Intra-Industry Trade, Multilateral Trade Integration, and Invasive Species Risk

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Working Paper 06-WP 439
December 2006

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The authors thank Harvey Lapan, GianCarlo Moschini and Rajesh Singh for comments on earlier drafts, and Denis McGee for providing invasive species information. Earlier versions were presented at the ISU Heartland Environmental and Resource Economics Workshop, the AAEA Meetings, the Annual Global Economic Analysis Conference, and the AARES meetings. We thank their participants for comments. John Beghin acknowledges support from the Marlin Cole endowment at Iowa State University.

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Abstract

We analyze the linkage between protectionism and invasive species (IS) hazard in the context of two-way trade and multilateral trade integration, two major features of real-world agricultural trade. Multilateral integration includes the joint reduction of tariffs and trade costs among trading partners. Multilateral trade integration is more likely to increase damages from IS than predicted by unilateral trade opening under the classic Heckscher-Ohlin-Samuelson (HOS) framework because domestic production (the base susceptible to damages) is likely to increase with expanding export markets. A country integrating its trade with a partner characterized by relatively higher tariff and trade costs is also more likely to experience increased IS damages via expanded domestic production for the same reason. We illustrate our analytical results with a stylized model of the world wheat market.

Keywords: exotic pest, intra-industry trade, invasive species, liberalization, trade cost, trade integration, trade protection, two-way trade.

1. Introduction

Our study resides at the confluence of international trade, the environment, and sanitary and phytosanitary (SPS) issues. International trade is an important conduit of environmental change (Copeland and Taylor; Beghin, Roland-Holst, and van der Mensbrugghe). The recent literature emerging on the triple interface of trade, the environment, and SPS focuses on accidental introductions of exotic or invasive species (IS), such as pests, weeds, and viruses, by way of trade (Perrings, Williamson and Dalmazzone; and Mumford). The trade-SPS-environment interface is almost inherent to the economics of IS since trade is a major vector of propagation. Many papers in this emerging literature are focused on the "right" criteria to use or the optimal environmental policy response to the hazard of IS (Sumner; and Binder) and around quarantine as a legitimate policy response to phytosanitary risk (Cook and Fraser; and 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 on IS risk. Integration is defined here as the joint lowering of both tariffs and other trade costs between two or more trading partners.

Agricultural imports have always been an important conduit for biological invasions. Despite the Uruguay Round Agreement of the World Trade Organization (WTO), protectionism remains significant 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 protectionism on IS hazards and damages is an important issue. In a standard one-way trade Heckscher-Ohlin-Samuelson (HOS) model, Costello and McAusland show that lowering agricultural tariffs could actually lower the damage from exotic species, even though the volume of trade increases 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 and consequently damages can be reduced as well, leading to an ambiguous effect of trade on IS damages.

Our paper extends and builds upon the inquiry of Costello and McAusland, with major departures. We study the linkage between protection and damages from IS in the context of two-way trade and trade integration. Intra-industry trade characterizes agricultural trade patterns in the real world.[1] For example, wheat is a differentiated commodity, with most trading countries importing and exporting wheat (see Table 1) (Larue; Mitchell and Mielke). 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 from the previous analysis by considering multilateral trade integration. Trade integration by way of policy reform is occurring mainly in the context of WTO multilateral or regional reforms (e.g., Uruguay Round Agreement on Agriculture, NAFTA, and Free Trade of the Americas). Seldom do countries engage in unilateral trade liberalization, but rather, they commit to jointly reduce their protection through regional or multilateral agreements (Bhagwati). Beyond the joint lowering of policy barriers, trade integration is occurring with a progressive lowering of transaction costs between trade partners. Costs associated with trade, although still significant, have been falling dramatically for both exports and imports through cheaper transportation, cheaper refrigeration, insurance, and so forth. Joint

[1] We use intra-industry trade and two-way trade interchangeably and as meaning the simultaneous import and export of a differentiated good. Similarly, we use exotic pest and invasive species interchangeably.

tariff reduction and the joint lowering of other trade costs (on both sides of any border) have similar qualitative effects on trade, production, and consumption and can be parameterized similarly.

We consider the effects of trade integration on expected IS damage in a two-way trade context. In the perfect competition benchmark case, we find that trade integration is much more likely to increase expected damage from exotic species in our two-way trade model, as compared with unilateral liberalization in the HOS paradigm. Imperfect competition often characterizes agricultural trade. We investigate variations in market structure. The influence of market structure is marginal. Trade integration increases IS damages in the two-way trade context, irrespective of market structure assumptions. The ambiguity raised by Costello and McAusland is much reduced in our more realistic context of joint integration and two-way trade. We illustrate our results with an application to wheat trade and associated IS.

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 protection in agriculture remain significantly higher in many parts of the world (Aksoy). We also look at IS risk associated with wheat.

Table 1 summarizes bilateral wheat trade between the United States, Canada, and the "rest of the world" in the marketing year of July 2001 through 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 Canadian 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 and illustrates that two-way trade is even more obvious in coarse grains than in wheat trade. To remain parsimonious, we focus on wheat trade between these countries.

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, notable trade integration has been occurring between these neighboring countries.

Trade integration goes beyond tariff reductions. Transaction costs are associated with trading across borders. The underlying problem addressed in our paper is even more relevant because trade costs other than tariffs remain substantial, although they have been falling over time. Anderson and van Wincoop review the recent literature on trade cost and provide a rough estimate of "representative" trade costs for industrialized countries including transportation and distribution costs, which are a staggering 170% in ad valorem equivalent of the ex-factory unit cost. The costs break down as follows: 21% transportation costs, 44% border-related trade barriers, and 55% retail and wholesale distribution costs. The 21% transport cost includes both directly measured freight costs and a 9% tax equivalent of the time value of goods in transit. Anderson and van Wincoop's overall representative estimate of policy barriers for industrialized countries is about 8%, which is low and reflects the successive rounds of the WTO and its GATT predecessor to liberalized manufacturing trade. Agricultural trade has been included in the last and ongoing WTO rounds. A rough breakdown of the 44% number for border-related barriers is as follows: an 8% policy barrier; a 7% language barrier, a 14% currency barrier (from the use of different currencies), a 6% informational cost barrier, and a 3% security barrier for rich countries. Inferred transaction costs appear, on average, to dominate the effect of trade policies, even if the 170% figure appears somewhat inflated.

A number of studies have found that transportation costs have been falling over time because of cheaper rates and reduced time of transportation. Bitzan et al. simulate the changes in US rail rates over the 1981-2000 time period relative to 1981 as shown in Figure 1, for three commodities of interest (wheat, corn, and soybeans). The figure shows large percentage decreases in rates since 1981 and some tapering since the mid-1990s. Hummels reports a world-wide value for transportation costs as measured by ratio of CIF to FOB valuation of trade as shown in Figure 2. The figure suggests that CIF/FOB transportation costs have declined precipitously—from 13% of trade to around 3% from 1949 to 1995. However, the measurement of transportation costs using importer CIF/FOB ratios is incomplete and suffers from quality problems, and inference based on these data has to be carefully qualified.[2] Despite these pitfalls regarding the magnitude of trade costs and their measurement, the evidence strongly suggests that trade costs have fallen but remain large.

Table 5 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, reflecting the exotic nature of these species. For example, Russian wheat aphid was first found in Russia in 1912 and was first reported in Texas in 1986. Karnal bunt in wheat was first reported in Pakistan in 1909 and was recently found in the southwestern United States (in 1996). The table also includes the likelihood of seedborne

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[2] Small discrepancies in importer/exporter reports yield large changes in CIF/FOB ratios. Also, importer/exporter reports of bilateral trade flow may vary for reasons unrelated to shipping costs. More troubling, for many pairings, only one partner reports data, and these constraints force the IMF to "construct" CIF/FOB ratios.

incidence, and the possibility of seed transmission and seed treatment of these species. The common bunt, for example, can be transmitted through seeds, but seed treatment is available, which lightens its economic impact. An important feature of this table is that it gives some measures of economic impacts of these species at different times 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, the findings of Pimentel et al. support losses arising in many ways beyond yield loss and affecting an array of potential economic agents summarized in the estimated expected loss. Losses are often associated with the size of the crop or land under cultivation but go beyond yield loss.

Therefore, in our conceptual model, we consider a central case with general IS damages linked to domestic production but not specific to loss in yield. IS risk is increasing in imports, and damages are increasing in the size of domestic grain production. Damages could affect the representative consumer through loss of biodiversity associated with the crops or regions in which crops are grown, for example. The yield-specific effect of IS is later used in the calibrated model of the wheat illustration as a tractable indicator of losses.

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

Trade model

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 industry produces output x for domestic consumption and output x* for Foreign consumption. Similarly, the Foreign industry 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) $x(p_x, p_y) = a_x - b_x p_x + kp_y(1+\tau)$,

and

(2) $y(p_x, p_y) = a_y - b_y p_y(1+\tau) + kp_x$,

where (p_X, p_Y) are prices of Home and Foreign goods in the Home market, and (τ, τ^*) are the Home and Foreign ad-valorem tariffs on imports. For simplicity, we assume that tariffs embody all trade costs, as they lead to a similar parameterization (a price wedge between buyers and sellers across borders). 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 imports from Home are

(3) $y^*(p_{x^*}, p_{y^*}) = a_{y^*} - b_{y^*} p_{y^*} + k^* p_{x^*}(1+\tau^*)$,

and

(4) $x^*(p_{x^*}, p_{y^*}) = a_{x^*} - b_{x^*} p_{x^*}(1+\tau^*) + k^* p_{y^*}$.

Again, all parameters are assumed to be positive and so is the expression $b_{x^*} b_{y^*} - k^{*2}$.

The Home and Foreign firms' unit costs are *c* and *c**, respectively. Tariffs are expressed in ad valorem rate of unit cost or price. Assume that firms charge constant average-cost pricing in both markets and make zero profit. That is, $p_x = p_x^* = c$, and $p_y = p_{y^*} = c^*$.

Then, the equilibrium sales, represented by the corresponding capital letters, are

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

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

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

and

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

with $Q(\tau,\tau^*) = X(\tau) + X^*(\tau^*)$ denoting total Home production. Comparative-statics of these variables with respect to policies and evaluated at equilibrium lead to the following intermediate results:

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

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

(*iii*) $Q_\tau = \partial Q / \partial\tau = c^* k > 0$, $Q_{\tau^*} = \partial Q / \partial\tau^* = -cb_{x^*} < 0$;

and

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

Modeling the interface of IS damages and policy

The expected damages caused by IS are $E[D(Y,Q)] = \rho(Y)F(Q)$, where ρ is the rate of successful IS introduction to Home country, and *F* is the IS damages to Home given total production *Q*.[3] We assume that ρ is increasing in the volume of imports *Y* ($\rho_Y > 0$). 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 $F_Q > 0$ ($F_Q = 0$, $F_Q < 0$) with the subscript denoting the derivative of *F* with respect to *Q*. The augmented damages are the most frequent case in the real world.

[3] In an earlier version we followed Costello and McAusland’s elaborate approach to modeling IS risks. But both approaches yield identical qualitative results. In Costello and McAusland, an additional component in the expected damages is the probability that an introduced species establishes a viable population in Home. Damages are a sum of discounted damages over time from successful IS introduction linked to imports.

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 by a minimum percent change, and open their markets to imports under the minimum access provision. Using this type of reform as a motivation, we parameterize integration into our model as a joint proportional reduction of tariffs inclusive of trade costs. Assume $d\tau/\tau = d\tau^*/\tau^* = -\kappa$, i.e., a proportional decrease of tariffs, where κ is any arbitrary positive fraction.

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

$$\begin{aligned} dED &= \rho F_Q\left[Q_\tau d\tau + Q_{\tau^*} d\tau^*\right] + F\rho_Y\left[Y_\tau d\tau + Y_{\tau^*} d\tau^*\right] \\ &= \rho F_Q\left[Q_\tau d\tau + Q_{\tau^*} d\tau^*\right] + F\rho_Y\left[Y_\tau d\tau\right] \text{ by intermediate result (iv)} \end{aligned} \quad (5)$$

A lowering of tariffs has 3 effects on expected damages: an increase in the incidence of successful IS introduction via larger imports, and expanded damages via larger production for exports, and a reduction in damages via a contraction of production destined for domestic consumption.

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

$$\begin{aligned} dED &= \rho F_Q\left[Q_\tau(-\kappa)\tau + Q_{\tau^*}(-\kappa)\tau^*\right] + F\rho_Y\left[Y_\tau(-\kappa)\tau\right] \\ &= -\kappa\left[c^*\tau\left(\rho F_Q k - F\rho_Y b_y\right) - c\tau^*\rho F_Q b_{x^*}\right]. \end{aligned} \quad (6)$$

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

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

(7) $$dED \underset{<}{\overset{>}{-}} 0 \Leftrightarrow \varepsilon_{\rho_Y} \underset{<}{\overset{>}{-}} \frac{Y}{F}\varepsilon_{F_Q}\left[\frac{k}{b_y} - \frac{c}{c^*}\frac{\tau^*}{\tau}\frac{b_{x^*}}{b_y}\right].$$

This finding is stated in result 1.

Result 1: *Given the demand structure as specified in equations (1)-(4), trade integration* *($d\tau/\tau = d\tau^*/\tau^* = -\kappa$) 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 unit costs; the relative tariffs; the imports and total production in equilibrium; and demand parameters b_{x^*}, b_y, and *k*.

For trade integration to *decrease* the expected damages requires that $\varepsilon_{\rho_Y} < \frac{Y}{F}\varepsilon_{F_Q}\left[\frac{k}{b_y} - \frac{c}{c^*}\frac{\tau^*}{\tau}\frac{b_{x^*}}{b_y}\right]$. Assuming that damages are augmented ($F_Q > 0$), and since $\rho_Y > 0$, this condition requires that $\frac{\tau^*}{\tau} < \frac{c^*}{c}\frac{k}{b_{x^*}} \equiv \hat{\tau}$, which is equivalent to having Home production falling with integration.[4] This is a necessary condition. The response of Home production to the trade reform is represented by $dQ = -\kappa\left(\tau Q_\tau + \tau^* Q_{\tau^*}\right)$. Hence, by comparative statics results stated earlier, we have $dQ \underset{<}{\overset{>}{-}} 0 \Leftrightarrow \frac{\tau^*}{\tau} \underset{<}{\overset{>}{-}} -\frac{Q_\tau}{Q_{\tau^*}} = \frac{c^* k}{c b_{x^*}}$. We have $dQ < 0$ if and only

[4] This is true because $\frac{k}{b_y} - \frac{c}{c^*}\frac{\tau^*}{\tau}\frac{b_{x^*}}{b_y}$ has to be positive.

if $\frac{\tau^*}{\tau} < \frac{c^* k}{c b_{x^*}} = \hat{\tau}$. Again, this is a necessary condition for reduction of damages caused by IS due to trade integration. By equation (7), we have a sufficient condition equivalent to $\varepsilon_{\rho_Y} < \tilde{\varepsilon}$, which is $\frac{\tau^*}{\tau} < \frac{c^*}{c}\left(\frac{k}{b_{x^*}} - \frac{\varepsilon_{\rho_Y}}{\varepsilon_{F_Q}}\frac{Q}{Y}\frac{b_y}{b_{x^*}}\right) \equiv \tilde{\tau}$. The latter means that multilateral trade integration decreases the expected damages if and only if the relative initial tariff (the ratio between foreign and domestic initial tariffs) is lower than critical value $\tilde{\tau}$. Since $\tilde{\tau} < \hat{\tau}$, we see that not only must total production contract 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, by means of (7) and still assuming that damages are augmented, we then have a necessary and sufficient condition in terms of the relative initial tariffs for trade integration to increase the expected damages from IS:

(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 noting 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 integration, always increases expected damages if (a) Home pre-reform tariff is not higher than foreign pre-reform tariff or if (b) Home pre-reform tariff is higher than Foreign pre-reform tariff but not substantially, so that* $\omega < \frac{\tau^*}{\tau} < 1$.

Condition (a) holds because $\tau \le \tau^* \Rightarrow \frac{\tau^*}{\tau} \ge 1 > \omega$. Note also in case (*b*), the condition is more likely to hold for (*i*) large b_{x*} and 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 with lower trade cost/protection further integrating its trade with a partner with higher protection/trade cost will face increase expected damages, other things being equal. We note that the cost symmetry assumption could be obtained by simple normalization (*c* = *c**= 1). Condition $\omega < \frac{\tau}{\tau^*} < 1$ can be further simplified with further restrictions imposed on the demand structure across the two countries.

Trade integration and IS risks: Two-way trade versus one-way trade

We want to compare the reform-induced damages from IS in the two-way trade context to the outcome in the one-way trade *cum* unilateral opening case. The one-way trade context can be interpreted in our framework as the case when the Home firm's export *X** to the Foreign market does not exist.[5] 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 (OWT) model is characterized by equation (6) but with $Q_{\tau*} = 0$ or vanishing. Subscript *OWT* denotes the special case:

(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, $dED_{OWT} \overset{>}{\underset{<}{}} 0 \Leftrightarrow -\kappa c^* \tau \left(\rho F_Q k - F\rho_Y b_y \right) \overset{>}{\underset{<}{}} 0$.

[5] This situation can be justified (*i*) if Home products do not generate any utility to the foreign consumers and 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 $x^* \le 0$).

Comparing (6) and (9), we see that $dED = dED_{OWT} + \rho F_Q\left[Q_{\tau*}(-\kappa)\tau*\right]$, with $\rho F_Q\left[Q_{\tau*}(-\kappa)\tau*\right]$ positive (negative) under augmented (diminished) damages. Note that it is legitimate to compare the two conditions for two-way and one-way trade. With two-way trade we have $Q_\tau = X_\tau + X_\tau^*$, with the subscript indicating the derivative with respect to *τ*; we know that $\partial X*/\partial\tau = 0$ in the two-way trade or vanishes in the one-way-trade case. The two expected damages have to be compared at similar initial levels of damage and incidence. For completeness of the result, we compare the likelihood for all kind of damages, although augmented damages are considered to be the most relevant ones. Since in the two-way trade case, $\partial Q/\partial\tau* = -cb_x^* < 0$, but with $Q_{\tau*} = 0$ or vanishing under one-way trade, we get the following result.

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

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

(*i*) In the 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 in *Q* through demand is not equal to the corresponding change in *Q* in HOS (via own price). HOS would predict a larger contraction of output in absolute value.

(*ii*) The change in imports, which increases the risk of IS through own-price effect b_y, is as in the HOS case.

(*iii*) There is a production expansion by way of 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

Market structure

One may argue that agricultural trade is rather imperfectly competitive. For example, Schmitz and Furtan show the oligopolistic nature of wheat trade. We want to investigate the implication of imperfect competition on the interface between integration and IS damages. We will show that market structure is not critical to deriving our analytical results. The qualitative results of the paper do not change under 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 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.[6] Home firm and Foreign firm regard each country as a separate market and therefore choose to maximize their profits by making price discrimination of the third degree. Home and Foreign firms' problems are

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

and

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

respectively, where $\vec{p} = (p_x, p_{x*}, p_y, p_{y*})$, $\vec{\tau} = (\tau, \tau*)$. This setting is similar to the "reciprocal

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

dumping" model of Brander and Krugman, 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) $$BR_x^H(p_y) = \left\{\left[a_x + b_x c\right] + k(1+\tau)p_y\right\}/2b_x,$$

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 are represented by the corresponding capital letters with a hat to indicate the imperfect competition setup. They are

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

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

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

and

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

with $V \equiv 4b_xb_y - k^2$ and $V^* \equiv 4b_{x*}b_{y*} - k^{*2}$. Home equilibrium production is

$\hat{Q}(\tau,\tau^*) = \hat{X}(\tau) + \hat{X}^*(\tau^*)$.

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 from those obtained under perfect competition. Appendix 4 provides a comparison of the magnitude of comparative statics under two alternative market structures. Because firms use their market power, decreases in distortions induce smaller changes in equilibrium variables in absolute value under imperfect competition. However, the qualitative results of the paper do not change with the imperfect competition set-up. Hence, the findings do not hinge on assuming a particular market structure. Note that it is also reasonable to establish a one-way trade Bertrand competition model, which is represented by equations (1), (3), and (4), since, as shown in Appendix 5, the Bertrand equilibrium exists and is unique in this one-way trade system.

Market structure and feedback in production

The model with market structure presented in the previous section is in the context of “diffuse” externality; therefore, 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 affect another agent (e.g., the consumer’s valuation of IS). However, in the strategic framework it is plausible to assume that firms observe the expected damages. To have any relevance this assumes that ED translates into a loss of yield and hence a cost increase. The unit cost of production of the 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 the Home firm change. The new best responses of the Home firm are

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

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 equations (12) and (14) define equilibrium prices (p_x, p_y), and 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 IS risk

We calibrate the analytical model using data on wheat production and trade and plausible assumptions on IS 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: US wheat, Canadian wheat, and ROW wheat.

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.[7] Fixed costs are assumed to be zero for the long-term version of the model. US exports to Canada are negligible compared with the other trade flows. Hence, we assume that there are no US 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 the three-country model version of equations (1) through (4) specified in the previous section, are used for calibration.[8] Eight best responses, which are the three-country model version of equations (7) through (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 set to 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% tariff reduction. We contrast results in the multilateral trade

[7] The feedback effect of IS damages on costs is through 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 10,000 to get convergence.

[8] Demand system specification is provided in Appendix 6.

integration scenario in which all countries reduce tariffs with unilateral trade integration in which only a single country lowers its tariffs.

Results are reported in Table 6. The second column shows that in the multilateral integration scenario, the United States increases imports from Canada by 1.24% and those from ROW by 1.83%. 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 unilaterally by 20%. This scenario yields the Costello and McAusland result: imports increase while production decreases; therefore, trade integration lowers the expected IS damages in the country. It is worth noting that we reproduce the 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 in our application 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 appear in columns 4 and 5. Results in column 5 are obtained from the scenario in which 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 decrease 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 in which 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, then 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 dramatic trade integration in the last 25 years following numerous regional and multilateral trade agreements and because natural protection provided by trade costs has been decreasing substantially. These changes are more recent for some agricultural trade but qualitatively similar: agricultural tariffs and trade costs have been falling and will continue to do so. Natural protection, including transportation costs, information costs, and security barriers for rich countries, remains significant. 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 interaction between IS damages and trade integration.

In a one-way trade, homogenous-good world, it is quite possible that unilateral trade opening reduces the expected damages from IS in importable sectors. When accounting for joint reduction of protection or trade integration 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 were offset by other kinds of protection? Elucidating these issues would further improve our understanding of the interface between IS damage and trade.

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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 [a]	16,093,022	26,789,683	125,988	43,008,693

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

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 [a]	2,536,034	56,528,209	591,811	59,656,054

Source: Wheat and Coarse Grains Shipments 2001/2002, International Grains Council.
[a] 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: US Wheat Tariffs

Tariff Item	Description	1980-1987	Unit
	Wheat and meslin		
130.63/66	Feed	**5**	%
130.70	Food	**0.21**	$/bu

HSNo	Description	1988	1989	**1990**	1991	1992	1993	1994	1995	1996	1997	1998	1999	**2000**	Unit
MFN Tariff															
1001	Wheat and meslin														
10011000	Durum wheat	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
100190	Other wheat and meslin														
10019010	Seed	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**	%
10019020	Other	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
Tariffs facing Canada															
1001	Wheat and meslin														
10011000	Durum wheat	0.0077	0.006	**0.006**	0.005	0.004	0.003	0.003	0.002	0.001	0	0	0	**0**	$/kg
100190	Other wheat and meslin														
10019010	Seed	6.3	5.6	**5.0**	4.4	3.7	3.1	2.5	1.80	1.20	0.60	0	0	**0**	%
10019020	Other	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

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

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**

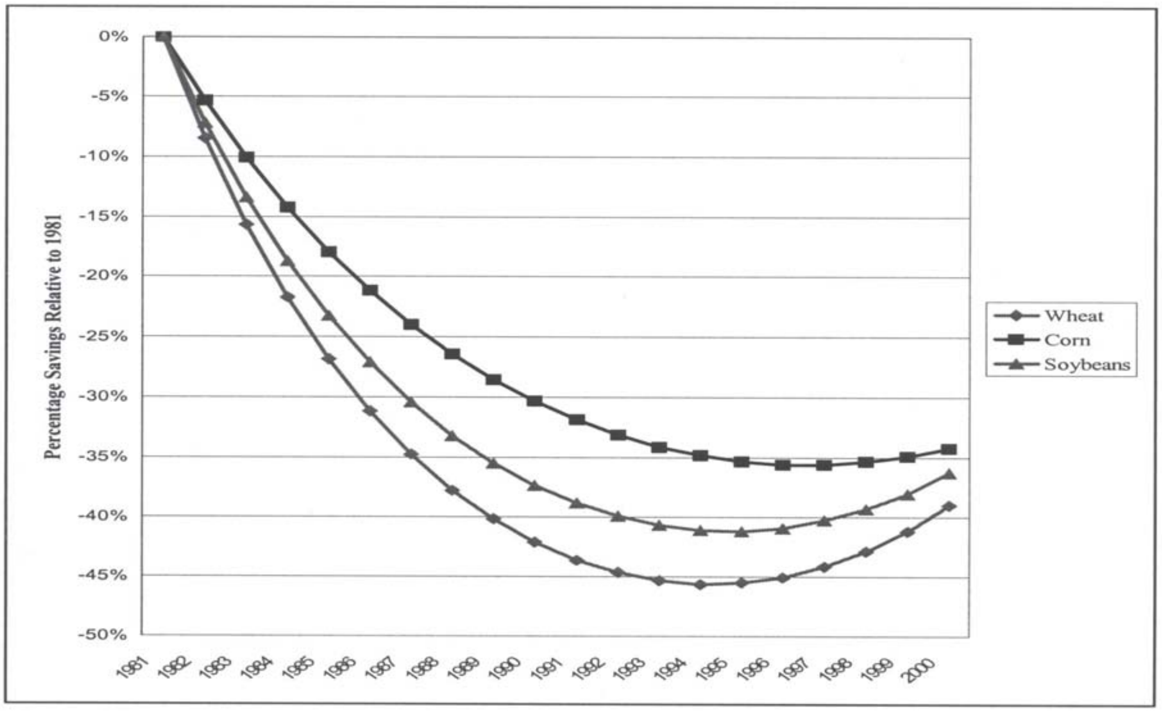
Source: USDA.

Table 5: Economic Impacts of Wheat Pests and Insects in the United States

Name (economic importance)	1.Seedborne 2. Incidence 3.Transmission 4.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 Revolutionary 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 $16 million/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)	1.Low 2.Not recorded 3.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 and 1964 report a maximum yield loss of about 30% on the most susceptible cultivar, Westmont.
septoria leaf blotch (moderate)	1.Low 2.Not recorded 3.Yes		Yield losses of up to 50% were reported in 1978 for the US. In Illinois, the losses were 15%-20% in winter wheat trials in 1974-75.
scab (moderate)	1.Moderate 2.Yes 3.Yes	Scab is not a new disease in the US. Damages were already reported in 1917.	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 Illinois. In 1919, losses were estimated at 2.18 million mt throughout the 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 tons worth, $826 million, although total losses associated with the epidemic approached $1 billion. 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.

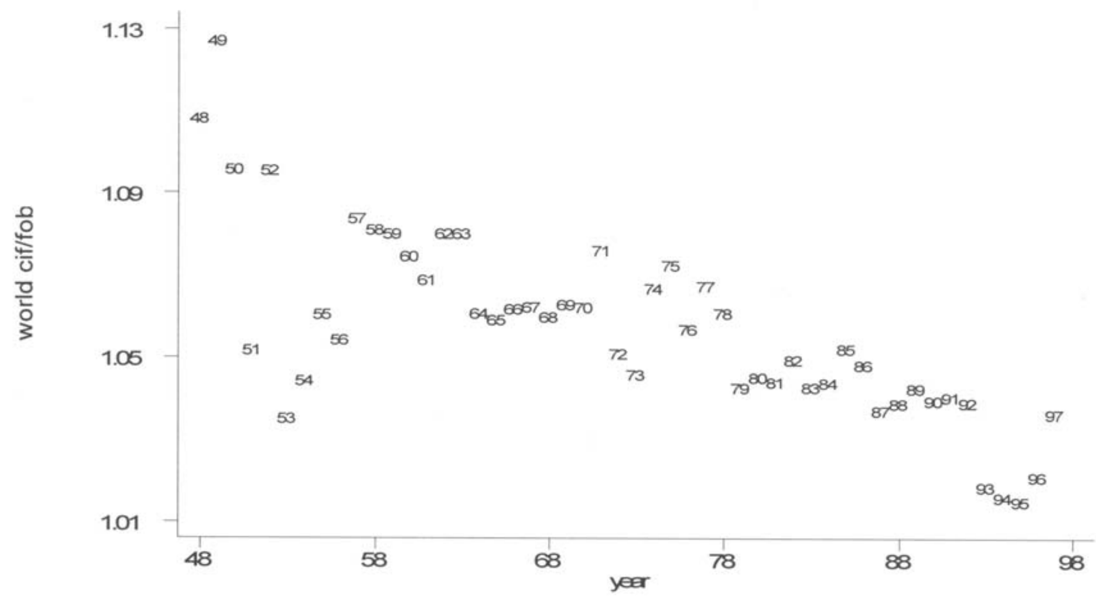
karnal bunt of wheat (moderate)	1.low 2.Not Recorded 3.Yes	First reported in 1909 in Pakistan; formally recorded in 1930 near the north Indian city of Karnal; Very recently found in southwestern US.	In Mexico where karnal bunt appears regularly, direct losses are not very significant and do not exceed 1%, but indirect costs to Mexican economy are higher because of quarantine measures that have to be applied for grain exports.
leaf spot of wheat (moderate)	1.Low 2.Yes 3.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)	1.Not Recorded 2.Not Recorded 3.Yes	First reported in 1926, now widespread in the US	Generally, it is capable of causing 35%-50% loss in endemic area. Between 1973 and 1975, nearly 4.1 million tons of wheat were lost 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 northeastern Saskatchewan were estimated at 30% (value at $30 million), and in 1984 some areas of northwestern 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)	1.Low 2.Yes 3.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, dwarf bunt destroyed 50%-90% of the seed in several 1-year-old fields.
common bunt (high)	2.High 3.Yes 4.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)	1.Low 2.Yes 3.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 southeastern Washington.

Figure 1: Cumulative percentage decrease in US rail rates between 1981 and 2000, relative to 1981



Source: Bitzan et al..

Figure 2: World transportation costs as measured by CIF/FOB ratios



Source: Hummels 1999.

Table 6: 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 (2), $\kappa = 0.2$	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

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

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 *numéraire* good and u is a quadratic function defined by

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

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

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

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

On the other hand,

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

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) $\partial \hat{X}^* / \partial \tau = 0$, $\partial \hat{X}^* / \partial \tau^* = -b_x^* c(2b_{x^*} b_{y^*} - k^{*2}) / V^* < 0$;

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

(iii) $\partial \hat{Q} / \partial \tau = c^* b_x b_y k / V > 0$, $\partial \hat{Q} / \partial \tau^* = -cb_{x^*}(2b_{x^*} b_{y^*} - k^{*2}) / V^* < 0$.

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

Appendix 4:

Comparative statics results under perfect competition can be compared to that under imperfect competition reported in Appendix 3 as follows: [9]

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

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

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

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

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 $BR_x^H(p_y) = \left\{\left[a_x + b_x c\right] + k(1+\tau)p_y\right\}/2b_x$, and $BR_x^F(p_y) = \left\{-\left[a_y + b_y c^*\right] + 2b_y p_y\right\}(1+\tau)/k$.

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, $P_y^* = \left[a_y^* + b_y^* c^*\right]/2b_y^*$, 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:

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

$x = a_x - b_x p_x + kp_y + hp_z$, $y = a_y + kp_x - b_y p_y + gp_z$, 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

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