers to shut out imports of low-quality good. Hence, in their model, if firm J is the high-quality producer, total domestic welfare increases as the quota becomes more restrictive (that is, it falls farther below the laissez faire solution), and is greater than under laissez faire for sufficiently restrictive quota. In our setting, country J's welfare monotonically decreases as the market share gets larger, and its welfare is always lower than under free trade.

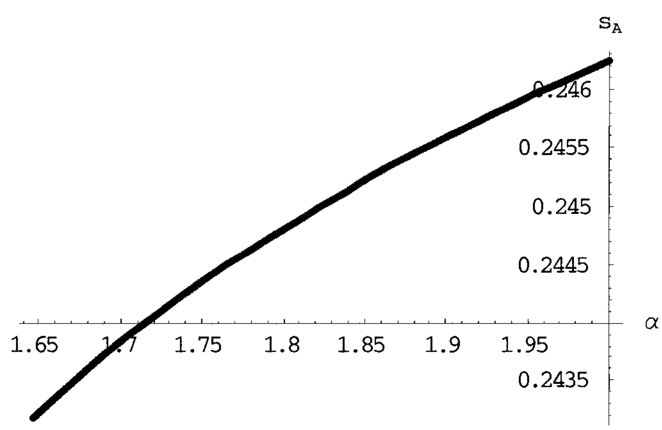
[16] A restrictive quota is a quota strictly less than laissez faire level of imports.

Figure 14b: Firm A's quality in equilibrium against α.

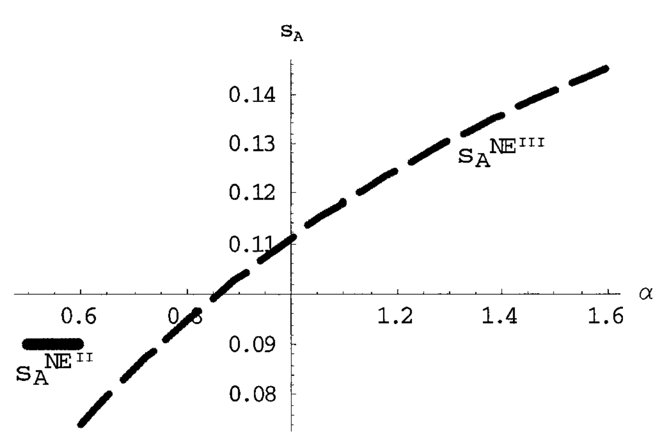
(i) $s_A^{NE^{III}}$ against α



(ii) $s_A^{NE^{IV}}$ against α.



(iii) $s_A^{NE^{II}}$ and $s_A^{NE^{III}}$ against α.



(iv) $s_A^{NE^I}$, $s_A^{NE^{II}}$, $s_A^{NE^{III}}$ and $s_A^{NE^{IV}}$ against α.

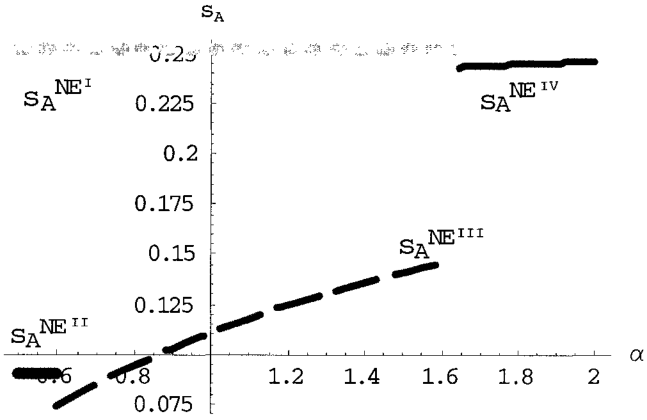
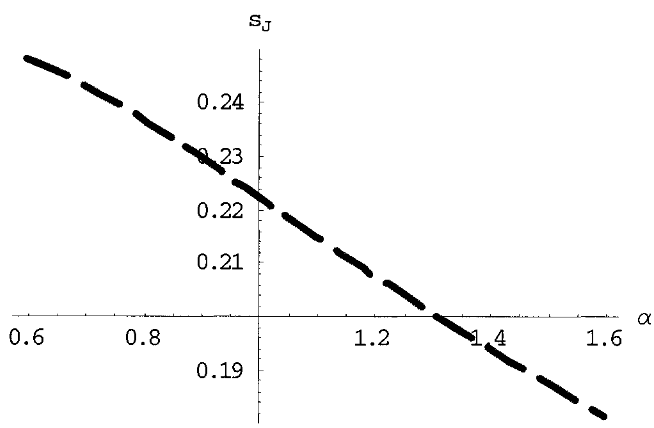
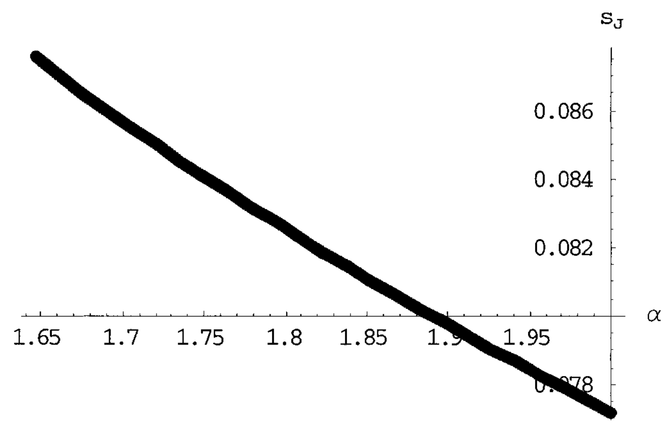


Figure 14c: Firm J's quality in equilibrium against α

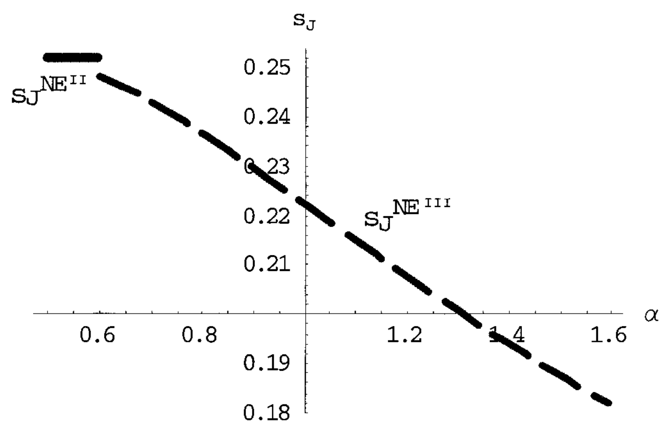
(i) $s_J^{NE^{III}}$ against α



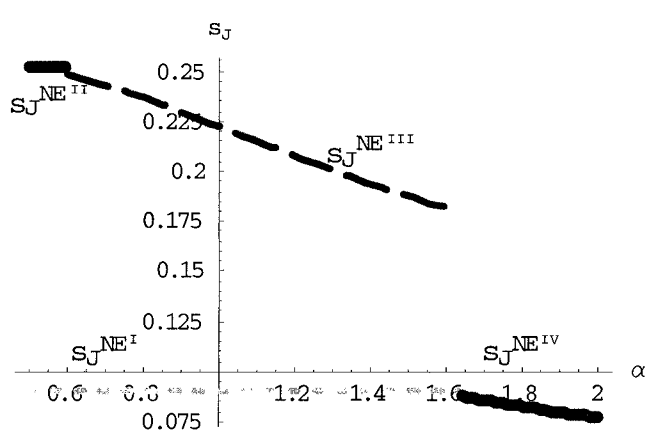
(ii) $s_J^{NE^{IV}}$ against α.



(iii) $s_J^{NE^{II}}$ and $s_J^{NE^{III}}$ against α.



(iv) $s_J^{NE^{I}}$, $s_J^{NE^{II}}$, $s_J^{NE^{III}}$ and $s_J^{NE^{IV}}$ against α.



4. Bertrand competition

4.1. Free trade outcome

We turn to study the price game in this section. If firms compete in prices in the last stage, then in free trade, using the pair of demands in (2) and quality choices (s_1, s_2) as given, the problem of the firms consists of finding p_i to maximize its profits. Firms' price best responses are

$$BR_1^b = 0.5[p_2 + \Theta(s_1 - s_2)] \text{ and } BR_2^b = p_1 s_2 / 2s_1 . \qquad (20)$$

The subgame equilibrium prices of the two firms are

$$p_1^b = 2\Theta s_1(s_1 - s_2)/(4s_1 - s_2) \text{ and } p_2^b = \Theta s_2(s_1 - s_2)/(4s_1 - s_2) . \qquad (21)$$

The subgame equilibrium quantities of the two firms are

$$q_1^b = 2\Theta s_1 /(4s_1 - s_2) \text{ and } q_2^b = \Theta s_1 /(4s_1 - s_2) . \qquad (22)$$

In the second stage, firms anticipate the equilibrium prices of the continuation game obtained in (10), and choose their qualities to maximize reduced-form (net) profits as:

$$\pi_1^b = \frac{4\Theta^2 s_1^{\,2}(s_1 - s_2)}{(4s_1 - s_2)^2} - \frac{s_1^{\,2}}{2} \text{ and } \pi_2^b = \frac{\Theta^2 s_1 s_2 (s_1 - s_2)}{(4s_1 - s_2)^2} - \frac{s_2^{\,2}}{2} .$$

The first order conditions that define firms' quality best responses are:

$$\frac{\partial \pi_1^b}{\partial s_1} = \frac{4\Theta^2 s_1(4s_1^{\,2} - 3s_1 s_2 + 2s_2^{\,2})}{(4s_1 - s_2)^3} - s_1 \text{ and } \frac{\partial \pi_2^b}{\partial s_2} = \frac{\Theta^2 s_1^{\,2}(4s_1 - 7s_2)}{(4s_1 - s_2)^3} - s_2 .$$

We proceed to find firms' quality best responses. Denote $\rho = s_2 / s_1$, we have :

$$\pi_1 = \frac{4\Theta^2 s_1(1-\rho)}{(4-\rho)^2} - \frac{s_1^{\,2}}{2} \text{ and } \pi_2 = \frac{\Theta^2 s_2(1-\rho)}{(4-\rho)^2} - \frac{s_2^{\,2}}{2} \text{; and}$$

$$\frac{\partial \pi_1^b}{\partial s_1} = \frac{4\Theta^2(4 - 3\rho + 2\rho^2)}{(4-\rho)^3} - s_1 \text{ and } \frac{\partial \pi_2^b}{\partial s_2} = \frac{\Theta^2(4 - 7\rho)}{(4-\rho)^3} - s_2 .$$

Define domain I as the region where $s_A \geq s_J$, and domain II as the area where $s_A \leq s_J$.

Given s_J, firm A's reduced profit is: $\pi_A{}^b = \begin{cases} \pi_1{}^b(s_1 = s_A, s_2 = s_J) = \pi_A{}^I \text{ for } s_A \geq s_J \\ \pi_2{}^b(s_1 = s_J, s_2 = s_A) = \pi_A{}^{II} \text{ for } s_A \leq s_J \end{cases}$.

Therefore, firm A's best response is: $s_A{}^{BR} = \begin{cases} s_1{}^{BR}(s_2 = s_J) = s_A{}^{BR^I} \text{ for } s_A \geq s_J \\ s_2{}^{BR}(s_1 = s_J) = s_A{}^{BR^{II}} \text{ for } s_A \leq s_J \end{cases}$.

In domain I, since $\lim_{s_A \to s_J^+} \frac{\partial \pi_A}{\partial s_A} = \lim_{s_A \to s_J^+} \frac{\partial \pi_1}{\partial s_1}\bigg|_{s_1 = s_A, s_2 = s_J} = \frac{4}{9} - s_J$, firm A's best response in this region only exists for $s_J \leq \frac{4}{9}$. In addition, $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A}{\partial s_A}\right) = \frac{8\Theta^2 s_A s_J (5s_A + s_J)}{(4s_A - s_J)^4} > 0$ implies that $\frac{\partial s_A{}^{BR^I}}{\partial s_J} > 0$ in this domain.

On the other hand, in domain II, since $\frac{\partial \pi_A}{\partial s_A}\bigg|_{s_A = 0} = \frac{\partial \pi_2}{\partial s_2}\bigg|_{s_2 = 0} > 0$ and $\lim_{s_A \to s_J^-} \frac{\partial \pi_A}{\partial s_A} = \lim_{s_A \to s_J^-} \frac{\partial \pi_2}{\partial s_2}\bigg|_{s_2 = s_A, s_1 = s_J} = -\frac{1}{9} - s_J < 0$, there exists a local best response for any s_J.

Furthermore, in this region, $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A}{\partial s_A}\right) = \frac{2\Theta^2 s_A s_J (7s_A + 8s_J)}{(4s_J - s_A)^4} > 0$ leads to $\frac{\partial s_A{}^{BR^{II}}}{\partial s_J} > 0$.

By simulation, the exact shapes of firm A's quality best responses are obtained as below:

Figure 15a: $s_A^{BR^I}$ and the 45^0 line with respect to s_J for $s_A \geq s_J$

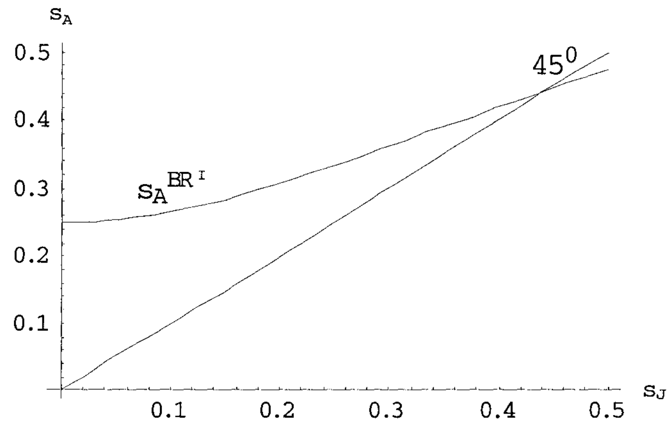
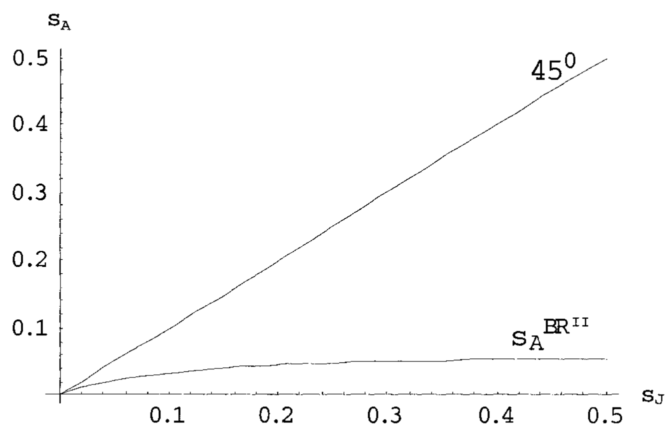


Figure 15b: $s_A^{BR^{II}}$ and the 45^0 line with respect to s_J for $s_A \leq s_J$

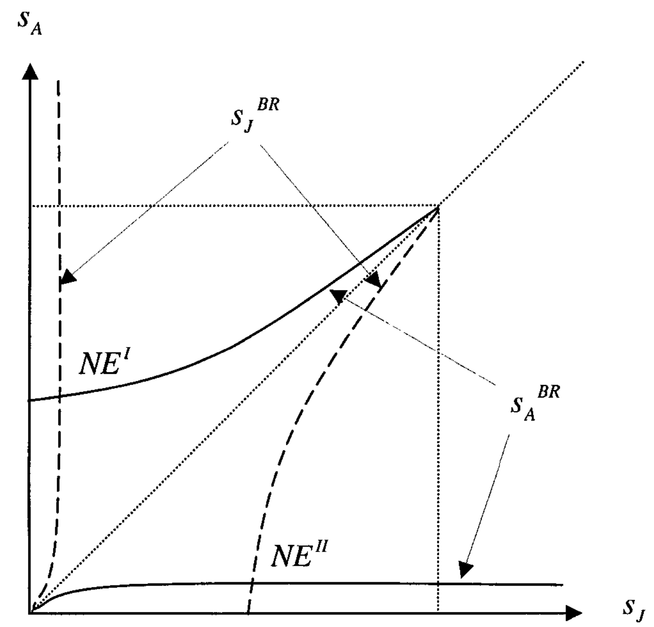


Similar argument holds for firm J's quality best response. Therefore, there exist 2 local equilibria which are characterized as below where if A=1 and J=2 then it is the NE^I and if A=2 and J=1 then it is the NE^{II} :

$$s_1^b = 0.253\Theta^2,\ s_2^b = 0.048\Theta^2,\ \rho^b = s_2^{\ b} / s_1^{\ b} = 0.19,\ q_1^b = 0.5248\Theta,\ q_2^b = 0.2624\Theta,$$
$$\alpha_1^b \equiv q_1^b / q_2^b = 2,\ \alpha_2^b \equiv q_2^b / q_1^b = 0.5,\ s_{av}^b = 0.185\Theta^2,\ p_1^b = 0.108\Theta^3,\ p_2^b = 0.01\Theta^3,$$
$$\pi_1^b = 0.0245\Theta^4,\ \pi_2^b = 0.0015\Theta^4,\ W_1^b = 0.0676\Theta^4 \text{ and } W_2^b = 0.0446\Theta^4.$$

Graph of the two local equilibria are as follows.

Figure 16: Equilibrium of the unconstrained Bertrand game.



We need to verify whether these two local equilibria are global equilibria. Assume that $\Theta = 1$. For NE^I, given $s_J^{NE^I} = 0.048$, firm A's profits from not deviating are $\pi_A^{NE^I} = 0.0245$, while its profits from deviating to domain II are $\pi_A^{II,NE^I} = \pi_A^{II}(s_A = s_A^{BR^I}(s_J = s_J^{NE^I}), s_J = s_J^{NE^I}) = 0.0007$ which are lower. Hence firm A does not have an incentive to deviate. For firm J, given $s_A^{NE^I} = 0.253$, it does not want to deviate to domain II either since its profits from not deviating are $\pi_J^{NE^I} = 0.0015$ which is higher than the profits from deviating $\pi_J^{II,NE^I} = \text{-}0.025$. Hence NE^I is a global equilibrium. By symmetry, NE^{II} is also a global equilibrium. Therefore, the unconstrained model has two symmetric pure strategy global equilibria.

4.2. Effects of a market share target

Similar to the Cournot game, we proceed to find the firms' best responses in the presence of the sales target, taking quality choice (s_A, s_J) as given. By the same reason as in the Cournot game, firm A's response function remains unchanged. On the other hand, firm J faces two possibilities: either the minimum market share r is satisfied and the profit function is $\pi_J(p_A, p_J)$, or it is not and the penalty cost V is applied hence the profit function is $\pi_J(p_A, p_J) - V$. Corresponding to "low"[17] values of firm A's price, the export target is always satisfied, and the constraint is nonbinding. Firm J will choose the price level on its best response function. This is the case when

$$R(p_A) < BR_J^b(p_A) \Leftrightarrow p_A < p_A^* \text{ where } R(p_A) = \bar{p}_J\big|_{q_A(p_A,\bar{p}_J)/q_J(p_A,\bar{p}_J)=\alpha}. \quad (23)$$

For "intermediate" values of firm A's price, the firm J's best decision is to respect the target. Consequently, the target is met, and the constraints bind. This happens when

$$\pi^J\left(p_A, R(p_A)\right) \geq \pi^J\left(p_A, BR_J^b(p_A)\right) - V \Leftrightarrow p_A \in \left[p_A^*, \hat{p}_A\right]. \quad (24)$$

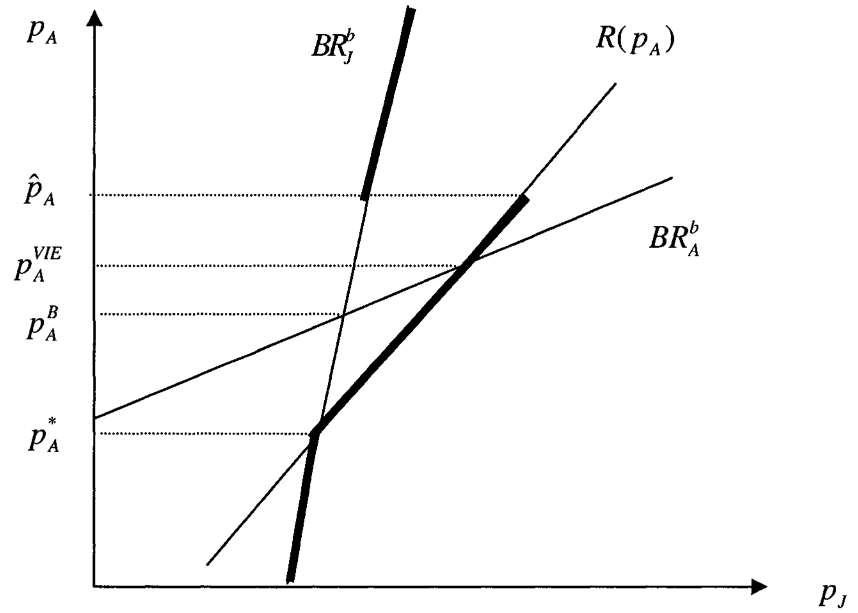
For "large" values of firm A's price, firm J will choose to violate the VIE and suffer the penalty. Hence, the target constraint is not met. This is the case when

$$\pi^J\left(p_A, R(p_A)\right) < \pi^J\left(p_A, BR_J^b(p_A)\right) - V \Leftrightarrow p_A > \hat{p}_A. \quad (25)$$

Hence, firm J's best response in the presence of the export target looks like the three segments in bold type shown in figure 17. One could see that, since the target is set above the foreign firm's share in free trade equilibrium, p_A^* is always higher than p_A^B. However, $\hat{p}_A$ can be higher or lower than p_A^{VIE} depending on whether the penalty V is low or high. When the penalty is high enough, $\hat{p}_A$ will not be lower than p_A^{VIE}. In consequence, the equilibrium under a VIE is the pair of prices $\left(p_A^{VIE}, p_J^{VIE}\right)$ as appeared in this figure.

[17] Low, intermediate and large prices are defined in equations (22), (23) and (24).

Figure 17: Firms' price best responses in The Bertrand game.



4.2.1. Effects of a low market share target

Assume that the penalty V is large enough such that $q_A / q_J \geq \alpha$, and $\alpha \in [0.5, 2]$. Given the quality choice, we need to know when the constraints bind.

For $s_A > s_J$, the constraints never bind since $\frac{q_A}{q_J} = 2 > \alpha$. Therefore, this area is still domain I. The unconstrained profits π_A^I , π_J^I and reaction functions $s_A^{BR^I}$, $s_J^{BR^I}$ as characterized in the previous section hold.

For $s_A < s_J$, constraints bind since $\frac{q_A}{q_J} = \frac{1}{2} \leq \alpha$. Define this region as domain III. In this region, firm J chooses the quantity such that constraints just bind, that is $q_A / q_J = \alpha$. Writing this in terms of prices to get:

$$\frac{p_J - p_A}{s_J - s_A} - \frac{p_A}{s_A} = \alpha\left(\Theta - \frac{p_J - p_A}{s_J - s_A}\right).$$

Firm A's price best response $p_A = \frac{p_J s_A}{2s_J}$ remains the same as in (9). Therefore, the last stage equilibrium prices are:

$$p_A{}^b = \frac{\Theta \alpha s_A (s_J - s_A)}{s_J + \alpha(2s_J - s_A)} \text{ and } p_J{}^b = \frac{2\Theta \alpha s_J (s_J - s_A)}{s_J + \alpha(2s_J - s_A)}.$$

The quantities are:

$$q_A{}^b = \frac{\Theta \alpha s_J}{s_J + \alpha(2s_J - s_A)} \text{ and } q_J{}^b = \frac{\Theta s_J}{s_J + \alpha(2s_J - s_A)}.$$

In the second stage, firms simultaneously choose their quality level by maximizing net profits, given the firms' quantity strategies and hence price choice at the last stage. The net profits are:

$$\pi_J^{III} = \frac{2\Theta^2 \alpha s_J{}^2 (s_J - s_A)}{[s_J + \alpha(2s_J - s_A)]^2} - \frac{s_J{}^2}{2} \text{ and } \pi_A^{III} = \frac{\Theta^2 \alpha^2 s_A s_J (s_J - s_A)}{[s_J + \alpha(2s_J - s_A)]^2} - \frac{s_A{}^2}{2}.$$

The first order conditions that define quality best responses are:

$$\frac{\partial \pi_J^{III}}{\partial s_J} = \frac{2\Theta^2 \alpha s_J \left[s_J{}^2 + \alpha(2s_A{}^2 - 3s_A s_J + 2s_J{}^2) \right]}{[s_J + \alpha(2s_J - s_A)]^3} - s_J \text{ and}$$

$$\frac{\partial \pi_A^{III}}{\partial s_A} = \frac{\Theta^2 \alpha^2 s_J{}^2 [(1+2\alpha)s_J - (2+3\alpha)s_A]}{[s_J + \alpha(2s_J - s_A)]^3} - s_A.$$

Since $\frac{\partial}{\partial s_J}\left(\frac{\partial \pi_A{}^{III}}{\partial s_A}\right) = \frac{2\Theta^2 s_A s_J [s_A \alpha(2+3\alpha) + s_J(1+2\alpha)]}{[s_J + 2\alpha(s_J - s_A)]^4} > 0$, it follows that $\frac{\partial s_A{}^{BR^{III}}}{\partial s_J} > 0$.

Similarly, $\frac{\partial}{\partial s_A}\left(\frac{\partial \pi_J{}^{III}}{\partial s_J}\right) = \frac{4\Theta^2 \alpha^2 s_A s_J [s_A \alpha + s_J(2+\alpha)]}{[s_J + 2\alpha(s_J - s_A)]^4} > 0$ leads to $\frac{\partial s_J{}^{BR^{III}}}{\partial s_A} > 0$. By simulation, the exact shapes of quality best responses are obtained as in figure 18a and 18b that follow.

Figure 18a: $s_A^{BR^{III}}$ and 45^0 line against s_J for $\alpha = 2/3$.

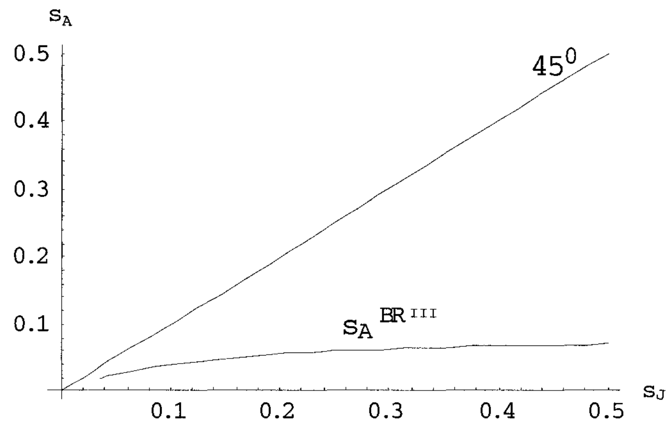
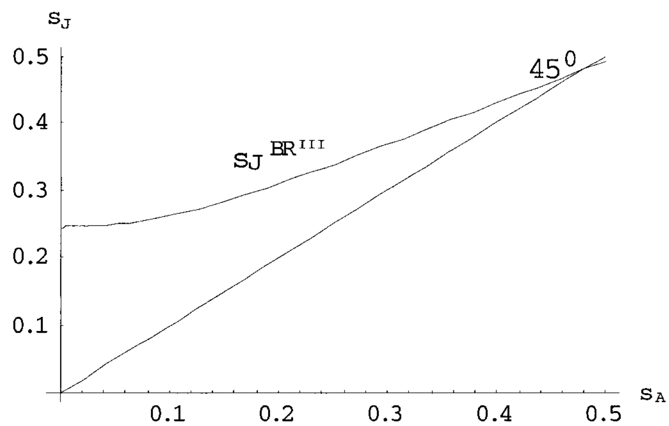
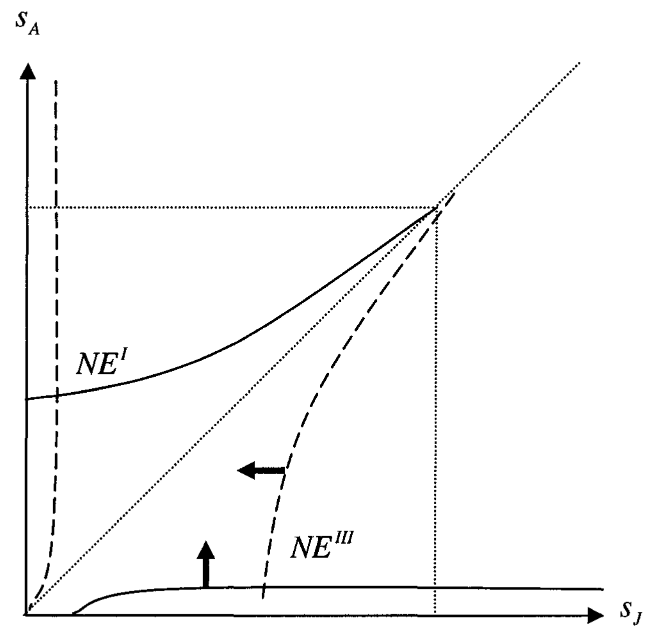


Figure 18b: $s_J^{BR^{III}}$ and 45^0 line against s_A for $\alpha = 2/3$.



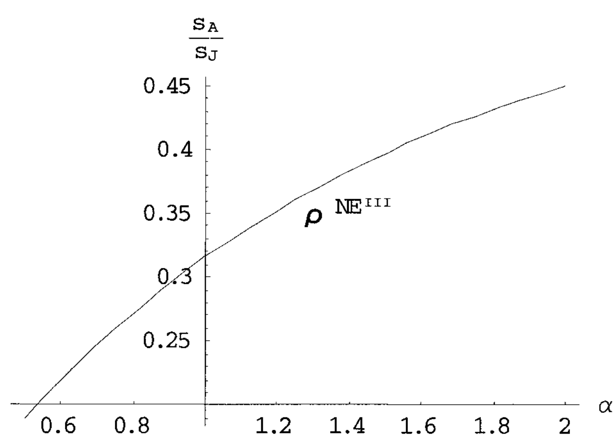
The two local equilibria are plotted against $\alpha \in [0.5, 2]$ in figure 19, assuming that they exist. In this figure, the bold arrows show the shift of the best responses when the share target increases.

Figure 19: Local equilibrium of the constrained Bertrand game for $\alpha \in [0.5,2]$.



We want to see when a local equilibrium exists in domain III for $\alpha \in [0.5,2]$. To do so, the quality gap in equilibrium $\rho^{NE^{III}} = \frac{s_A^{NE^{III}}}{s_J^{NE^{III}}}$ is computed by taking the ratio of the first derivative of the two gross profits and equating it to ρ. In figure 20, $\rho^{NE^{III}}$ is plotted against $\alpha \in [0.5,2]$. It is clear that $\rho^{NE^{III}}$ <1 for all $\alpha \in [0.5,2]$. Hence NE^{III} exists for any $\alpha \in [0.5,2]$.

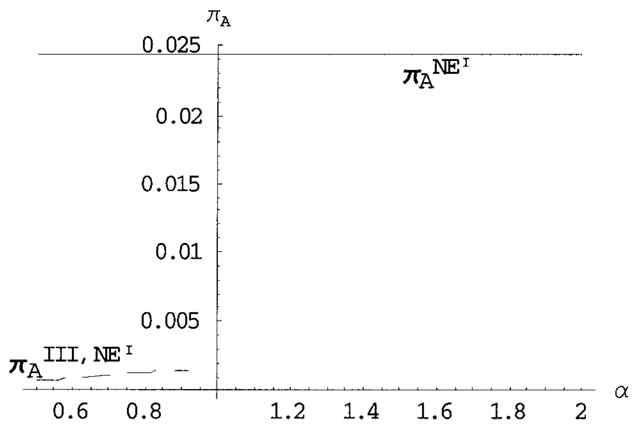
Figure 20: Quality gap versus $\alpha \in [0.5,2]$.



We need to verify whether the local equilibria are global equilibria. Assume that $\Theta = 1$.

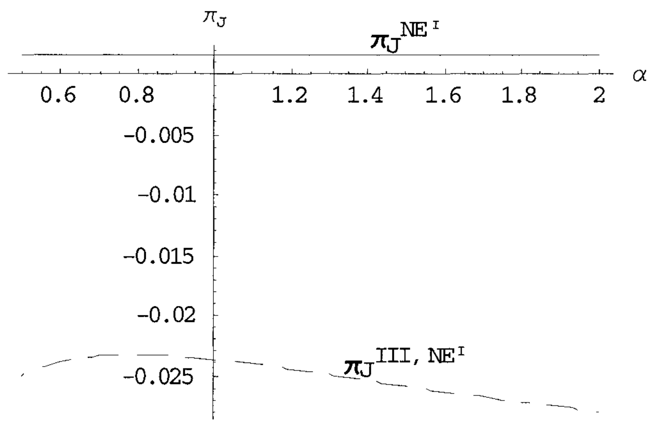
For NE^I, given $s_J^{NE^I} = 0.048$, **firm A**'s profits from not deviating are $\pi_A^{NE^I} = 0.0245$. On the other hand, its profits form deviating to domain III are $\pi_A^{III,NE^I} = \pi_A^{III}(s_A = s_A^{BR^{III}}(s_J = s_J^{NE^I}), s_J = s_J^{NE^I})$. Plotting $\pi_A^{NE^I}$ and π_A^{III,NE^I} in figure 21a, it is apparent that π_A^{III,NE^I} are lower than $\pi_A^{NE^I}$. Hence firm A does not have any incentive to deviate.

Figure 21a: Firm A's profits versus $\alpha \in [0.5, 2]$.



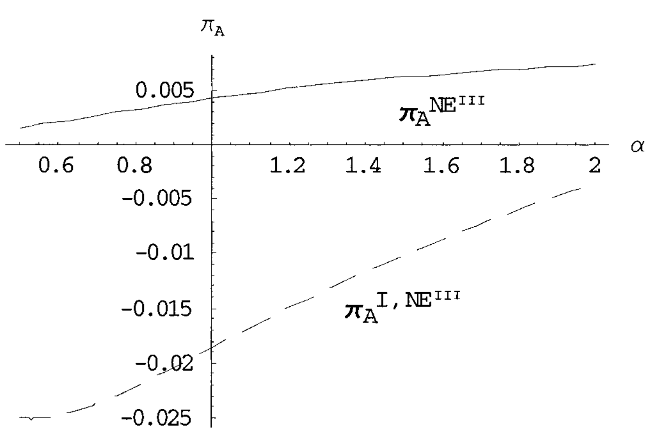
For **firm J**, given $s_A^{NE^I} = 0.253$, firm J does not want to deviate to domain III either since, as appeared in figure 21b, its profits from not deviating are $\pi_J^{NE^I} = 0.0015$ which are higher than its profits from deviating π_J^{III,NE^I}. **Hence** NE^I **is a global equilibrium for all** $\alpha \in [0.5, 2]$.

Figure 21b: Firm J's profits versus $\alpha \in [0.5, 2]$.



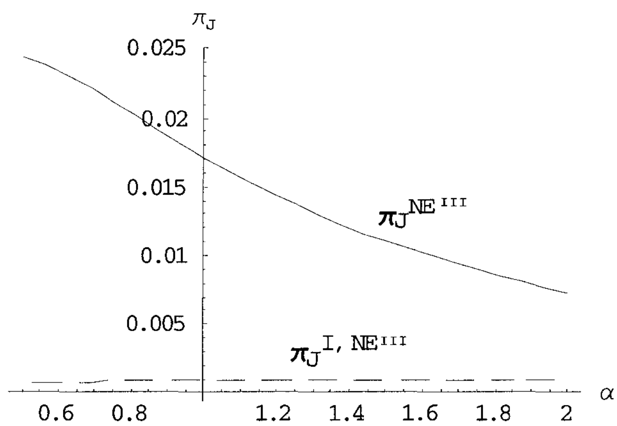
For NE^{III}, given $s_J^{NE^{III}}$, firm A's profits from not deviating are $\pi_A^{NE^{III}}$. In addition, its profits from deviating to domain I are $\pi_A^{I,NE^{III}} = \pi_A^{I}(s_A = s_A^{BR^I}(s_J = s_J^{NE^{III}}), s_J = s_J^{NE^{III}})$. Plotting $\pi_A^{NE^{III}}$ and $\pi_A^{I,NE^{III}}$ in figure 22a, it is obvious that $\pi_A^{I,NE^{III}}$ are lower than $\pi_A^{NE^{III}}$. Hence firm A does not have any incentive to deviate.

Figure 22a: Firm A's profits versus $\alpha \in [0.5, 2]$.



For **firm J**, given $s_A^{NE^{III}}$, its profits from not deviating are $\pi_J^{NE^{III}}$ which are higher than its profits from deviating $\pi_J^{I,NE^{III}}$ as shown in figure 22b.[18] Hence firm J does not have any incentive to deviate to domain I and NE^{III} **is a global equilibrium for all** $\alpha \in [0.5, 2]$**.**

Figure 22b: Firm J's profits versus $\alpha \in [0.5, 2]$.



4.2.2. Effects of a high market share target

Suppose $\alpha \geq 2$. Given the quality choice, we need to know when the constraints bind.

For $s_A < s_J$ the constraints always bind since $\frac{q_A}{q_J} = \frac{1}{2} < \alpha$. The profits π_A^{III}, π_J^{III} and reaction functions $s_A^{BR^{III}}, s_J^{BR^{III}}$ hold.

For $s_A > s_J$ the constraints always bind too since $\frac{q_A}{q_J} = 2 \leq \alpha$. Define this area as domain IV.

Assume that the penalty V is large enough such that constraints bind, firm J will choose the quantity so that constraints just bind, that is $q_A / q_J = \alpha$. Writing this in terms of prices to get:

$$\Theta - \frac{p_A - p_J}{s_A - s_J} = \alpha\left(\frac{p_A - p_J}{s_A - s_J} - \frac{p_J}{s_J}\right).$$

---

[18] $\pi_J^{I,NE^{III}}$ appears to be concave in α, but when it is plotted together with $\pi_J^{NE^{III}}$, the scale is too large to see its concavity.

In addition, firm A's price best response $p_A = \dfrac{p_J + \Theta(s_A - s_J)}{2}$ remains the same as in (9). Therefore, the last stage equilibrium prices are:

$$p_A{}^b = \frac{\Theta \alpha s_A(s_A - s_J)}{s_J + \alpha(2s_A - s_J)} \text{ and } p_J{}^b = \frac{\Theta s_J(\alpha - 1)(s_A - s_J)}{s_J + \alpha(2s_A - s_J)}.$$

The equilibrium quantities are:

$$q_A{}^b = \frac{\Theta \alpha s_A}{s_J + \alpha(2s_A - s_J)} \text{ and } q_J{}^b = \frac{s_A}{s_J + \alpha(2s_A - s_J)}.$$

In the second stage, firms simultaneously choose their quality level by maximizing net profits, given the firms' quantity strategies and hence price choice at the last stage. The net profits are:

$$\pi_A^{IV} = \frac{\Theta^2 \alpha^2 s_A{}^2(s_A - s_J)}{\left[s_J + \alpha(2s_A - s_J)\right]^2} \text{ and } \pi_J^{IV} = \frac{\Theta^2 s_A s_J(\alpha - 1)(s_A - s_J)}{\left[s_J + \alpha(2s_A - s_J)\right]^2}.$$

The first order conditions that define the quality best responses are:

$$\frac{\partial \pi_A^{IV}}{\partial s_A} = \frac{\Theta^2 \alpha^2 s_A\left[(3s_A - 2s_J)s_J + \alpha(2s_A{}^2 - 3s_A s_J + 2s_J{}^2)\right]}{\left[s_J + \alpha(2s_A - s_J)\right]^3} \text{ and}$$

$$\frac{\partial \pi_J^{IV}}{\partial s_J} = \frac{\Theta^2 s_A{}^2(\alpha - 1)\left[2\alpha s_A - (1 + 3\alpha)s_J\right]}{\left[s_J + \alpha(2s_A - s_J)\right]^3}.$$

Since $\dfrac{\partial}{\partial s_J}\left(\dfrac{\partial \pi_A{}^{IV}}{\partial s_A}\right) = \dfrac{2\Theta^2 s_A s_J(\alpha - 1)[s_A(3 + \alpha) + s_J(\alpha - 2)]}{[s_J + 2\alpha(s_A - s_J)]^4} > 0$, it follows that $\dfrac{\partial s_A{}^{BR^{IV}}}{\partial s_J} > 0$.

Similarly, $\dfrac{\partial s_J{}^{BR^{IV}}}{\partial s_A} > 0$ holds since $\dfrac{\partial}{\partial s_A}\left(\dfrac{\partial \pi_J{}^{IV}}{\partial s_J}\right) = \dfrac{2\Theta^2(\alpha - 1)s_A s_J[4s_A\alpha + s_J(\alpha - 1)(1 + 3\alpha)]}{[s_J + 2\alpha(s_A - s_J)]^4} > 0$. By simulation, the exact shapes of quality best responses are obtained as in figures 23 that follow.

Figure 23a: $s_A^{BR^{IV}}$ and 45^0 line against s_J for $\alpha = 3$.

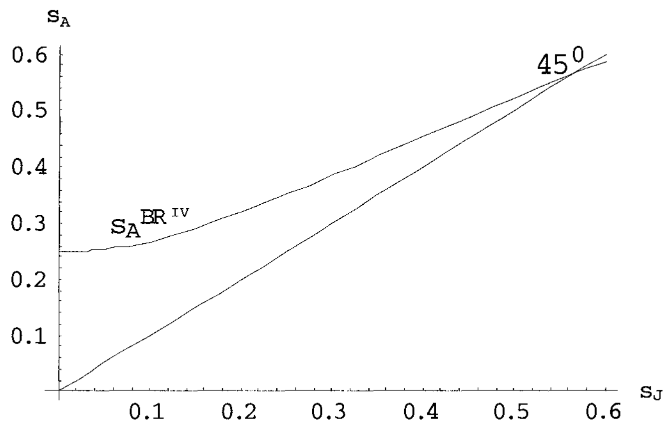
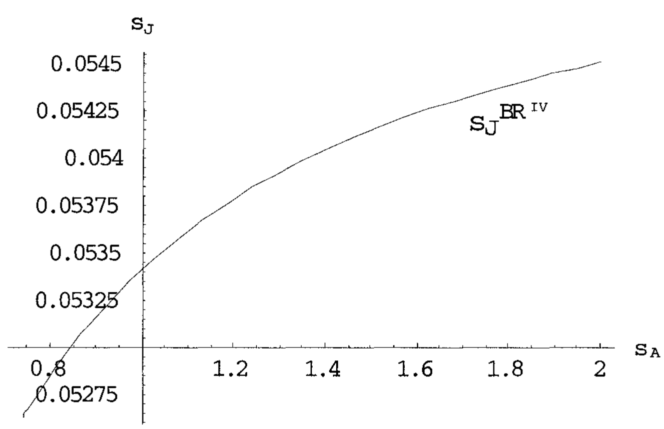
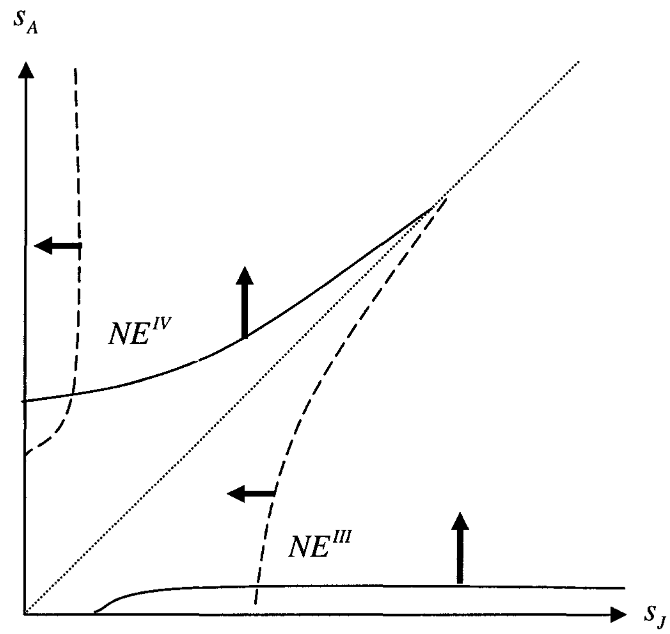


Figure 23b: $s_J^{BR^{IV}}$ against s_A for $\alpha = 3$.



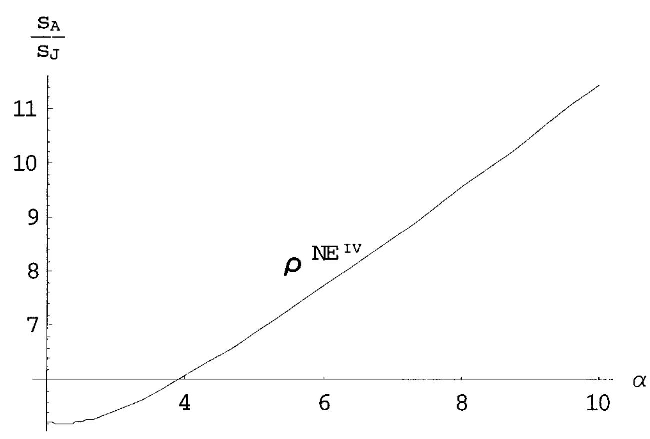
The two local equilibria are plotted in figure 24, assuming that they both exist. In this figure, the bold arrows show the shift of the best responses when the share target increases.

Figure 24: Local equilibrium of the constrained Bertrand game for $\alpha \geq 2$.



We need to know when the local equilibrium exists in domain IV. To do that, the quality gap in equilibrium $\rho^{NE^{IV}} = \frac{s_A^{NE^{IV}}}{s_J^{NE^{IV}}}$ is calculated and plotted against α for $\alpha \geq 2$ in figure 25. It is obvious that that $\rho^{NE^{IV}} > 1$ for all $\alpha \geq 2$. Hence NE^{IV} exists for any $\alpha \geq 2$.

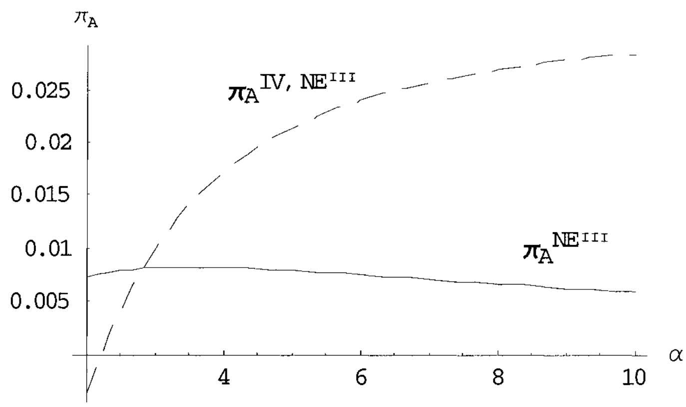
Figure 25: Quality gap versus $\alpha \geq 2$.



We turn to verify whether the local equilibria are global equilibria. Assume that $\Theta = 1$.

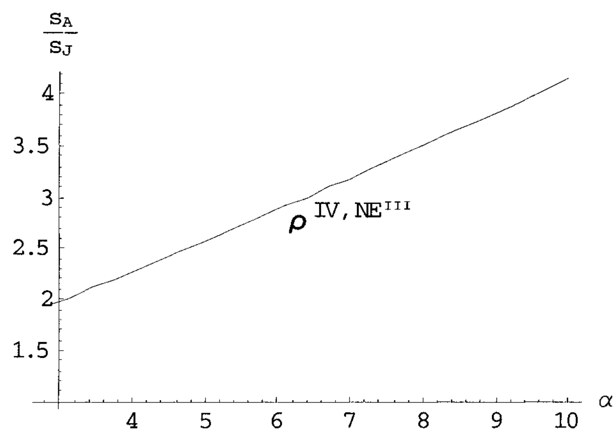
For NE^{III}, given $s_J^{NE^{III}}$, firm A's profits from not deviating are $\pi_A^{NE^{III}}$. On the other hand, its profits from deviating to domain IV are $\pi_A^{IV,NE^{III}} = \pi_A^{IV}(s_A = s_A^{BR^{IV}}(s_J = s_J^{NE^{III}}), s_J = s_J^{NE^{III}})$. Plotting $\pi_A^{NE^{III}}$ and $\pi_A^{IV,NE^{III}}$ in figure 26a, it is apparent that $\pi_A^{IV,NE^{III}}$ are higher than $\pi_A^{NE^{III}}$ if $\alpha \geq 2.823$. The latter suggests that firm A may deviate to domain III in this range of α depending on whether the deviating point belongs to this domain.

Figure 26a: Firm A's profits versus $\alpha \geq 2$.



If the deviating point belongs to domain III then firm A will actually deviate. For this verification purposes, the quality gap at the deviating point $\rho^{IV,NE^{III}} = \dfrac{s_A^{IV,NE^{III}}}{s_J^{NE^{III}}} = \dfrac{s_A^{BR^{IV}}(s_J = s_J^{NE^{III}})}{s_J^{NE^{III}}}$ is computed and plotted against α for $\alpha \geq 2.823$ in figure 26b. It is clear that this quality gap is bigger than 1 for all $\alpha \geq 2.823$. Hence the deviating point does lie in domain I. Hence firm A does have an incentive to deviate for all $\alpha \geq 2.823$.

Figure 26b: Quality gap versus $\alpha \geq 2.823$.

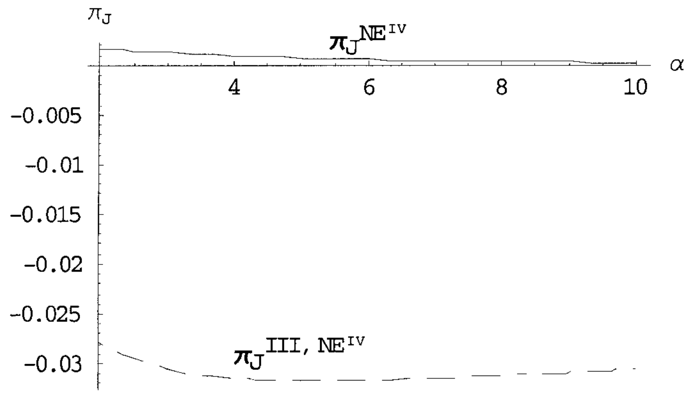


For **firm J**, firm J's best response in domain IV $s_J^{BR^{IV}}(s_A)$ is rewritten as s_A in terms of s_J, and defined as $\hat{s}_J^{BR^{IV}}(s_J)$. Given $s_A^{NE^{III}}$, firm J does not want to deviate to domain IV since $s_A^{NE^{III}} < \hat{s}_J^{BR^{IV}}(s_J = 0)$ for all $\alpha \geq 2.823$. **Therefore,** NE^{III} **is a global equilibrium for** $\alpha \in [2, 2.823]$**, and it is not for** $\alpha \geq 2.823$**.**

For NE^{IV}, again, **firm A**'s best response in domain III $s_A^{BR^{III}}(s_J)$ is expressed as s_J in terms of s_A, and denoted as $\hat{s}_A^{BR^{III}}(s_A)$. Given $s_J^{NE^{IV}}$, firm A does not want to deviate to domain III since $s_J^{NE^{IV}} < \hat{s}_A^{BR^{III}}(s_A = 0)$ for all $\alpha \geq 2$.

For **firm J**, given $s_A^{NE^{IV}}$, its profits from not deviating are $\pi_J^{NE^{IV}}$. On the other hand, its profits from deviating to domain III are $\pi_J^{III,NE^{IV}} = \pi_J^{III}(s_J = s_J^{BR^{III}}(s_A = s_A^{NE^{IV}}), s_A = s_A^{NE^{IV}})$. Plotting $\pi_J^{NE^{IV}}$ and $\pi_J^{III,NE^{IV}}$ in figure 27, it is apparent that $\pi_J^{NE^{IV}}$ are higher than $\pi_J^{III,NE^{IV}}$ for all $\alpha \geq 2$. **Therefore,** NE^{IV} **is a global equilibrium for all** $\alpha \geq 2$.

Figure 27: Firm J's profits versus $\alpha \geq 2$.



All findings of the Bertrand game are summarized in result 3.

Result 3: *Assume that firms compete in prices at the last stage of the game;* NE^{I} *is the equilibrium where firm A produces the high-quality products in free trade,* NE^{III} *and* NE^{IV} *are the two local equilibria where the constraints bind and firm A is the low- or the high- quality producer.*

i) If $\alpha \in [0.5, 2]$ *then the game has two global equilibria:* NE^{I} *and* NE^{III},

ii) If $\alpha \in [2, 2.823]$ *then it has two global equilibria:* NE^{III} *and* NE^{IV},

iii) If $\alpha \geq 2.823$ *then it has only one global equilibrium:* NE^{IV}.

Turning to comparative statics, due to the complexity of the underlying variables in equilibrium at NE^{III} and NE^{IV}, result 4 is obtained by numerical calculations.

Result 4:

(a) Comparative statics of qualities, prices, quantities and welfare at NE^{III} *are as the following:*

i) $\partial s_A^{NE^{III}} / \partial \alpha \gtrless 0 \Leftrightarrow \alpha \lessgtr 1.778 \leq 2.823, \partial s_J^{NE^{III}} / \partial \alpha < 0, \partial s_{av}^{NE^{III}} / \partial \alpha < 0, \partial \rho^{NE^{III}} / \partial \alpha > 0$,

ii) $\partial p_A^{NE^{III}} / \partial \alpha \gtrless 0 \Leftrightarrow \alpha \lessgtr 1.857 \leq 2.823, \partial p_J^{NE^{III}} / \partial \alpha \gtrless 0 \Leftrightarrow \alpha \lessgtr 0.852 \leq 2.823$, *iii)* $\partial q_A^{NE^{III}} / \partial \alpha > 0, \partial q_J^{NE^{III}} / \partial \alpha < 0, \partial q_{total}^{NE^{III}} / \partial \alpha \underset{<}{\overset{>}{-}} 0 \Leftrightarrow 2.226 \underset{>}{\overset{<}{-}} \alpha \le 2.823$,

$q_{total}^{NE^{III}} < q_{free-trade}$.

iv) $\partial \pi_A^{NE^{III}} / \partial \alpha > 0, \partial W_J^{NE^{III}} / \partial \alpha < 0, \partial W_{world}^{NE^{III}} / \partial \alpha < 0$.

(b) Comparative statics of qualities, prices, quantities and welfare at NE^{IV} *are as the following:*

i) $\partial s_A^{NE^{IV}} / \partial \alpha \underset{<}{\overset{>}{-}} 0 \Leftrightarrow 2 \le \alpha \underset{>}{\overset{<}{-}} 2.505$, $\partial s_J^{NE^{IV}} / \partial \alpha \underset{<}{\overset{>}{-}} 0 \Leftrightarrow 2 \le \alpha \underset{>}{\overset{<}{-}} 2.25$,

$\partial s_{av}^{NE^{IV}} / \partial \alpha > 0$, $\partial \rho^{NE^{IV}} / \partial \alpha > 0$,

ii) $\partial p_A^{NE^{IV}} / \partial \alpha > 0, \partial p_J^{NE^{IV}} / \partial \alpha \underset{<}{\overset{>}{-}} 0 \Leftrightarrow 2 \le \alpha \underset{>}{\overset{<}{-}} 3.739$,

iii) $\partial q_A^{NE^{IV}} / \partial \alpha \underset{<}{\overset{>}{-}} 0 \Leftrightarrow 2 \le \alpha \underset{>}{\overset{<}{-}} 3.514, \partial q_J^{NE^{IV}} / \partial \alpha < 0, \partial q_{total}^{NE^{IV}} / \partial \alpha < 0, q_{total}^{NE^{IV}} < q_{free-trade}$,

iv) $\partial \pi_A^{NE^{IV}} / \partial \alpha > 0, \partial W_J^{NE^{IV}} / \partial \alpha < 0, \partial W_{world}^{NE^{IV}} / \partial \alpha < 0$.

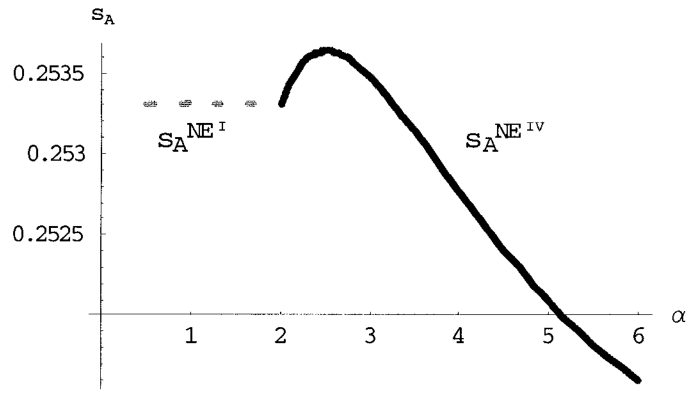
In figures 28, firms' qualities in equilibrium are plotted against α. The free trade market share is 2 when firm A is the high-quality producer. When the share gets a little bit larger than 2, to extend sales, firm A has to upgrade s_A to a higher level than the laissez faire solution. Since qualities are strategic complements in the price game, to meet the target, firm J also has to upgrade its quality even though it is to lower its sales. When the share target is large enough (2.25), firm J is able to downgrade s_J while decreasing the quantity to respect the target. As a result, firm A benefits from this quality-downgrading behavior of firm J by, starting at $\alpha = 2.5$, reducing s_A and hence saving on the sunk costs of quality. At the same time, it does not lose any sales, instead enjoys the high market share. When the share α gets as large as 3.25, firm A's quality in NE^{IV} is equal to the laissez faire solution with that firm being the high-quality producer. When the share α gets as large as 2.55, firm J's quality in NE^{IV} is equal to its free trade level with that firm being the low-quality producer. For large

α, s_A and s_J both go below the laissez faire solution. About quality at NE^{III}, $s_A^{NE^{III}}$ is always higher than laissez faire solution (0.048) while $s_J^{NE^{III}}$ is always lower than the laissez faire solution (0.253).

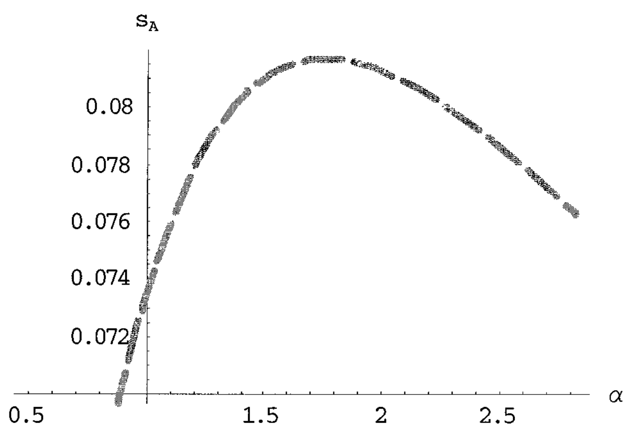
Unlike in the Cournot competition, our results in the Bertrand competition are substantially different from those existing in the literature. Lutz (2002) studies a similar question to that of Herguera et al. (2000) using a Bertrand competition model. He finds that under price competition, a quantitative restriction leads to quality-upgrading (down-grading) of the low-quality (high-quality) firm, an increase in average quality and a reduction of quality differentiation, irrespective of whether the exporting firm is of high or low quality. He also shows that a quota increases (decreases) the importing firm's profit and decreases (increases) importing country's welfare only if the exporting firm produces low- (high-) quality good. Our Bertrand game in the presence of a VIE yields a consistent welfare reduction of the importing country no matter the firms' identity. Furthermore, while other papers (either dealing with quantity or price competition) find some monotonic behavior of the underlying agents against a policy change (i.e. more or less restrictive), the exporting firm's quality adjustment in our price game is non-monotonic.

Figure 28a: Firm A's quality in equilibrium against α

(i) $s_A^{NE^I}$ and $s_A^{NE^{IV}}$ against α



(ii) $s_A^{NE^{III}}$ against α.



(iii) $s_A^{NE^I}$, $s_A^{NE^{III}}$ and $s_A^{NE^{IV}}$ against α.

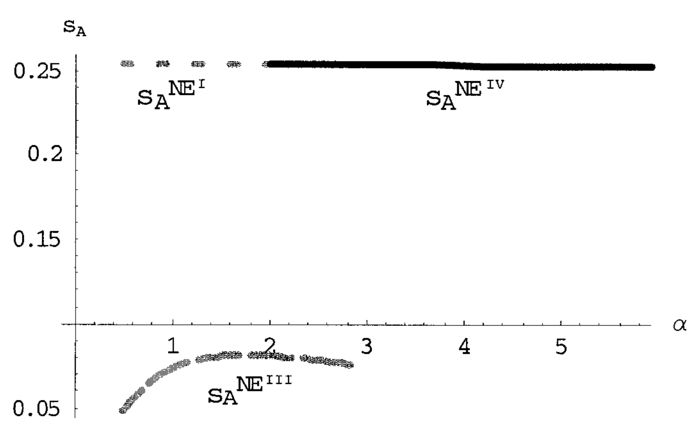
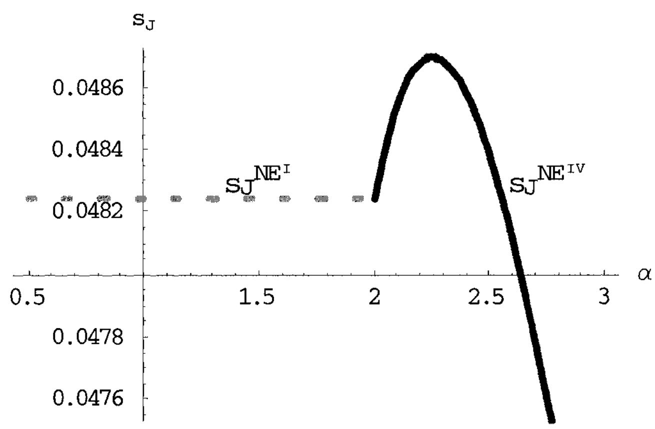
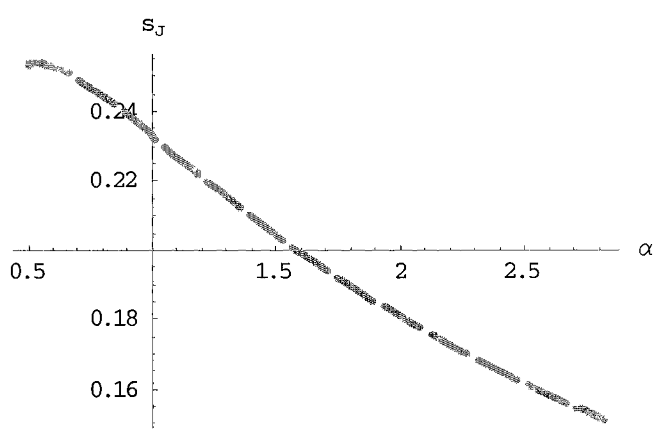


Figure 28b: Firm J's quality in equilibrium against α

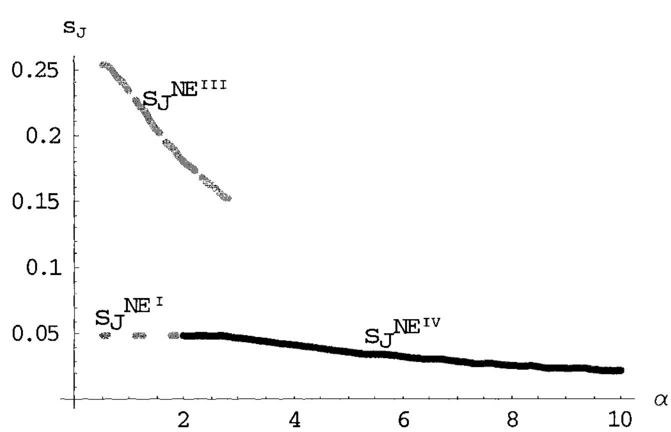
(i) $s_J^{NE^I}$ and $s_J^{NE^{IV}}$ against α



(ii) $s_J^{NE^{III}}$ against α



(iii) $s_J^{NE^I}$, $s_J^{NE^{III}}$ and $s_J^{NE^{IV}}$ against α



5. Conclusions

This paper is the first step toward highlighting the linkage between VIE and quality choice, using a vertical product differentiation model. The latter is worth analyzing since there is evidence that intra industry trade characterized by different levels of quality is a significant proportion of trade (see Greenaway et al., 1990 among others).

This paper differs from the other papers that examine the effects of trade policy on quality choice by not defining firms' quality identity (high- or low- quality firm). It is found that the market share VIE can affect the equilibrium even though it may not bind at the original equilibrium. The paper also points out the possibility that a VIE lower than laissez faire solution binds. The findings highlight the importance of strategic interaction for the choice of quality and the role of timing of the decisions. It is shown that the market share VIE is a powerful protection to the exporting firm not only at the quantity or price competition stage but also when the impact of VIE on quality choice is taken into account. The paper provides another argument for the anti-competitiveness of VIE. The VIE appears not to be "voluntary" since the domestic welfare (of country J) is lower than the laissez faire solution in the presence of the policy, no matter the firms' quality choice.

The paper could be extended in a number of ways. First, a very important issue that is left behind in this study is how a VIE is determined. Throughout the paper, the government of the exporting country is assumed to be the only decisive party in this process. Instead, it would seem natural to have the two countries bargain over the VIE. Second, in our settings, firms operate in a world of perfect information. Introducing uncertainty or asymmetric information into the analysis will shed new lights on this topic.

References

Aw - Roberts, B. Y. and Mark J., 1986. Measuring quality change in quota-constrained import markets: The case of US footwear, J. Intl. Economics 21, 45–60.

Bergsten, C. F., 1993. Good and bad managed trade, Financial Times, 18 August.

Bhagwati, J., 1987. VERs quid pro quo DFI and VIEs: Politico-economy-theoretic analyse. International Economic Journal 1, 1-14.

Boorstein, R. and Feenstra, R.C., 1991. Quality upgrading and its welfare cost in US steel imports. In: Helpman, E., Razin, A. (Eds.), International Trade and Trade Policy, MIT Press, 167–186.

Cronshaw, M. B. and Markusen, J. R.,1995. The Theory and Consequences of Results-Oriented Trade Policy. In Alan V. Deardorff, Jim Levinsohn and Robert M. Stern (ed.), New Directions in Trade Theory, Ann Arbor: The University of Michigan Press.

Das, S.P. and Donnenfeld, S., 1987. Trade policy and its impact on the quality of imports: A welfare analysis. Journal of International Economics 23, 77–95.

Das, S.P. and Donnenfeld, S., 1989. Oligopolistic competition and international trade: Quantity and quality restrictions. Journal of International Economics 27, 299–318.

Dinopolous, E. and Kreinin, M., 1990. An analysis of import expansions policies. Economic Inquiry 28, 99-108.

Dongsheng, Z., Spencer B. J., Vertinsky I., 2002. Strategic trade policy with endogenous choice of quality and asymmetric costs. Journal of International Economics 56: 205–232.

Ethier, W.J. and Horn, H.,1996. Results-Oriented Trade Policy. Review of International Economics 4 :17-39.

Falvey, R., 1979. The composition of trade within import restricted categories. Journal of Political Economy 87(5), 1105-1114.

Feenstra, R.C., 1988. Quality change under trade restrictions: Theory and evidence. Quarterly Journal of Economics 102, 131–146.

Feenstra, R.C. (Ed.), 1997. The effects of US trade protection and promotion policies. The University of Chicago Press, Chicago.

Gabszewicz, J.J. and Thisse, J.F., 1980. Entry (and exit) in a differentiated industry. Journal of Economic Theory 22, 327–338.

Gabszewicz, J.J. and Thisse, J.F., 1986. On the nature of competition with differentiated products. The Economic Journal 96 (31), 160–172.

Greaney, T., 1996. Import Now! An Analysis of Market-Share Voluntary Import Expansions (VIEs). Journal of International Economics 40,149-163.

Herguera, I., Kujal, P. and Petrakis, E., 1994. Quantity restrictions and endogenous quality choice, Working Paper 94-39, Universidad Carlos III.

Herguera, I., Kujal, P. and Petrakis, E., 1996. Endogenous quality and leapfrogging-provoking trade policies, Mimeo, Universidad Carlos III.

Herguera, I., Kujal, P. and Petrakis, E., 1997. Non-credible policies and leapfrogging in vertically differentiated industries, Working Paper 97-73, Universidad Carlos III.

Herguera, I., Lutz, S., 1998. Oligopoly and quality leapfrogging. The World Economy 21, 75–94.

Herguera, I., Kujal, P. and Petrakis, E., 2000. Quantity restrictions and endogenous quality choice. International Journal of Industrial Organization 18, 1259–1277.

Herguera, I., Kujal, P. and Petrakis, E., 2002. Tariffs, quality reversals and exit in vertically differentiated industries. Journal of International Economics 58, 467-492.

Irwin, D. A., 1994, Managed Trade: The Case Against Import Targets, Washington, D.C.: The AEI Press.

Irwin, D. A., 1996. Trade Politics and the Semiconductor Industry. In Anne O. Krueger (ed.), The Political Economy of American Trade Policy, Chicago: The University of Chicago Press.

Ishikawa, J. 1999. Expanding the Purchase of a Foreign Intermediate good: an analysis of VIEs and Content protection under Oligopoly, in Global Competition and Integration, Kluwer Academic Publisher, 99-126.

Krishna, K., 1987. Tariffs vs. quotas with endogenous quality. Journal of International Economics 23, 97–122.

Krishna, K., 1989. Trade restrictions as facilitating practices. Journal of International Economics 26, 251–270.

Krishna, K., and Morgan, J., 1998. Implementing Results-Oriented Trade Policies: The Case of the US-Japanese Auto Parts Dispute. European Economic Review 42 (8), 1443-1467.

Krishna, K., Roy, S. and Thursby, M., 1998. Implementing Market Access. Review of International Economics 6(4), 529-544.

Krishna, K., Roy, S. and Thursby, M., 2001. Can Subsidies for MARs Be Procompetitive?. Canadian Journal of Economics 34(1), 212-224.

Larue, B. and Lapan, H. E., 1992. "Market Structure, quality and the World Wheat Market". Canadian Journal of Agricultural Economics, 40(2), 311-328.

Lutz, S., 1997. Quotas with vertical differentiation and price competition, Mimeo, University of Bonn.

Lutz, S., 2002. The effects of Quotas on Vertical Intra-Industry Trade, Discussion Paper No. 02-61, Centre for European Economic Research (ZEW).

Motta, M., 1993. Endogenous quality choice: price vs. quantity competition. The Journal of Industrial Economics 2, 113–132.

Mussa, M., Rosen, S., 1978. Monopoly and product quality. Journal of Economic Theory 18, 301–317.

Qiu, L. D. and Spencer, B., 2001. Keiretsu and Relationship-Specific Investment: Implications for Market-Opening Trade Policy, NBER Working Paper No 8279.

Ries, J.C., 1993. Voluntary export restraints, profits, and quality adjustment, Canadian Journal of Economics 3, 688–706.

Santoni, G.J., Van Cott, T.N., 1980. Import quotas: The quality adjustment problem. Southern Economic Journal 46 (4), 1206–1211.

Shaked, A., Sutton, J., 1982. Relaxing price competition through product differentiation. Review of Economic Studies 49, 3–13.

Shaked, A., Sutton, J., 1983. Natural oligopolies. Econometrica 51 (5), 1469–1483.

Shaked, A., Sutton, J., 1984. Natural oligopolies and international trade. In: Kierzkowski, H. (Ed.), Monopolistic Competition and International Trade, Oxford University Press, 34–50.

Sutton, J., 1992. Sunk Costs and Market Structure, MIT Press, pp. 70–71.

Syropoulos, C., 1994. Endogenous timing in games of commercial policy. Canadian Journal of Economics, 847-864.

Tyson, L., 1990. Managed trade: Making the best of the second best. In: Lawrence, R., Schultze, C. (eds), An American Trade Strategy: Options for the 1990s. The Brookings Institution, Washington, D. C.

Vandenbussche, H. and Wauthy X., 2001. Inflicting injury through product quality: how European antidumping policy disadvantages European producers. European Journal of Political Economy 17:101-116.

Verdier, T., 1998. Results-Oriented Versus Rules-Oriented Trade Policies: A theoretical Survey. European Economic Review 42: 733-744.

Appendix: VIEs - An introduction

(Source: Irwin 1994).

The first and the most important VIE came as a direct outgrowth of a section 301 case. In 1985, the Semiconductor Industry Association (SIA) files a section 301 complaint against Japan for supporting informal barriers to the importation of foreign semiconductor devices. While no formal government policies were ever identified, the SIA maintained that the U.S. market share in Japan (at roughly 10 percent) was implausibly low compared with the U.S. market share in third markets. The SIA further argued that the market structure in Japan and the buying preferences of Japanese firms, both resulting from government policy, hindered the sales efforts of foreign producers. The association called for an "affirmative action" scheme from the US government to help to penetrate the Japanese market in the face of hidden, invisible trade barriers. As a result, in a 1986 agreement the US forced the Japanese government to help ensure that the foreign suppliers would obtain 20 percent of Japan's semiconductor market within five years.

Although foreign semiconductor producers achieved a 20.2% share of the Japanese market, in the fourth quarters of 1992, the market share target has been a source of continual friction between the US and Japan. The foreign share fell to nearly 18 percent in the first three quarters of 1993, although that share jumped back over 20 percent in the fourth quarter of 1993.

A second operative VIE between the US and Japan concerns automobile parts and the resulted, not from a section 301 case, but from presidential action over Japan's perceived closeness to outside part suppliers. During President Bush's visit to Japan in 1992 the US and Japan agreed to a Global Partnership Plan of Actions. Part if this package was the pledge by Japanese automobile manufacturers to purchase a specific amount of U.S.-made auto parts.

The Clinton administration attempts to broaden the reach of VIEs to other sectors and thus to institutionize the use of quantitative indicators of market share targets as parts of U.S. trade policy towards Japan. In July 1993, the US and Japan established a Framework for a New Economic Partnership as a guide for new negotiations over structural and sectoral issues. In the framework negotiations, the US had strongly pushed for quantitative benchmarks such as

VIEs. The US demanded early agreements on the use of quantitative markets indicators in four sectors: (1) auto parts and automobiles, (2) medical equipment, (3) telecommunications equipment, and (4) insurance. Japan has refused to adopt quantitative benchmarks and insisted that such standards would constitute guaranteed market shares in violation of free trade principles. The two countries failed to conclude any early agreements.

In April 1992, Micron Technology, Inc., a small semiconductor producer in Boise, Idaho, filed an antidumping petition alleging less-than-fair-value imports of IM DAM semiconductors and higher from Korea. In October, the Commerce Department announced preliminary dumping margins (based on petitioner information) as high as 87 percent against Samsung, Gold Star, and Hyundai. Faced with stiff antidumping duties, the Korean industry and government proposed in January 1993 a bilateral semiconductor trade agreement fashioned on the earlier one with Japan. The Korean government offered to sign an agreement committing itself to a VIE to increase sales in Korea of U.S. semiconductors and semiconductor equipment. However, confident of resting securely behind high antidumping duties imposed against Korea and itself unaffected by the prospective Korean market opening actions, Micron vetoed the Korean proposal.

CHAPTER 3. INTRA-INDUSTRY TRADE, MULTILATERAL TRADE INTEGRATION AND INVASIVE SPECIES RISK

1. Introduction

Our paper locates at the confluence of international trade, the environment, and sanitary and phytosanitary (SPS) issues. International trade can be an important conduit of environmental change (Copeland and Taylor; Beghin, Roland-Holst, and van der Mensbrugghe). A recent literature is emerging on this triple interface of trade, the environment and SPS, with a focus on accidental introductions of exotic or invasive species (IS) like pests, weeds, and viruses, by way of trade (Perrings, Williamson and Dalmazzone; Mumford). The trade-SPS-environment interface is almost inherent to the economics of IS since trade is a major vector of propagation of these species, although it is not the only one.[19] Many papers in this new literature are focused on the "right" criteria to use or the optimal environmental policy response to the hazard of IS (Sumner; Binder) and around quarantine as a legitimate policy response to phyto-sanitary risk (Cook and Frazer; Anderson, McRae, and Wilson). Our paper contributes to this new literature on trade and IS risk in the specific context of agricultural markets and trade and looks at the impact of multilateral trade integration and its impact on IS risk.

Agricultural imports have always been an important conduit for biological invasions. Despite of the Uruguay Round Agreement of the WTO, protection remains high in agriculture and its reduction in future trade agreements will influence agricultural trade patterns and associated IS damages. Elucidating the impact of the structure of agricultural protection on IS hazards and damages is an important question. In a standard one-way trade Heckscher-Ohlin-Samuelson (HOS) model, Costello and McAusland show that lowering agricultural tariffs could lower the damage from exotic species, even though the volume of trade rises and the rate of IS introduction rises, because an increase in imports results in a reduced domestic agricultural output. Thus the crop volume susceptible and available for damage and the land area potentially affected by the pest are reduced, hence damages can be

[19] "Natural" invasions occur because of natural vectors (weather related ones, animal migration) such as the recent spread of soybean rust in the Southern United States by hurricanes.

reduced as well leading to an ambiguous effect of trade on IS damages.

Our paper extends and builds upon the enquiry of Costello and McAusland with major departures. We study the linkage between protectionism and damages from IS in the context of two-way trade and multilateral trade liberalization. Intra-industry trade characterizes agricultural trade patterns in the real world. For example, wheat is a differentiated commodity with most trading countries importing and exporting wheat (See Table 1). Two-way trade patterns hold even more for more broadly defined commodities such as coarse grains as shown in table 2. Because they can cross grain types, many pests and IS represent a risk for several types of grains and coarse grains, hence the relevance of two-way trade for broader commodity definitions. The HOS framework has limited empirical relevance in this context. We further depart with the previous analysis by considering multilateral trade liberalization. Trade integration is occurring mostly in the context of WTO multilateral or regional reforms (e.g., The Uruguay Round Agreement on Agriculture, Free Trade of the Americas). Seldom do countries engage in unilateral trade liberalization but rather commit to jointly reduce their protection through regional or multilateral agreements.[20] Another argument to consider joint reforms is that transaction costs, although still significant, have been falling dramatically for both exports and imports through cheaper transportation, cheaper refrigeration and insurance, etc. Joint tariff reduction and the joint lowering of transaction costs on both sides of any border have the similar effects on trade, production, and consumption and can be parameterize similarly.

We consider joint tariff reductions and their effect on expected IS damage. Under perfect competition, we find that this type of trade integration is much more likely to increase expected damage from exotic species in our two-way trade model, as compared to unilateral liberalization in the HOS paradigm. Multilateral liberalization in the context of imperfect competition and two-way trade of close substitutes produces the same qualitative result of increasing IS risk. Hence the ambiguity of Costello and McAusland is much reduced in our more realistic context.

The remainder of the paper is organized as follows. Section 2 highlights some

---

[20] There are exceptions such as New Zealand's unilateral trade liberalization in the 1980s but by and large joint reforms are much more common (Bhagwati).

stylized facts about grain trade, trade integration, and IS associated with wheat. The main model that highlights the linkage between trade reforms and IS introduction is formalized in section 3. Extensions that bring market structure into account are considered in section 4. We illustrate and examine the robustness of the results in section 5 by calibrating the analytical model to recent data on wheat trade and the associated damages from exotic species. Summary remarks then conclude the paper.

2. Stylized facts on grains trade integration and associated IS risk

In this section, we briefly discuss the nature of wheat trade patterns and integration with emphasis on that of the United States and Canada. Similar patterns hold for many countries and many commodities, although tariffs and protectionism in agriculture remain significant in many parts of the world. Then we look at IS risk associated with wheat.

Table 1 summarizes the bilateral trade on wheat between the US, Canada and the "rest of the world" in the marketing year of July 2001-June 2002. There is a large two-way trade between the US and Canada: 98% of US wheat imports come from Canada, while 25% of Canada wheat imports are from the US. For a broader picture of grain trade, table 2 highlights the bilateral trade on coarse grains between these three countries in the same period of time. It is seen that two-way trade is even more obvious in coarse grains than in wheat trade. However, for the sake of simple illustration, we will focus on wheat trade between these countries for the rest of the paper.

Tables 3 and 4 show that trade policy barriers have been falling during the past 25 years. The United States adopted the Harmonized System (HS) nomenclature and shifted from charging wheat imports based on food and feed to durum and other in 1988 (Wainio). Tariffs on wheat in these two countries have been falling remarkably. They become quite negligible, especially those of Canada. Hence, on the policy front, remarkable trade integration has been occurring between these neighboring countries.

Trade integration goes beyond tariff reductions. Trade barriers are considered to be a part of trade costs, along with transaction costs associated with trading across borders. The underlying problematic addressed in our paper is even more relevant because trade costs remain enormous although they have been falling overtime. Anderson and van Wincoop

(2004) review the recent literature on trade cost and provide a rough estimate of "representative" trade costs for industrialized countries which are 170 percent in ad valorem equivalent of unit cost. They break down as follows: 21 percent transportation costs, 44 percent border related trade barriers, and 55 percent retail and wholesale distribution costs. The 21 percent transport cost includes both directly measured freight costs and a 9 percent tax equivalent of the time value of goods in transit.[21] Their overall representative estimate of policy barriers for industrialized countries (including non-tariff barriers) is about 8 percent, which is very low since they mostly address manufacturing trade, not agricultural trade. Amazingly, inferred border costs appear on average to dwarf the effect of tariff and non-tariff policy barriers. A rough breakdown of the 44 percent number reported above is as follows: an 8 percent policy barrier; a 7 percent language barrier, a 14 percent currency barrier (from the use of different currencies), a 6% informational cost barrier, and a 3 percent security barrier for rich countries.

Table 5 directly from Anderson and van Wincoop (2004), presents tariff equivalent estimates of trade cost in percent of unit cost from a number of studies. Column two reports the tax equivalent of trade barriers reported by authors, with the corresponding common elasticity of substitution among all goods in bracket.[22] As this column reflects, the results are sensitive to the elasticity of substitution. The last column computes the trade barriers for a representative of the elasticity estimated in the literature which is eight. In some cases two numbers are reported with the lower number applying to countries that share the same language and border. An average US-Canada trade barrier is suggested to be 46-58 percent (the lower 58 percent reported by Eaton and Kortum applies to countries that share a border and language which include the case of US-Canada). For more general situations, international trade barriers are in the range of 40-78 percent for the representative elasticity of substitution of eight.

A number of studies have found that trade costs have been falling overtime. One of the main components of trade costs is transportation cost. Bitzan et al. (2003) simulate the

[21] In 1998, half of US shipments was by air and half by boat. Anderson and Wincoop assign one day to shipment by air anywhere in the world, as Hummels does, and use twenty days average for ocean shipping to lead to an average of 9 percent tax equivalent of time cost.

[22] It relates to one-sector economy where consumers have CES preferences with common elasticity of substitution.

changes in US rail rates over the 1981 through 2000 time period relative to 1981 as shown in Figure 1. As appeared in this figure, three commodities of their interest which are wheat, corn and soybeans show large percentage decreases in rate since 1981 and some tapering since the mid 1990s.[23]

Hummels (1999), on the other hand, reports a world-wide value for transportation costs as measured by ratio of CIF to FOB valuation of trade as appeared in Figure 2. The figure suggests that CIF/FOB transportation costs have declined precipitously – from 13 percent of trade to a few percent from 1949 to 1995. It also shows that transportation costs were almost exactly constant at 3.5 percent of trade from 1953 to 1997.[24] However, the measurement of transportation costs using importer CIF/FOB ratios suffer from severe quality problems and broad inferences based on these data has to be carefully qualified. [25]

Despite these pitfalls regarding the magnitude of trade costs and their measurement, the evidence strongly suggests that trade costs have fallen, but remain large. Hence, the correlation between trade integration and damages caused by IS reflects recent market and policy developments which are likely to continue in the future, making our investigation very relevant.

Table 6 summarizes information about wheat pests and insects in the United States with their economic importance which ranges between low, moderate and high. The table was constructed with information from the *Crop Protection Compendium* (CABI Compendium). It shows the origin of a lot of pests and insects which in turn reflect the exotic nature of these species. E.g. Russian wheat aphid was first found in Russia in 1912, and first reported in Texas in 1986. Or, the karnal bunt of wheat was first reported in Pakistan in 1909, and recently found in southwestern United States (in 1996). The table also includes the likelihood of seedborne incidence, and the possibility of seed transmission and seed treatment of these species. The common bunt, for example, is of high seedborne incidence,

---

[23] It is well documented that railroad deregulation in the US has been successful in a broad overall context. Studies have shown that increased productivity, decreased rates and increased profitability in the rail industry can be attributed to deregulation.

[24] This could be read from Figure 2 since world CIF/FOB is 1.035 for both 1953 and 1997.

[25] Among the serious problems can be small discrepancies in the report of the importer or exporter yielding large changes in CIF/FOB ratio. Also, exporter and importer reports of bilateral trade flow may vary for reasons unrelated to shipping costs. More troubling is, for many pairings, only one partner reports data and these constraints force the IMF to construct CIF/FOB ratios for most of the countries and years.

and it can be transmitted through seeds, but seed treatment is available which lightens its economic impacts. The most important feature of this table is some measures of economic impacts of these species at different time and places. These impacts are usually measured in terms of yield losses, and often recorded only when the effects were severe. In brief, the table brings some facts about possible considerable effects on wheat yields of these species.

However, Pimentel's findings support losses arising in many ways beyond yield loss and affecting an array of potential economic agents summarized in the expected loss. According to Pimentel et al., $23.4 billion per year of U.S. crop losses are due to introduced weeds, but approximately $3 billion is used for control of nonindigenous weeds. Also, introduced pest insects cause approximately $13.9 billion in U.S. crop losses each year, but approximately $1.2 billion worth of pesticides are applied for control of all crop insects each year. Or, U.S. crop losses to nonindigenous plant pathogens are about $21 billion, but growers spend $500 million each year on fungicides to combat these nonindigenous pathogens. Therefore, in this paper, the yield specific effect of IS is used for calibrated model, but not for the central case since damages are no specific to the industry. They could affect the representative consumer (e.g. loss of biodiversity associated with the crops or regions in which crops are grown) or other sectors not explicitly represented by the grain industry and the consumer but somehow associated with the regions or land in which IS would occur.

3. Multilateral trade integration and invasive species risk in a two-way trade model

3.1. Trade model

We present the trade model in this section. Assume that there are two countries, Home and Foreign, and that each country has one industry producing a given commodity. The industries in the two countries are perfectly competitive. The Home firm produces output x for domestic consumption and output x^* for Foreign consumption. Similarly, the Foreign firm produces output y for export to Home, and output y^* for its own market.

Assume that Home good and Foreign good are imperfect substitutes in each market such that the Home demands for domestic good and imports are

(1) $x(p_x, p_y) = a_x - b_x p_x + kp_y$, and

(2) $y(p_x, p_y) = a_y - b_y p_y + kp_x$,

where (p_X, p_Y) are price of Home and Foreign goods in the Home market. All parameters are assumed to be positive and so is the expression $b_x b_y - k^2$ by integrability of a demand system derived by maximizing a quasi-linear utility under budget constraint (see appendix 1). Similarly, Foreign demands for its own domestic good and the imports are

(3) $y^*(p_{x^*}, p_{y^*}) = a_{y^*} - b_{y^*} p_{y^*} + k^* p_{x^*}$, and

(4) $x^*(p_{x^*}, p_{y^*}) = a_{x^*} - b_{x^*} p_{x^*} + k^* p_{y^*}$.

Again, all parameters are assumed to be positive and so is the expression $b_{x^*} b_{y^*} - k^2$. Assume that Home and Foreign governments impose tariffs on imports (τ, τ^*), and the home and foreign firms' unit cost are c and c^* respectively. Tariffs are expressed in ad valorem rate. Assume that firms charge constant average cost pricing in both market and make zero profit. That is $p_x = p_x^* = c$, and $p_y = p_{y^*} = c^*$. Then, the equilibrium sales which are represented by the corresponding capital letters are as the following:

(1') $X = a_x - b_x c + kc^*(1+\tau)$, and

(2') $\hat{Y} = a_y - b_y c^*(1+\tau) + kc$,

(3') $\hat{Y}^* = a_y^* - b_{y^*} c^* + k^* c(1+\tau^*)$, and

(4') $\hat{X}^* = a_x^* - b_{x^*} c(1+\tau^*) + k^* c^*$.

Comparative statics of these variables with respect to policy can be derived as the following:

(i) $\partial \hat{X}^* / \partial \tau = 0$, $\partial \hat{X}^* / \partial \tau^* = -b_x^* c < 0$;

(ii) $\partial \hat{X} / \partial \tau = c^* k > 0$, $\partial \hat{X} / \partial \tau^* = 0$;

(iii) $\partial \hat{Q} / \partial \tau = c^* k > 0$, $\partial \hat{Q} / \partial \tau^* = -cb_x^* < 0$.

(iv) $\partial \hat{Y} / \partial \tau = -c^* b_y < 0$, $\partial \hat{Y} / \partial \tau^* = 0$.

3.2. Modeling IS hazard and policy interface

We assume that effects of imports and total production on the expected damages are

The expected damages caused by IS are:

$E[D] = \rho(Y)F(Q)$,

where ρ is the rate of successful IS introduction to Home country, and F is the IS damages to Home given that total production is Q.[26] Assume that ρ is increasing in the volume of imports Y. Damages are called augmented (neutral, diminished) if they increase (remain unchanged, decrease) as the level of agricultural activity increases (Costello and McAusland), that is if $F_Q > 0$ ($F_Q = 0$, $F_Q < 0$). The augmented damages are relevant and most important in the real world.

We now consider the effects of trade integration on expected damages in equilibrium. Under the Uruguay Round Agreement on Agriculture, WTO member countries have had to convert quantitative restrictions on imports into bound tariffs, reduce these tariffs over an implementation period, open their markets to imports under the minimum access provision. We reflect and summarize these reforms into our model as a joint reduction of tariffs. Assume that trade negotiations yields the joint trade policy reform outcome $d\tau/\tau = d\tau^*/\tau^* = -\kappa$, i.e., a proportional decrease of tariffs, where κ is any arbitrary positive fraction.

To understand the effect of trade liberalization on the damage from exotic species, we seek the sign of the total derivative

(5) $$dED = \rho F_Q\left[Q_\tau d\tau + Q_{\tau^*} d\tau^*\right] + F\rho_Y\left[Y_\tau d\tau + Y_{\tau^*} d\tau^*\right].$$

Using $d\tau/\tau = d\tau^*/\tau^* = -\kappa$ where $\kappa > 0$ and results (i)-(iv), we get:

(6) $$dED_{TWT} = \rho F_Q\left[Q_\tau(-\kappa)\tau + Q_{\tau^*}(-\kappa)\tau^*\right] + F\rho_Y\left[Y_\tau(-\kappa)\tau + Y_{\tau^*}(-\kappa)\tau^*\right]$$
$$= -\kappa\left[c^*\tau\left(\rho F_Q k - F\rho_Y b_y\right) - c\tau^*\rho F_Q b_{x^*}\right].$$

Hence $dED_{TWT} \gtreqless 0 \Leftrightarrow -\kappa\left[c^*\tau\left(\rho F_Q k - F\rho_Y b_y\right) - c\tau^*\rho F_Q b_{x^*}\right] \gtreqless 0$.

---

[26] Costello and McAusland (2003) have a more elaborate approach to model IS risks. But the qualitative results do not change. In Costello and McAusland's modeling, there is one more component in the expected damages which is the probability that an introduced species establish a viable population in Home. Since this probability is assumed to be constant, it can be viewed as a scale factor in our simplified expected damages.

Define $\varepsilon_{\rho_Y} \equiv \rho_Y \frac{Y}{\rho} > 0$ and $\varepsilon_{F_Q} \equiv F_Q \frac{Q}{F} \gtrless 0$, rewrite the expression above to get:

$$(7) \qquad dED_{TWT} \gtrless 0 \Leftrightarrow \varepsilon_{\rho_Y} \gtrless \frac{Y}{F} \varepsilon_{F_Q} \left[\frac{k}{b_y} - \frac{c}{c^*} \frac{\tau^*}{\tau} \frac{b_{x^*}}{b_y} \right].$$

This finding is stated in result 1.

Result 1: *Given the demand structure as specified in equations (1)-(4), multilateral trade liberalization increases (decreases) the expected damages if and only if the elasticity of the rate of successful IS introduction with respect to volume of imports is higher (lower) than* $\tilde{\varepsilon}$ *where* $\tilde{\varepsilon} \equiv \frac{Y}{F} \varepsilon_{F_Q} \left[\frac{k}{b_y} - \frac{c}{c^*} \frac{\tau^*}{\tau} \frac{b_{x^*}}{b_y} \right]$.

The critical value $\tilde{\varepsilon}$ depends on the elasticity of the conditional damages with respect to total domestic production, the relative cost, the relative tariffs, the imports and total production in equilibrium, and demand parameters b_{x^*}, b_y and k.

For trade liberalization to decrease the expected damages, it must be that $\varepsilon_{\rho_Y} < \frac{Y}{F} \varepsilon_{F_Q} \left[\frac{k}{b_y} - \frac{c}{c^*} \frac{\tau^*}{\tau} \frac{b_{x^*}}{b_y} \right]$. Since $\rho_Y > 0$, this condition requires that $\frac{\tau^*}{\tau} < \frac{c^*}{c} \frac{k}{b_{x^*}} \equiv \hat{\tau}$.[27] This is necessary but the sufficient condition is $\varepsilon_{\rho_Y} < \tilde{\varepsilon}$. Economically, the possibility that trade liberalization reduces the damages caused by IS exists because total production of Home may decrease. The reply of Home production to trade reform in these scenarios is represented by

$$dQ = -\kappa \left(\tau \frac{\partial Q}{\partial \tau} + \tau^* \frac{\partial Q}{\partial \tau^*} \right).$$

Hence, by comparative statics results stated earlier, the following holds:

$$dQ \gtrless 0 \Leftrightarrow \frac{\tau^*}{\tau} \gtrless -\frac{\partial Q / \partial \tau}{\partial Q / \partial \tau^*} = \frac{c^* k}{c b_x^*} .$$

[27] Since $\frac{k}{b_y} - \frac{c}{c^*} \frac{\tau^*}{\tau} \frac{b_{x^*}}{b_y}$ need to be positive.

So, $dQ<0$ if and only if $\frac{\tau^*}{\tau}<\frac{c^*k}{cb_{x^*}}=\hat{\tau}$. Again, this is a necessary condition for reduction of damages caused by IS due to trade liberalization. However, $dQ<0$ is not a sufficient condition. Assume that damages are augmented, that is $\varepsilon_{F_Q}=F_Q\frac{Q}{F}>0$, by equation (7), we have an equivalent sufficient condition to $\varepsilon_{\rho_Y}<\tilde{\varepsilon}$, which is $\frac{\tau^*}{\tau}<\frac{c^*}{c}\left(\frac{k}{b_x^*}-\frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}}\frac{Q}{Y}\frac{b_y}{b_x^*}\right)\equiv\tilde{\tau}$.

That means multilateral trade liberalization decreases the expected damages if and only if the relative tariff which is defined by the ratio between foreign and domestic tariffs is lower than $\tilde{\tau}$. Since $\tilde{\tau}<\hat{\tau}$, it is clear that not only total production must fall, but it has to fall enough such that effects of the reduction of production on total damages offset the effects of the increase of imports on total damages. This is an intuitive result.

In contrast, also by (7), assume that damages are augmented, a necessary and sufficient condition for trade liberalization to increase the expected damages is obtained as

(8) $$\frac{\tau^*}{\tau}>\frac{c^*}{c}\left(\frac{k}{b_{x^*}}-\frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}}\frac{Q}{Y}\frac{b_y}{b_{x^*}}\right)\equiv\tilde{\tau}.$$

Further and for sake of intuition, we assume symmetric costs of the two countries, that is c=c*. Then (8) becomes $\frac{\tau^*}{\tau}>\frac{k}{b_{x^*}}-\frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}}\frac{Q}{Y}\frac{b_y}{b_{x^*}}\equiv\omega$. It is worth to notice that $\omega<1$. Result 2 follows directly from this argument.

Result 2: *Given the demand structure as specified in equations (1)-(4), and assuming* symmetric costs, *multilateral trade reform involving joint tariff reduction always increases expected damages, if (i) Home pre-reform tariff is not higher than foreign pre-reform tariff, or if (ii) Home pre-reform tariff is higher than Foreign pre-reform tariff but not substantially so that* $\omega<\frac{\tau}{\tau^*}<1$.

The first condition holds because $\tau\leq\tau^*\Rightarrow\frac{\tau^*}{\tau}\geq 1>\omega$. Note also in case (ii), the condition is more likely to hold for (i) large b_{x^*}, small b_y and small k; (ii) small ε_{ρ_Y} and large ε_{F_Q} in equilibrium; and (iii) small Q and large Y in equilibrium. This result suggests that a relatively open country liberalizing its trade with a more protectionist partner will face increase expected damages, other things being equal.

Assume further that the own-price and cross-price effects are the same in Foreign, that is $b_{x*} = b_y = b* > k$, then $\omega|_{b_{x*}=b_y=b*} = \frac{k}{b*} - \frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}} \frac{Q}{Y}$. Hence result 2 can be stated as: multilateral trade reform involving joint tariff reduction always increases expected damages, if (i) Home pre-reform tariff is not higher than foreign pre-reform tariff, or if (ii) Home pre-reform tariff is higher than Foreign pre-reform tariff but not substantially so that $\frac{k}{b*} - \frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}} \frac{Q}{Y} < \frac{\tau *}{\tau} < 1$.

3.3. Trade liberalization and IS risks: Two-way trade versus one-way trade

We want to compare the reform-induced damages from IS in the imperfect competition and two-way trade context to the outcome in the one-way trade *cum* unilateral reform case. The "one-way trade" context can be interpreted in our framework as when the Home firm's export $X*$ to the Foreign market does not exist.[28] Therefore, the demand system is characterized only by equations (1), (2) and (4). As a result, the relation between trade reform and the damages from IS in the one-way trade model is characterized by equation (6) but with $Q_{\tau*}$=0.

(9) $$dED_{OWT} = \rho F_Q \left[Q_\tau(-\kappa)\tau\right] + F\rho_Y\left[Y_\tau(-\kappa)\tau + Y_{\tau*}(-\kappa)\tau *\right] = -\kappa c * \tau\left(\rho F_Q k - F\rho_Y b_y\right).$$

Hence $dED_{OWT} \gtreqless 0 \Leftrightarrow -\kappa c * \tau\left(\rho F_Q k - F\rho_Y b_y\right) \gtreqless 0$.

One should notice that it is reasonable to compare the two conditions for two-way and one-way trade since, though the two-way trade occurs which leads to $Q_\tau = X_\tau + X_\tau^*$, by element (i) of corollary 1, $X_\tau^* = 0$. Therefore, corollary 2 still holds. For completeness of the result, we compare the likelihood for all kind of damages, although augmented damages are

---

[28] This situation can be justified as i) if Home products do not generate any utility to the foreign consumers. Hence the foreign utility is of the form $u*(y*) = A_{y*}y* - 0.5B_{y*}y*^2$; or ii) if foreign purchasers do want to consume Home products, but their demand is not high enough to be realized (i.e. a_x^* is so small that $x* \leq 0$).

considered to be the most relevant ones. Since in two-way trade case, $\partial\hat{Q}/\partial\tau^* = -cb_x^* < 0$, we get the following result.

Result 3: *If the damages are* $\begin{pmatrix} augmented \\ neutral \\ diminished \end{pmatrix}$ *then trade liberalization is* $\begin{pmatrix} more\,likely \\ equally\,likely \\ less\,likely \end{pmatrix}$ *to increase the expected damages in a two-way-trade cum multilateral- reform context than in a one-way-trade cum unilateral reform case.*

Finally, we could also compare the underlying condition for two way trade and one way trade framework by looking back at equation (6). We observe the followings:

(i) In two-way trade framework, production Q falls with the Home tariff falling through cross price effect k. A difference from the one-way trade framework is that this change dQ through demand is not equal to the corresponding dQ in HOS (own price). HOS would predict a larger change in absolute value;

(ii) A change in imports which increase the risk of IS through own price effect b_y. this is as in HOS;

(iii) A production expansion via export expansion which is through b_{x^*}. This is due to the tariff decrease in the rest of the world or integration in the context of two way trade.

4. Extensions

4.1. Market structure

One may argue that agricultural trade is rather imperfectly competitive. For example, Schmitz and Furtan (2000) show oligopolistic nature of wheat trade. We want to investigate the imperfect competition nature of grain markets. We will show that market structure is not critical to derive our analytical results. The qualitative results of the paper do not change with the imperfect competition set-up.

The basic model presented in the previous section is now modified to incorporate firms' market power. Assume that there is one firm in each country instead of one industry. Assume further that firms now compete in prices against each other in the two markets. The markets are segmented. The demands as specified in equations (1)-(4) remain the same. The constant unit cost structure remains unchanged too.[29] Home firm and Foreign firm regard each country as a separate market and therefore chooses to maximize their profits by making price discrimination of the third degree. Home and foreign firms' problems are

(10) $\underset{w.r.t.\{p_x, p_{x*}\}}{Max} \; \pi(\vec{p},\vec{\tau}) = [p_x - c]x\left(p_x, p_y(1+\tau)\right) + \left[p_{x*} - c\right]x*\left(p_{x*}(1+\tau*), p_{y*}\right)$, and

(11) $\underset{w.r.t.\{p_y, p_{y*}\}}{Max} \; \pi*(\vec{p},\vec{\tau}) = \left[p_y - c*\right]y\left(p_x, p_y(1+\tau)\right) + \left[p_{y*} - c*\right]y*\left(p_{x*}(1+\tau*), p_{y*}\right)$

respectively, where $\vec{p} = (p_x, p_{x*}, p_y, p_{y*})$, $\vec{\tau} = (\tau, \tau*)$. This setting is similar to the "reciprocal dumping" model of Brander and Krugman (1983), except that these authors worked with homogenous goods and did not introduce trade policies into the analysis. The home firm's best responses are

(12) $BR_x^H(p_y) = \left\{[a_x + b_x c] + k(1+\tau)p_y\right\}/2b_x$, and

(13) $BR_{x*}^H(p_{y*}) = \left\{\left[a_{x*} + b_{x*}c(1+\tau*)\right] + k*p_{y*}\right\}/2b_{x*}(1+\tau*)$.

The Foreign firm's best responses are

(14) $BR_y^F(p_x) = \left\{\left[a_y + b_y c*(1+\tau)\right] + kp_x\right\}/2b_y(1+\tau)$, and

(15) $BR_{y*}^F(p_{x*}) = \left\{\left[a_{y*} + b_{y*}c*\right] + k*(1+\tau*)p_{x*}\right\}/2b_{y*}$.

Equilibrium in the two countries' markets can be solved independently. That is, equations (12) and (14) simultaneously define the equilibrium prices in the Home markets $\left(P_x, P_y\right)$, and equations (13) and (15) simultaneously define the equilibrium prices in the Foreign markets $\left(P_{x*}, P_{y*}\right)$. Appendix 2 establishes the existence and uniqueness of the Bertrand equilibrium in our model; two-way trade exists given arbitrary trade and agricultural policies.

Home and Foreign equilibrium quantities consumed for both goods which are represented by the corresponding capital letters with a hat are

(16) $\hat{X}(\tau) = \frac{b_x}{D}\left\{2a_x b_y + ka_y + c(k^2 - 2b_x b_y) + kb_y c*(1+\tau)\right\}$,

---

[29] Results remain the same if the fixed costs are taken into account. Hence for the sake of simplicity, we will not introduce the fixed costs in the model.

$$(17)\qquad \hat{Y}(\tau) = \frac{b_y}{D}\left\{2a_y b_x + k a_x + ckb_x + c^*(k^2 - 2b_x b_y)(1+\tau)\right\},$$

$$(18)\qquad \hat{X}^*(\tau^*) = \frac{b_{x^*}}{D^*}\left\{2a_{x^*}b_{y^*} + k^* a_{y^*} + c^* k^* b_{y^*} + c(k^{*2} - 2b_{x^*}b_{y^*})(1+\tau^*)\right\}, \text{ and}$$

$$(19)\qquad \hat{Y}^*(\tau^*) = \frac{b_{y^*}}{D^*}\left\{2a_{y^*}b_{x^*} + k^* a_{x^*} + ck^* b_{x^*}(1+\tau^*) + c^*(k^{*2} - 2b_{x^*}b_{y^*})\right\},$$

with $D \equiv 4b_x b_y - k^2$ and $D^* \equiv 4b_{x^*}b_{y^*} - k^{*2}$. Home equilibrium production is $\hat{Q}(\vec{\tau}) = \hat{X}(\tau) + \hat{X}^*(\tau^*)$.

The comparative statics are derived in appendix 3. It is obvious that the signs of the comparative statics still hold in the imperfect competition set-up, although the magnitude differs. Appendix 4 provides the comparison of the magnitude of comparative statics under two alternative market structures. Effects of policy on Home imports or exports under perfect competition are not smaller than that under imperfect competition, while these effects on Home consumption of its own good go on the opposite way. Home policy has smaller impacts on total home production under perfect competition than that under imperfect competition; and foreign policy has opposite impacts on total home production. However, the qualitative results of the paper do not change with the imperfect competition set-up. Hence, the findings do not hinge on market structure. Note that it is reasonable to establish a one-way trade Bertrand competition model which is represented by equations (1), (3) and (4) since it is shown in appendix 5 that the Bertrand equilibrium exists and is unique in this one-way trade system.

So the central case of the paper is the perfect competition model. We have just shown that the market structure does not matter to the qualitative results of the paper.

4.2. Market structure and feedback in production

The model with market structure presented in the previous section is in the context of "diffuse" externality, hence we assume that firms do not observe damages caused by the IS introductions. That means there is no feedback on the industry or firm cost because the externality could bo to another agent (e.g. consumer's valuation of IS). However, since in the strategic framework, it is plausible to assume that firms observe the expected damages. To have any relevance this assumes that ED maps into a loss of yield and hence a cost increase. The unit cost of production of Home firm is assumed to be $c+\beta$ where $\beta=\delta y$ reflects the feedback of externality in the cost of production.

The best responses of the foreign firm remain the same as reported in equations (14) and (15). However, the best responses of Home firm change. The new best responses of Home firm will be as follows:

$$(12') \quad BR_x^H(p_y, p_{x*}, p_{y*}) = \begin{Bmatrix} a_x(k\delta-1) - b_x(c+\delta a_y) + \delta k a_{x*} + \\ [b_x b_y \delta + k(k\delta-1)]\tau p_y + kk*\delta p_{y*} - kb_{x*}\tau*\delta p_{x*} \end{Bmatrix} / 2b_x(k\delta-1),$$

and

$$(13') \quad BR_{x*}^H(p_x, p_y, p_{y*}) = \left[a_{x*} + k*p_{y*} + b_{x*}\tau*(c + a_y\alpha + k\alpha p_x - b_y t\alpha p_y)\right] / 2b_{x*}\tau*.$$

Note that the system characterized by equations (12'), (13'), (14) and (15) is no longer separable as it was. That is, the properties that the equations (12) and (14) define equilibrium prices (p_x, p_y), and the equations (13) and (15) define equilibrium prices (p_{x*}, p_{y*}) no longer hold for equations (12') and (13'). The system is solved and used for calibration in the next section.

5. Calibration of the wheat model in the presence of invasive species risk

We calibrate the analytical model using data on wheat production and trade and plausible assumptions on invasive species associated with wheat for the three country case (the United States, Canada, and the rest of the world (ROW)), with a vector of exports and imports for each country since there are several partners for each country. Wheat is assumed to be differentiated, hence we have three kinds of wheat: U.S. wheat, EU wheat, Canada wheat, and wheat produced by the rest of the world.

Data for production, consumption and trade were gathered from the World Grain Statistics of the International Grains Council for the year 2001/02. Price data were obtained from the USDA, Attaché Reports, AgCanada and the International Grains Councils. The protection data were collected from the OECD and WITS. Trade costs including trade barriers, transportation costs and others are assumed to be 70% for the United States, 60% for Canada, and 40% for ROW. These costs are treated as additive to tariffs and enter the model under the same parameter τ in the analytical model.

Costs of production are assumed to be flat in all countries, which are \$100/MT for the United States and Canada, and \$110/MT for ROW. In addition, the feedback of imports on cost of the US is assumed to be 0.001.[30] Fixed costs are assumed to be zero for the long-term version of the model. U.S. exports to Canada are negligible comparing to the other trade flows. Hence we assume that there are no U.S. exports to Canada in the simulation. Our target is to calibrate 23 demand parameters of the system, then use them to simulate important variables of the model.

Eight demands (three for the United States, two for Canada, and three for ROW), which are demands for three-country model version of equations (1) to (4) specified in the previous section are used for calibration.[31] Eight best responses which are the three-country model version of equations (7) to (10) are also taken into the calibration procedure. Additional information is gathered by assuming specific conditions for integrability of the demand system. That is all Hessian matrices are guaranteed to be negative definite by strict equalities for determinants of leading principal minors.

For IS damages, we assume that the rate of successful introduction to the United States is linear in total imports with an intercept and the slope of 0.05. We simulate the change in imports and production of the United States under trade integration together with the change in expected damages to the United States created by the exotic species. Trade integration is calibrated at a fixed level of 20 percent tariff reduction. We contrast results in multilateral trade integration scenario where all countries reduce tariffs with unilateral trade integration where only a single country lowers its tariffs.

Results are reported in table 7. The second column shows that in multilateral integration scenario, the United States increase imports from Canada by 1.24 percent and those from ROW by 1.83 percent. Production increases slightly which leads to an increase in expected IS damages of 0.26% in the United States. This result is consistent with the analytical findings. Column 3 reflects results when the United States reduces tariffs

---

[30] The feedback effect of IS damages on costs is via the parameter δ =0.001. The Home firm's cost is $c+\delta(y+z)$ where c=100. Note that imports y and z are scaled down by 10000 to get convergence.

[31] Demand system specification is provided in appendix 6.

unilaterally by 20 percent. This scenario yields the Costello and McAusland result: imports increase while production decreases, hence trade integration lowers the expected IS damages in the country. It is worth noticing that we reproduce Costello and McAusland result in a two-way trade context, but with unilateral reform. This fact suggests that the multilateral trade integration/liberalization is the pivotal feature that eradicates the possibility of the counterintuitive outcome of decreased IS damages with lower tariffs. The feedback effects of imports on US production yield results appeared in columns 4 and 5. Results in column 5 are obtained from the scenario where ROW reduces tariffs unilaterally by 20%. If there were no feedback on US production, there would be no change in US imports from ROW and from Canada. In the presence of the second round feedback, US imports from both ROW and Canada are affected by this unilateral tariff reduction of ROW. In fact, US imports from ROW and Canada reduce by 3.07% and 2.07% respectively. US production and expected damages increase by 2.42% and 2.01% respectively which would also be expected in the situation where the second round feedback is absent. Results in column 4 stress the second round feedback in the model. Since Canadian imports from the US are assumed to be negligible, if there were no second round feedback, when Canada unilaterally reduces tariffs by 20%, there would be no effects on the US economy. However, in the presence of these effects, this unilateral tariff generates a reduction in US imports from both Canada and ROW, and an increase in production and hence in total expected damages, similar to the situation when ROW unilaterally reduces its tariff.

6. Conclusions

The world has been experiencing a dramatic trade integration in agricultural markets in the last 25 years following numerous regional and more recently multilateral trade agreements and because natural protection has been decreasing substantially (Aksoy). Trade policy barriers have been reducing remarkably and will continue to do so. However, natural protection including transportation costs, information costs, security barriers for rich countries, etc. remains high. How further reduction of trade protection and trade cost will influence associated IS damages is a relevant and important issue. Our paper provides a step toward a better understanding of this complex IS-trade interaction.

In a one-way trade homogenous good world, it is possible that unilateral trade liberalization reduces the expected damages from IS. When accounting for joint distortion reductions and two-way trade of differentiated products, this outcome is still possible but unlikely. In this more realistic situation, IS damages induced by trade integration are much more likely to increase because production does not have to fall as imports increase. Furthermore, the findings are robust to variation in market structures (perfect competition or oligopoly).

The paper could be extended in a number of ways. Agriculture in OECD countries is characterized by heavy subsidies which have to some extent, substituted for the lower border protection (OECD). Since 1996 these subsidies have been slowly reduced as part of the Uruguay Round Agreement on Agriculture. The current Doha round is also considering further reduction in production subsidies in agriculture. One could consider this second-best dimension of domestic subsidies in integrated markets and their role on IS risk introduction and damages. Another extension would take into account the endogeneity of trade protection in a political economy setting: what would happen if tariff decreases are offset by other kind of protection? Elucidating these issues would further improve our understanding of the interface between IS damage and trade.

References

Aksoy, M. A. "The Evolution of Agricultural Trade Flows," Chapter 2 in M.A. Aksoy, and J.C. Beghin, eds. *Global Agricultural Trade and Developing Countries*. The World Bank, 2004: 17-35.

Anderson, J. and E. van Wincoop. "Trade Costs," *Journal of Economic Literature*, XLII (2004): 691-751.

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

Beghin J., D. Roland-Holst, and D. van der Mensbrugghe, eds. *Trade and the Environment in General Equilibrium. Evidence from Developing Economies*, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2002.

Ben-Zvi, S. and E. Helpman. "Oligopoly in segmented markets," in *Imperfect Competition and International Trade,* G. M. Grossman Ed. The MIT Press. 31-54, 1992.

Bhagwati, J. ed. *Going Alone. The Case for Relaxed Reciprocity in Freeing Trade*, Cambridge, MA: The MIT Press, 2002.

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

Bitzan, J., K. Vachal, T. VanWechel and D. Vinjie. "The differential Effects of Rail Rate Deregulation: US Corn, Wheat, and Soybean Markets," paper prepared for Transportation and Marketing Program, Agricultural Marketing Service, USDA, June 2003.

Brander, J. "Intraindustry trade in identical commodities," *Journal of International Economics* 11 (1981):1-14.

Brander, J. and P. R. Krugman. "A "reciprocal dumping" model of international trade," *Journal of International Economics* 15 (1983): 313-321.

CABI. *CAB International Crop Protection Compendium*, CDrom. CABI, Wallingford, UK, 2003.

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

Copeland, B.R., and M.S. Taylor. "Trade, Growth, and the Environment," *Journal of Economic Literature* XLII (2004): 7-71

Costello, C. and C. McAusland. "Protectionism, Trade, and Measures of Damage from Exotic Species Introductions," *American Journal of Agricultural Economics* 85(4) (2003): 964-975.

Eaton, J. and S. Kortum. "Technology, Geography and Trade," *Econometrica* 70(5) (2002): 1741-79.

Evans, C. L. "The Economic Significance of National Border Effects," *American Economic Review* 93(4) (2003): 1291-312.

Fulton, M., B. Larue and M. Veeman. "The Impact of Export State Trading Enterprises under Imperfect Competition: The Small Country Case," *Canadian Journal of Agricultural Economics,* 47(4) (1999): 363-73.

Head, K. and J. Ries. "Increasing Returns vs National Product Differentiation as an Explanation for the Pattern of US-Canada Trade," *American Economic Review* 94(4) (2001), 858:76.

Hummels, D. "Have International Transportation Costs declined?," Working paper, Graduate School of Business, University of Chicago, July 1999.

Larue, B. "Is Wheat a Homogeneous Product? Reply," *Canadian Journal of Agricultural Economics,* 40(1) (1992): 147-50.

Mitchell, D. and M. Mielke. "The Global Wheat Market: Policies and Priorities," chapter 11 in D. Aksoy, M. A. and J. Beghin, eds. *Global Agricultural Trade and Developing Countries*. The World Bank, 2004: 195-214.

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

OECD. *Agricultural policies in OECD Countries. Mo*nitoring and Evaluation 2003. OECD publications, Paris, 2003.

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

Perrings, C., M. Williamson, E. B. Barbier, D. Delfino, S. Dalmazzone, J.F. Shogren, P.J. Simmons, and A. R. Watkinson. "Biological Invasion Risks and the Public Good: an Economic Perspective," *Conservation Ecology* 6 (2002).

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.

Rose, A. K. and E. van Wincoop. "National Money as a Barrier to Trade: The Real Case for Currency Union," American Economic Review Pap. Proceed, 91(2) (2001): 386-90.

Schmitz, A. and H. Furtan. *The Canadian Wheat Board, Marketing in the New Millennium*, Canadian Plains Research Center, 2000.

Sumner, D. ed. *Exotic Pest and Diseases: Biology, Economics, and Public Policy for Biosecurity*, Iowa State press, 2004.

Wainio, J. Private email communication. October 2004.

Wei, S. J. "Intra-national versus International Trade: How Stubborn Are Nations in Global Integration," NBER Working Paper 5531, Cambridge, MA, 1996.

Table 1: Trade in all wheat (including durum wheat), wheat flour and semolina

metric tons (wheat equivalent)

Importing Country	*Exporting Country*			
	Canada	*United States*	*Others*	*Total*
Canada		25,486	77,956	103,442
United States	1,910,964		48,032	1,958,996
Others	14,182,058	26,764,197		40,946,255
Total [32]	16,093,022	26,789,683	125,988	43,008,693

Source: Wheat and Coarse Grains Shipments 2001/2002, International Grains Council

Table 2: Trade in Coarse Grains (corn, barley, sorghum, oats, rye, millet and trinicale)

metric tons

Importing Country	*Exporting Country*			
	Canada	*United States*	*Others*	*Total*
Canada		3,651,002	35,090	3,686,092
United States	1,795,701		556,721	2,352,422
Others	740,333	52,877,207		53,617,540
Total [33]	2,536,034	56,528,209	591,811	59,656,054

Source: Wheat and Coarse Grains Shipments 2001/2002, International Grains Council.

[32] This is the total of world wheat trade excluding transactions where either the US or Canada is a trader. The actual total world wheat trade of this year is 108,645,553 MT.

[33] This is the total of world coarse grains trade excluding transactions where either the US or Canada is a trader. The actual total world coarse grain trade of this year is 105,609,043 MT.

Table 3: U.S. Wheat tariffs.

	1980-1987	Unit
neslin		
	5	%
	0.21	$/bu

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Unit
neslin														
at	0.0077	0.0077	**0.0077**	0.0077	0.0077	0.0077	0.0077	0.0075	0.0073	0.0071	0.0069	0.0067	**0.0065**	$/kg
and meslin														
	6.3	6.3	**6.3**	6.3	6.3	6.3	6.3	5.7	5.1	4.6	4.0	3.4	**2.8**	%
	0.0077	0.0077	**0.0077**	0.0077	0.0077	0.0077	0.0077	0.007	0.0063	0.0056	0.0049	0.0042	**0.0035**	$/kg
neslin														
at	0.0077	0.006	**0.006**	0.005	0.004	0.003	0.003	0.002	0.001	0	0	0	**0**	$/kg
and meslin														
	6.3	5.6	**5.0**	4.4	3.7	3.1	2.5	1.80	1.20	0.60	0	0	**0**	%
	0.0077	0.006	**0.006**	0.005	0.004	0.003	0.003	0.002	0.001	0	0	0	**0**	$/kg

Source: USDA.

Table 4: Canadian Wheat tariffs

a. Canadian MFN wheat tariffs before Uruguay Round and US-Canada FTA tariffs

	Unit	**1980-1988**	1989	**1990**	1991	1992	1993	1994	1995	1996	1997	1998
MFN wheat tariff	Can$/ton	**4.41**	4.41	**4.41**	4.41	4.41	4.41	4.41	3.99	3.57	3.16	2.74
Wheat tariff faced by the United States	Can$/ton	**4.41**	3.97	**3.53**	3.09	2.65	2.22	1.78	1.32	0.88	0.44	0.00

b. Canadian wheat tariff cutting commitments under the Uruguay Round

Description	TRQ	Unit	BaseTariff	Bound Tariffs					
				1995	1996	1997	1998	1999	**2000**
Durum wheat	Within access	Can$/ton	4.41	3.99	3.57	3.16	2.74	2.32	**1.90**
Durum wheat	Over access	%	57.70	56.25	54.80	53.35	51.90	50.45	**49.00**
Wheat, other than durum	Within access	Can$/ton	4.41	3.99	3.57	3.16	2.74	2.32	**1.90**
Wheat, other than durum	Over access	%	90.00	87.75	85.50	83.25	81.00	78.75	**76.50**

Source: USDA.

Table 5: Tariff Equivalent of Trade Costs.

Source: Anderson and Wincoop (2004).

	reported by authors	$\sigma = 8$
all trade barriers		
Head and Ries (2001) U.S.-Canada, 1990-1995	48 ($\sigma = 7.9$)	47
Anderson and van Wincoop (2003) U.S.-Canada, 1993		46
Eaton and Kortum (2002) 19 OECD countries, 1990 750-1500 miles apart	48–63 ($\sigma = 9.28$)	58–78
national border barriers		
Wei (1996) 19 OECD countries, 1982-1994	5 ($\sigma = 20$)	14–38
Evans (2003a) 8 OECD countries, 1990	45 ($\sigma = 5$)	30
Anderson and van Wincoop (2003) U.S.-Canada, 1993	48 ($\sigma = 5$)	26
Eaton and Kortum (2002) 19 OECD countries, 1990	32–45 ($\sigma = 9.28$)	39–55
language barrier		
Eaton and Kortum (2002) 19 OECD countries, 1990	6 ($\sigma = 9.28$)	7
Hummels (1999) 160 countries, 1994	11 ($\sigma = 6.3$)	8
currency barrier		
Rose and van Wincoop (2001) 143 countries, 1980 and 1990	26 ($\sigma = 5$)	14

Table 6: Economic impacts of wheat pests and insects in the United States [34]

Name (economic importance)	Seedborne Incidence Transmission Treatment	Notes	Economic Impacts (in yield loss given infected)
Russian wheat aphid		First found in 1912 in Russia. Since its appearance in Texas in 1986, it has become a major pest of wheat and barley in the US.	It causes over $850 million in direct and indirect losses from 1987-1992 for all US. During 1992/93 cropping season, over 7 million acres (20%) of dryland winter wheat and 1 million acres (33%) of barley were infested throughout the western USA. In Canada, yield losses ranging from 25-37% without insecticide treatment in field trials.
wheat spindle streak mosaic virus		First described in 1927 in Japan, 1960 in Ontario Canada	In North central and northeastern US, the infection resulted in yield loss as high as 24-64% (according to studies in 1974, 1980, 1988, 1992).
Hessian fly		Accidentally introduce to the US from Europe by Hessian troops at the time of Revolution War	In Indiana alone over the period 1929-1936: 2 millions bushels/year and similar losses occur in other states. In 1945, which was the last year of general distribution of susceptible wheat varieties, the overall loss was about $37 million compared with average losses of about $16million/year in the 1980s.
glume blotch (moderate)			In 1965, average yearly losses in the USA were 1%. A study in 1981 considered annual losses in the US to range between 1-7%.
yellow rust (moderate)	Low Not recorded Yes	Mountainous and upland area	According to a study in 1964 using glasshouse experiments in US, maximum yield reductions of 64.5% were recorded when the top two leaves and the ear of wheat were severely infected. Using field trials, studies in 1963, 1964 report the maximum yield loss of about 30% on the most susceptible cultivar, Westmont.
septoria leaf blotch (moderate)	Low Not recorded Yes		Yield losses were reported of up to 50% in 1978 for the US. In Illinois, the losses were 15-20% in winter wheat trials in 1974-975.
scab (moderate)	Moderate Yes Yes	Scab is not a new disease in the US. Damages were reported in 1917 already.	In 1917, 31 of 40 states that were surveyed reported damage from scab with losses estimated at 288,000 MT, primarily from the winter wheat areas of Ohio, Indiana and

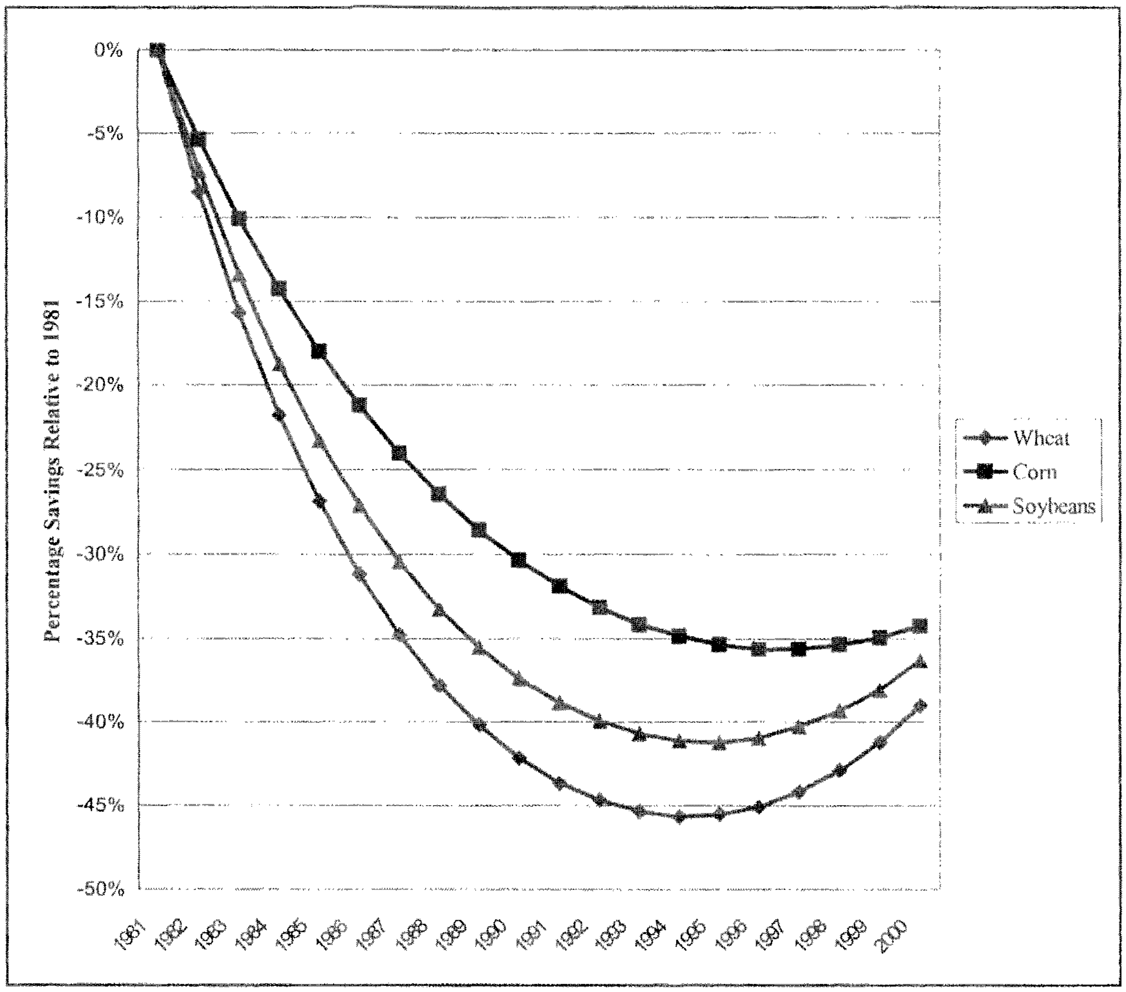
[34] Sometimes, impacts of these pests in Canada are reported instead, especially when the impacts in the US are more poorly reported.

			Illinois. In 1919, losses were estimated at 2.18 million MT throughout US. Losses for all US were 4% in 1982. A major epidemic affected 4 million hectares of the spring wheat and barley growing area of the northern Great Plains of North and South Dakota and Minnesota. Yield losses exceed 6.5 million tones worth $826 million, although total losses associated with the epidemic approached one billion dollars. In subsequent years, losses in theses states have been estimated at $200-400 million annually. In the winter wheat growing states of Ohio, Michigan, Indiana and Illinois, losses were in excess of $300 million in 1995 and 1996.
stern rust of cereals		Most important disease of wheat until 1950s when the use of resistant cultivars became widespread	Losses in North Dakota, during the severe epidemics of 1935 and 1954, were estimated at $356 and $260 million, respectively, based on wheat prices in late 1995.
karnal bunt of wheat (moderate)	Low Not Recorded Yes	First reported in 1909 in Pakistan; formally recorded in 1930 near the north Indian city of Karnal; Very recently found in southwestern US.	In Mexico where Karnal bunt appears regularly, direct losses are not vary significant and do not exceed 1%, but indirect costs to Mexican economy are higher due to quarantine measures which have to applied for grain exports.
leaf spot of wheat (moderate)	Low Yes Yes		The first occurrence was reported in North Dakota in 1971, yield losses range from 8% to 28% .A study in 1974 reported an average loss of 12.9% in grain yield and 1% reduction in test weight in damp weather, and no losses under dry conditions. In Montana, a study in 1976 recorded losses of up to 19.7% in 1000-kernel weight in evaluation of 30 cultivars in artificially inoculated small plots. In Kansas, a study in 1985 obtained yield losses of 27% . In Oklahoma, a study in 1999 reported a yield loss of 15% in untreated field plots.
wheat stem sawfly		Important consistent pest in northern Great Plains of North America	The losses are up to 25% less grain. Grain quality is also reduced. Damage occurs consistently and annually. Damage is greatest in Alberta, Manitoba, Saskatchewan, Montana, and North Dakota.
rown rust (high)	Not Recorded Not Recorded Yes	First reported in 1926, now widespread in the US	Generally, it is capable of causing 35%-50% in endemic area. Between 1973 and 1975, nearly 4.1 million tones of wheat were lost due to this rust in Oklahoma and Kansas. In Kansas in 1985,

			1986 and 1987, losses due to the rust were 5, 9 and 4% respectively.
green bug (spring grain aphid)		Greatest impact on winter wheat production in the southern great plains of the US	Millions of acres killed in outbreak years (before the use of organic insecticide)
orange wheat blossom midge		Accidentally introduced and well established for long in Canada and the US. First discovered near Quebec in 1828 and by 1854, spread into the US.	In Canada, an important breakout began in 1983 when yield losses in north eastern Saskatchewan were estimated at 30% (value at 30 million dollars), and in 1984 some areas of north western Manitoba reported grain losses as high as 26%. In the US, losses have generally been less marked, although a 40% loss of yield was reported on spring-sown wheat in the Pacific Northwest in 1945.
dwarf bunt of wheat (low)	Low Yes Yes	Since 1974, the export of wheat from Pacific Northwest ports to China has been halted as China has prohibited the intro. Of grain carrying dwarf bunt.	In Oregon, in 1952-1953, dwaft bunt destroyed 50-90% of the seed in several 1-year-old fields.
common bunt (high)	High Yes Yes	Potentially important damages, but readily controlled with chemical treatment. Now disease is rare or minor.	Untreated, common bunt can destroy more than 50% of grain, but losses are usually 5-10%.
flag smut (low)	Low Yes Yes		In the early 1960s, flag smut of wheat occurred in several counties of Washington state and Oregon, where the incidence varied from trace levels to about 30%. The disease was destructive in localized areas in south-central and south-eastern Washington.

Figure 1: Cumulative Percentage Decrease in US Rail Rates between 1981 and 2000, Relative to 1981.

Source: Bitzan et al., 2003.



0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%
-45%
-50%
Percentage Savings Relative to 1981
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Wheat
Corn
Soybeans

Figure 2: World Transportation Costs as Measured by CIF/FOB Ratios.

Source: Hummels 1999.

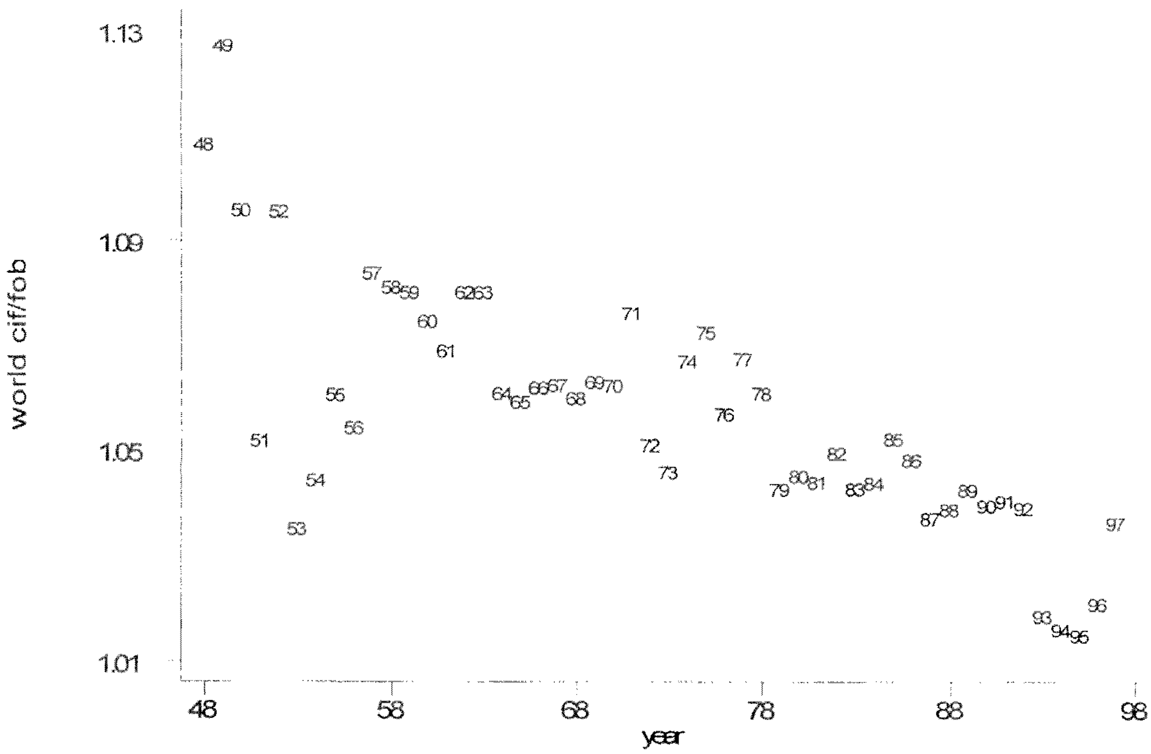


Table 7: Simulated change in imports, production and expected damages of the US.

$\tau = 0.7$ (US), $\tau^* = 0.6$ (Canada), $\tau^{**} = 0.4$ (ROW)

Changes in Trade Flows Production and Damages (1)	Multilateral Trade Integration $\kappa = 0.2$ (2)	Unilateral Trade Integration, $\kappa = 0.2$		
		$d\tau^* = d\tau^{**} = 0$ (US reduces tariff) (3)	$d\tau = d\tau^* = 0$ (CAN reduces tariff) (4)	$d\tau = d\tau^{**} = 0$ (ROW reduces tariff) (5)
Imports from Canada	+ 1.24 %	+ 1.24 %	- 2.07 %	- 2.07 %
Imports from ROW	+ 1.83 %	+ 1.83 %	- 3.07 %	-3.07 %
Production	+ 0.02 %	- 0.27 %	+ 2.12 %	+ 2.42 %
Expected damages	+ 0.26 %	- 0.03 %	+ 1.72 %	+ 2.01 %

Appendix

Appendix 1:

The inverse demands corresponding to equations (1)-(2) are

$$p_x(x,y) = A_x - B_x x - Ky \text{, and } p_y(x,y) = A_y - B_y y - Kx.$$

All parameters are positive and so is expression $B_x B_y - K^2$. This demand system can be derived by maximizing quasi-linear utility, subject to the budget constraint, $I = z + p_X x + p_Y y$, where I is Home income. The aggregate utility function is of the form: $U = z + u(x,y)$, where z is the aggregate consumption of a competitive numeraire good and u is a quadratic function defined by

$$u(x,y) = A_x x + A_y y - 0.5(B_x x^2 + B_y y^2 + 2Kxy).$$

Appendix 2:

Existence and uniqueness of a Bertrand Equilibrium in the model.

Given the demand structure as specified in equations (1)-(4), we show that the Bertrand equilibrium of the game exists and is unique for any ad-valorem tariffs (τ, τ^*).

Proof: Rewrite the Foreign firm's best response $BR_y^F(p_x)$ under the form $BR_x^F(p_y)$, that is

(14') $$BR_x^F(p_y) = \left\{-\left[a_y + b_y c^*\right] + 2b_y p_y\right\}(1+\tau)/k.$$

The two best responses $BR_x^H(p_y)$ and $BR_x^F(p_y)$ are two linear functions of p_y. One sees that

$$\partial BR_x^H / \partial p_y = k(1+\tau)/2b_x > 2b_y(1+\tau)/k = \partial BR_x^F / \partial p_y.$$

On the other hand,

$$BR_x^H \Big|_{p_y=0} \equiv \left[a_x + b_x c\right]/2b_x > 0 > -\left[a_y + b_y c^*\right](1+\tau)/k \equiv BR_x^F \Big|_{p_y=0}.$$

Hence, the Bertrand equilibrium in the Home market which is represented by the intersection point of these two linear correspondences always exists and is unique. Similar argument holds for the equilibrium in the Foreign market. Q.E.D.

Appendix 3:

By equations (16a)-(16d), we have:

(i) $\partial X^* / \partial \tau = 0$, $\partial X^* / \partial \tau^* = -b_x^* c(2b_x^* b_y^* - k^2)/D^* < 0$;

(ii) $\partial X / \partial \tau = c^* b_x b_y k / D > 0$, $\partial X / \partial \tau^* = 0$;

(iii) $\partial Q / \partial \tau = c^* b_x b_y k / D > 0$, $\partial Q / \partial \tau^* = -cb^*(2b_x^* b_y^* - k^2)/D^* < 0$.

(iv) $\partial Y / \partial \tau = -c^* b_y (2b_x b_y - k^2)/D < 0$, $\partial Y / \partial \tau^* = 0$.

Appendix 4:

Comparative statics results under perfect competition can be compared to that under imperfect competition which are reported in lemma 1 as the following: [35]

(i) $|\partial \hat{X}^* / \partial \tau| = |\partial X^* / \partial \tau|$, $|\partial \hat{X}^* / \partial \tau^*| > |\partial X^* / \partial \tau^*|$;

(ii) $|\partial \hat{X} / \partial \tau| < |\partial X / \partial \tau|$, $|\partial \hat{X} / \partial \tau^*| = |\partial X / \partial \tau^*|$;

(iii) $|\partial \hat{Q} / \partial \tau| < |\partial Q / \partial \tau|$, $|\partial \hat{Q} / \partial \tau^*| > |\partial Q / \partial \tau^*|$.

(iv) $|\partial \hat{Y} / \partial \tau| > |\partial Y / \partial \tau|$, $|\partial \hat{Y} / \partial \tau^*| = |\partial Y / \partial \tau^*|$.

Appendix 5:

Existence and uniqueness of a Bertrand Equilibrium in one-way trade model

Home firm chooses the price level (p_x), and foreign firm decides (p_y, p_y^*) to maximize its profits. Given the demand structure as specified in equations (1), (2) and (8), the Bertrand equilibrium of the game exists and is unique for any ad-valorem tariffs (τ, τ^*).

Proof: Expressing the Home and the Foreign firm's best response under the form $p_x(p_y)$, we have: $BR_x^H(p_y) = \{[a_x + b_x c] + k(1+\tau)p_y\}/2b_x$, and

---

[35] These expressions can be obtained after some simple derivations using $D = 4b_x b_y - k^2$ and $D^* = 4b_{x*} b_{y*} - k^2$, and the assumption that $\min\{b_x b_y, b_{x*} b_{y*}\} > k^2$ which was imposed in the basic model to guarantee integrability of demand system.

$BR_x^F(p_y) = \{-[a_y + b_y c^*] + 2b_y p_y\}(1+\tau)/k$. The same argument holds as in appendix 1.

Hence, the Bertrand equilibrium in the Home market which is represented by the intersection point of these two linear correspondences always exists and is unique.

The equilibrium price in the Foreign market is determined solely by the Foreign firm. That is: $P_y^* = [a_y^* + b_y^* c^*]/2b_y^*$, which obviously always exists and is unique.

Appendix 6:

Calibrated demand system.

Three US demands for three types of wheat are specified as the following:

$x = a_x - b_x p_x + kp_y + hp_z$, $y = a_y + kp_x - b_y p_y + gp_z$, and $z = a_y + hp_x + gp_y - b_z p_z$.

Two Canada demands for Canada and ROW wheat are as the following:

$y^* = a_y^* + k^* p_x^* - b_y^* p_y^* + g^* p_z^*$, and $z^* = a_z^* + h^* p_x^* + g^* p_y^* - b_z^* p_z^*$.

And three ROW demands for three types of wheat are:

$x^{**} = a_x^{**} - b_x^{**} p_x^{**} + k^{**} p_y^{**} + h^{**} p_z^{**}$, $y^{**} = a_y^{**} + k^{**} p_x^{**} - b_y^{**} p_y^{**} + g^{**} p_z^{**}$, and

$z^{**} = a_z^{**} + h^{**} p_x^{**} + g^{**} p_y^{**} - b_z^{**} p_z^{**}$.

CHAPTER 4. 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.

Table 1 shows that almost all groups of countries have highly escalating tariffs, and the manufacturing component of agriculture and food processing has very high protection, verifying the lack of penetration observed in food processing in industrial countries. Tariff escalation is predominant in all types of products, not just those that are produced in industrial countries. Table 2 shows the tariff escalation for two sets of products with low tariffs in industrial countries. The first group is the traditional products: coffee, and cocoa. The second group is the new products whose exports from developing countries have expanded rapidly over the last two decades such as fruits, vegetables and seafood. The tariff escalation is predominant in both traditional and new products. In the traditional products, the raw stages have extremely low tariffs, while the final stages and processed products have extremely high tariffs. Similar tariff escalation is apparent in the fruits and vegetables that were supposed to be items that are less protected and where the developing countries have found expanding markets. In addition, these averages mask very high peaks on individual products. In the US, maximum tariff on final fruit products is 136%, and on cocoa products is 186%. In the EU the maximum rates on processed fruits and vegetables are 98% and 146%, and on cocoa products, 63%. Again, many of the final product tariffs are non ad valorem such that the averages do not reflect the full extent of high tariffs. 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 a 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 $\theta \in (0,1)$.

Normalized $P_{\bar{K}} = 1$, profit maximization leads to the derived input demand and supply of *DFG* as follows:

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

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

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

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:[36]

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

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:

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

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

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

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

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

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

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

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:

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

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

---

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

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:

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

$$DFG^{**} = \left[\frac{\tau_I}{\theta\tau^N_{IFG}}\right]^{\frac{\theta}{\theta-1}} \overline{K}, \tag{9}$$

$$IFG^{**} = \tau^{N\ -\gamma}_{IFG} - \left[\frac{\tau_I}{\theta\tau^N_{IFG}}\right]^{\frac{\theta}{\theta-1}} \overline{K}, \tag{10}$$

$$DI^{**} = \left[\frac{\tau_I}{\theta\tau^N_{IFG}}\right]^{\frac{1}{\theta-1}} \overline{K}, \tag{11}$$

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

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

By using $\theta < 1, \gamma > 0, \tau^N_{IFG} < \tau_{IFG}$ 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 $DI^d(\tau, \tau_{IFG}) = \left(\dfrac{\tau}{\theta \tau_{IFG}} \right)^{\frac{1}{\theta-1}} \bar{K}$. 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:

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

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

Result 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 result 1. The findings stated in result 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,

$$\frac{\partial DWL}{\partial \tau} = \frac{1}{1-\theta}\left(\tau^{\frac{1}{1-\theta}} - \tau^{\frac{\theta}{1-\theta}}\right) > 0 \text{ since } \theta < 1.$$

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.[37] [38]

The last component to worry about is the externality. The reduction in the final-good

[37] A similar argument can be developed for the DWL associated with the supply DFG which is also increasing in τ.

[38] This argument holds for the single tariff reduction case considered previously too.

tariff ($\tau_{IFG}^{NN} < \tau_{IFG}$) works its way as in result 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

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

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

$$(DI/(1-\theta))(d\ln \tau_{IFG} - d\ln \tau_I)] - (\tau_I/\alpha) d\ln \tau_I < 0,$$ [39]

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

---

[39] In elasticity terms the expression 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* $\frac{d\ln \tau_{IFG}}{d\ln \tau_I} > 1 + \frac{s_D \varepsilon_{D P_D} - \eta_{DI\,P_D}}{\eta_{DI\,P_{FG}}}$.

result in the following result.

Result 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 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.[40]

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

---

[40] $1+ [\tau_I (1-\theta)/(\alpha DI))] = 1+ (1-\theta)(D^{ne}/DI)*1$, 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 $D^{ne}/DI < 1$.

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:

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

$$I^e = \frac{\alpha\bar{K}}{\alpha - z_I}\left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{1}{\theta-1}} + \frac{z_{IPG}}{\alpha - z_I}\left[\tau_{IFG}{}^{-\gamma} - \left[\frac{\tau_I}{\theta\tau_{IFG}}\right]^{\frac{\theta}{\theta-1}}\right] - \frac{\tau_I}{\alpha - z_I}.\text{[41]} \tag{18}$$

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 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 $t_{IFG}^N < t_{IFG}$ 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

---

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

as those in the initial equilibrium (**) in the situation with absence of invasive species risks associated with imported processed good.

Since $P_D = \tau_I = \alpha D^{ee} + z_I I^{ee} + z_{IFG} IFG^{ee}$, 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:

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

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

Result 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 $(-\gamma)$ 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 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 results 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 results

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.[42]

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 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

---

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

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.

Table 1. Tariff Rate Escalation in Agriculture

(MFN, applied, ad valorem, out-of quota duties)

Source: Aksoy 2004

	Raw	Intermediate	Final	Average	Percentage of lines covered
QUAD	6.1	9.3	14.8	10.7	86.7
Canada	1.4	3.4	6.5	3.8	76.0
Japan	4.2	10.2	15.9	10.3	85.5
US	5.5	7.1	12.6	9.5	99.3
EU	13.2	16.6	24.3	19.0	85.9
Large Middle Income Countries [43]	21.9	23.3	34.4	26.6	91.3
Other Middle Income Countries [44]	21.6	31.7	49.0	35.4	97.7
Lower Income Countries [45]	13.2	14.8	23.0	16.6	99.8

[43] Brazil (2001), China (2001), India (2000), Korea(2001), Mexico (2001), Russian Federation (2001), South Africa (2001), and Turkey (2001).

[44] Bulgaria (2001), Costa Rica (2001), Hungary (2001), Jordan (2000), Malaysia (2001), Morocco (1997), Philippines (2001), and Romania (1999).

[45] Bangladesh (1999), Guatemala (1999), Indonesia (1999), Kenya (2001), Malawi (2000), Togo (2001), Uganda (2001), and Zimbabwe (2001).

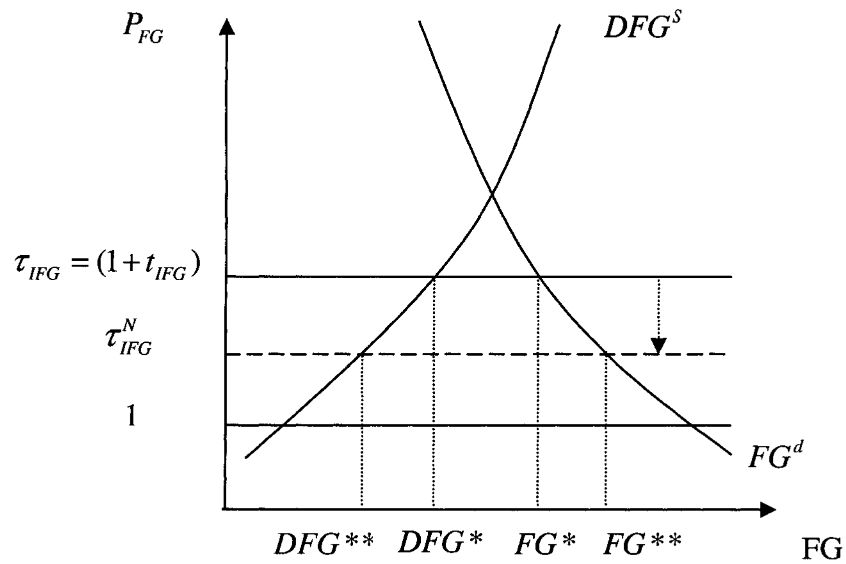
Table 2: Tariff Escalation in Selected Product Groups

(MFN, applied, ad valorem, out-of quota duties)

Source: Aksoy 2004

	EU	US	Japan
Tropical Products			
Coffee			
raw	7.3	0.1	6.0
final	12.1	10.1	18.8
Cocoa			
raw	0.5	0.0	0.0
intermediate	9.7	0.2	7.0
final	30.6	15.3	21.7
Expanding Commodities			
Fruits			
raw	9.2	4.6	8.7
intermediate	13.3	5.5	13.2
final	22.5	10.2	16.7
Vegetables			
raw	9.9	4.4	5.0
intermediate	18.5	4.4	10.6
final	18.0	6.5	11.6
Seafood			
raw	11.5	0.6	4.9
intermediate	5.1	3.2	4.3
final	16.2	3.5	9.1

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



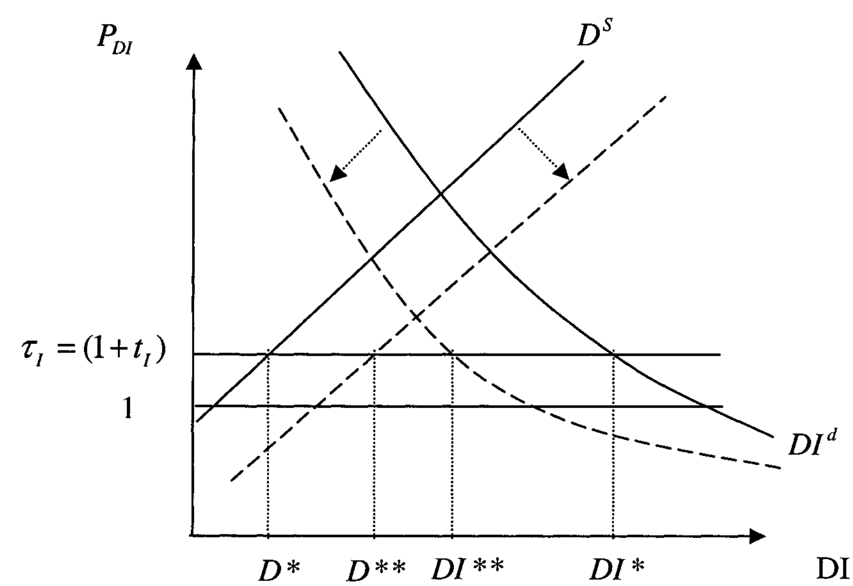
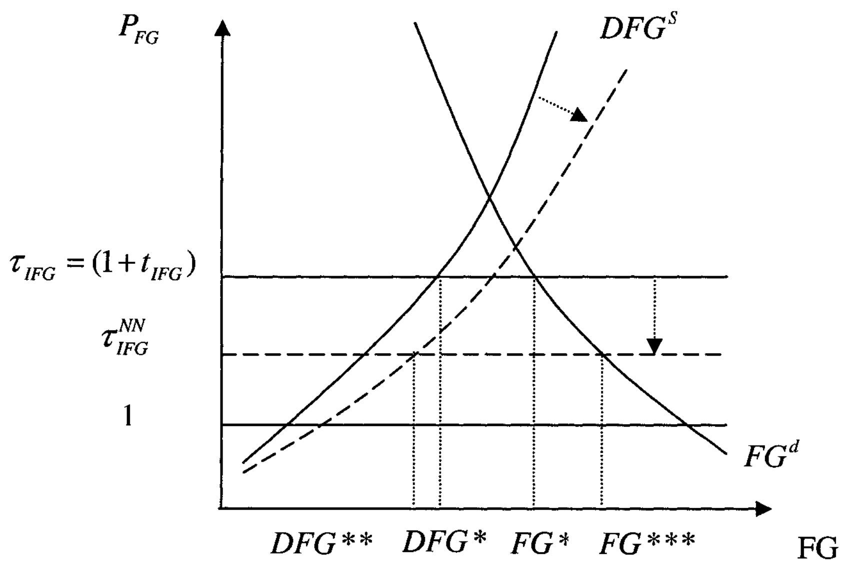
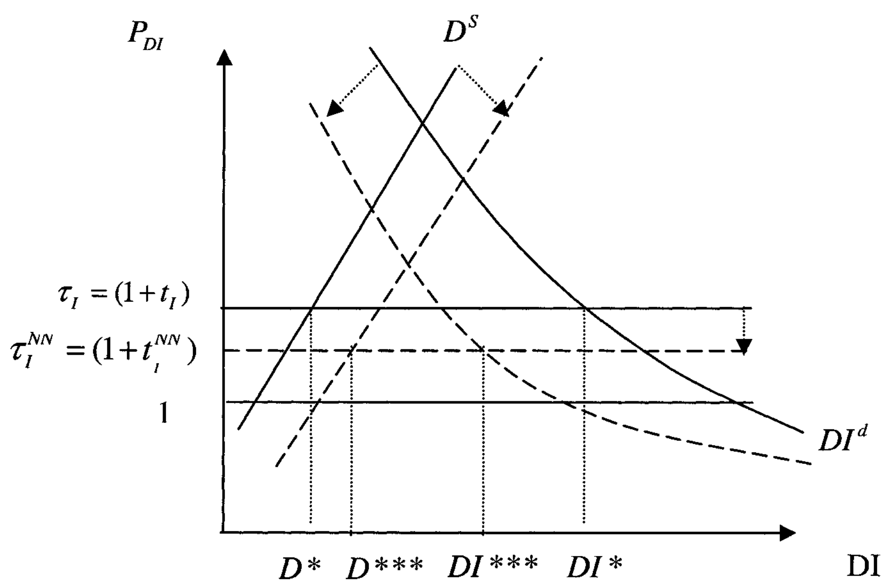


Figure 2a and 2b. Final good (2a) and input (2b) markets with both tariffs reduced.





CHAPTER 5. GENERAL CONCLUSIONS

In this dissertation, I present some new results on the relation between international trade and two important issues: the quality choice of the firms and the invasive species risk.

Chapter 2 sheds new light on the interaction of a special result-oriented trade policy, the VIEs and firms' quality choice. In the quantity game, our findings indicate that the imposition of VIEs affect the equilibrium even though it may not bind at the original equilibrium. VIEs may bind even when they are set below the laissez faire solution. VIEs imposed around the free trade level may also knock out all the pure strategy equilibrium of the game. All of these possibilities happen because of the strategic effects of quality. As quality choice is a long-run strategic variable in our model, a firm pre-commits to a quality level before it competes in the market (incurring a sunk cost of improving its quality at an earlier stage). Therefore, one firm's quality decision affects not only that firm's quantity choice but also the other firm's quantity decision hence price in the later stage. Consequently, effects of one firm's quality improvement may be positive or negative to that firm, given the other firm's quality choice. As such, our results emphasize the importance of the role of the timing of the decisions and strategic interaction for the choice of quality. Additionally, given VIEs, exporting firm may have less incentive to invest on its quality since VIEs are guaranteed market shares for that firm. Also in chapter 2, our results of the price game highlight the role of the strategic complements of qualities. To respect VIEs that are considerably higher than the laissez faire solution, the domestic firm has to lower its quality to reduce its sales. The exporting firm benefits from this quality down-grading behavior of the domestic firm by also down-grading the quality itself while not losing any sales, rather enjoying its guaranteed market share.

Although the quantity and the price games yield different equilibria, the sequential choice games consistently show that, as VIEs get more restrictive (in domestic firm's view point), the quality differentiation becomes larger, and the welfare of the domestic country as well as of the whole world become smaller. As such, the market share VIE is a powerful protection only to the exporting firm, and it is really not "voluntary".

On the interaction of international trade and invasive species, the dissertation makes a contribution in providing some knowledge about the relation between intra-industry trade, multilateral trade integration, tariff escalation and the IS risk with a focus on the agricultural markets.

Chapter 3 provides a step toward a better understanding of the impact of multilateral trade integration on damages associated with IS in a two way trade context. In the recent literature, the possibility that unilateral trade liberalization decreases is established in a one way trade homogenous good (Costello and McAusland 2003). The argument that supports this finding is that in that classical HOS model, unilateral trade liberalization not only increases imports but also decreases the production. The two opposite effects of imports and production on associated IS damages may result in a final impact of reducing damages. In a two-way trade context of differentiated good, when trade liberalization is multilateral, an increase in imports is not necessarily followed by a production reduction. Therefore, although the possibility that damages reducing due to trade integration still exists, it is much less likely. This result is robust to variation in market structure. The stylized model of the world wheat market supports our findings.

Chapter 4 is along the line of investigating the linkage between international trade and IS risk. It addresses and analyzes an overlooked but important aspect of the trade-IS debate: the interface between tariff escalation, especially on the existing tariff escalation in agricultural and food-processing markets and its impact on IS hazard and associated externalities. The economic literature is unambiguous about the existence of tariff escalation in processing sectors using agro-forestry inputs. The chapter suggests 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. The chapter also identifies the policy menu reducing the escalation by reducing tariffs on both raw input and processed good. This trade integration is consistent with the spirit of tariff reforms of the WTO with the Uruguay Round Agreement on Agriculture (WTO 1994) and is likely to continue in the Doha agreement (WTO 2004).