Exporters' Preferences over Import Protection Instruments when Markets are Volatile

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Abstract: We develop a theoretical framework showing that import demand shocks and export supply shocks can increase, keep constant, or reduce the expected level of trade relative to the volume of trade in the absence of volatility. The effect of volatility can be magnified or mitigated by the type of trade policy instrument used by an importing country. In the absence of volatility, the gains from trade for an exporting country can be reproduced whether an importing country uses a specific tariff, an ad valorem tariff or a tariff-rate quota (TRQ). This equivalence is generally not robust to the introduction of volatility and exporting countries' preferences vis-à-vis the type of trade barriers they face is influenced by the convexity of the import demand and export supply functions and the nature of the shocks. We show that the expected level of trade need not increase for the exporting country's expected trade gains to rise. This result also holds when perfect competition is relaxed in favor of Cournot competition. Empirical evidence from the estimation of a commodity gravity model about trade in corn confirms the pertinence of accounting for the volatility of daily futures prices. The positive effect exerted by daily variations in futures prices on annual bilateral trade flows is augmented by an interaction effect for the use of non-ad valorem tariffs.

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1. Introduction

There are two features of agri-food markets that distinguish them from markets for non-agricultural goods: the level of protection and the degree of volatility. The average ag and non-ag tariffs are 15.9% and 2.2% for Canada and 12.2% and 4.2% for the EU.[1] Why the average ag tariff is higher than its non-ag counterpart is most peculiar considering that food, like fresh air, is essential for survival and that production is influenced by exogenous factors like the weather. One would think that food security concerns would keep borders wide open. Furthermore, free trade is supported by most economists and has been for a long time as a general rule.[2] Yet, most economists are quick to point out that not everybody gains from trade liberalization, that more consideration ought to be given to compensation and adjustment policies to help those adversely affected, and that the introduction of externalities, endogenous terms of trade, and strategic policy considerations may justify interventions. Still, most economists are disheartened by the resilience of ag tariff peaks and the restrictive tariff-rate quotas (TRQs) imposed on sensitive agricultural and food products.

Highly respected policy experts believed in the 1980s that "bringing" agriculture in the GATT and bringing attention to the level of protection would spur public outrage and make agricultural protectionism melt away like an evil vampire exposed to sunlight. Unfortunately, the "Dracula effect" that Jagdish Bhagwati (1988, p.85) had predicted did not occur. Trade barriers in so-called sensitive agricultural sectors are well entrenched in public policy. One of the reasons is that the average person, and many politicians, do not understand comparative advantage and can easily be convinced by protectionist rhetoric (Baron and Kemp, 2004). The tariffication of non-tariff barriers in the Uruguay Round was to make border protection more transparent and put agricultural trade liberalization on a steady path to bring agricultural border protection in line with that for non-agricultural products. Over twenty years later, many countries remain reluctant to part with their protection on certain agricultural products. Perhaps the best example of widespread political support for overt protectionism is Canadian consensus amongst federal and provincial politicians over supply management policies for dairy and poultry products.[3] Canada is not alone in resisting liberalization for some of its agricultural sectors. Most industrial countries have sensitive products and exporters of agricultural products that

[1] See http://stat.wto.org/TariffProfiles/.

[2] See the views of a panel of 41 experts on the gains from free trade at http://www.igmchicago.org/igm-economic-experts-panel/poll-results?SurveyID=SV_0dfr9yjnDcLh17m . Even Malthus, who had been known as the intellectual force behind the Corn Laws in England that allowed for the imposition of tariffs to keep domestic grain prices high, had abandoned his penchant for agricultural protectionism by 1824 (Hollander, 1992). Hollander calls Malthus's original position on the Corn Laws an "anomaly".

[3] Historically, Canada has refused to make any concession regarding its supply-managed sectors. In the Uruguay Round, its negotiators argued for tariffication exceptions and a strict interpretation of GATT Article XI 2c to perpetuate the use of import quotas alongside domestic supply restrictions. An interesting precedent was created during the negotiations of the Canada-European Union Comprehensive Economic and Trade Agreement (CETA) when Canada agreed to increase its cheese TRQ.

have been facing well-entrenched trade barriers know to expect little from multilateral and regional trade liberalization initiatives.[4]

Agricultural markets are notoriously volatile (Jacks, O'Rourke and Williamson, 2011). Production is often slow to adjust (e.g., beef production, tree crops) and observed and planned productions can differ by much because of exogenous factors. Large shocks may provide incentives for countries to adjust their policies. For example, many importing countries reduced their import tariffs when agricultural commodity prices experienced large increases in 2008,[5] but some countries are more prone to react when border prices fall rapidly. Different trade policy instruments perform differently when volatility increases. The choice of policy instrument under risk and uncertainty has been analyzed from the importing country's perspective by many authors. It was a very fashionable research topic from the mid 1970s to the early 1980s (e.g., Fishelson and Flatters, 1975; Dasgupta and Stiglitz, 1977; Anderson and Young, 1982; Young and Anderson, 1982). However, the perspective of the exporting country has not been investigated as thoroughly.

Tariff-Rate-Quotas (TRQs) were introduced in the Uruguay Round to insure that foreign exports would not fall below a given threshold reflecting past market access. However, TRQs tend to have high over-quota tariffs that make over-quota imports impossible for all contingencies or at best possible over a limited range of very large shocks. Under these conditions, exporters do not benefit or gain little from shocks that increase the import demand. This can be changed when trade negotiations take place, as quota enlargements and in-quota and over-quota tariff reductions can potentially be secured. Similarly, if an exporting country is to face tariff protection, which of the ad valorem tariff or the specific tariff will generate the highest gains from trade when markets become volatile?

We analyze the performance of various import barriers from the perspective of exporting countries when markets become more volatile. Our comparisons are anchored by the level of exports in the absence of volatility. The trade policy instruments are set to generate the same level of trade under certainty. The first part of our analysis assumes that markets are perfectly competitive and that shocks originating in the importing country shifts the intercept of the import demand function and may also affect the slope and shocks to the export supply function.

2. Import-Demand Volatility under Perfect Competition

[4] In CETA and the TPP, Canada agreed to bring down to zero over 90 percent of its tariffs lines upon implementation. This is not drastic because 59% of Canada's applied tariffs on agricultural products were zero in 2014, as one would expect for a small open economy. However, 5% of Canada's ag tariffs were in excess of 100% and they will not drop to zero. See http://stat.wto.org/TariffProfiles/CA_E.htm for more details.

[5] Similarly, some countries have lobbied hard for the WTO Special Safeguard Mechanism (SSM) that will allow developing countries to raise their tariffs temporarily to deal with import surges and rapid price reductions.

We rely on a partial equilibrium structure to analyze the performance of various import restricting instruments. The importing country's import demand is defined by : $p^d \equiv f(q,\varepsilon)$, with q being the quantity imported, ε being a shock in the importing country arising from unforeseen changes in production or in demand. It is assumed that $f_q \equiv \partial f / \partial q < 0$, $f_{qq} \equiv \partial^2 f / \partial q^2 \geq 0$ and $f_\varepsilon \equiv \partial f / \partial \varepsilon > 0$. A shock may also impact on the slope of the import demand function such that $f_{q\varepsilon} \gtrless 0$. Since we do not have a prior on $f_{\varepsilon\varepsilon}$, we will assume that it is zero. Finally, it is assumed that the import demand shocks have a density ϕ, have finite bounds, $\varepsilon_{\min}$ and $\varepsilon_{\max}$, and a zero mean. The exporting country's export supply is defined by $p^s = g(q,\psi)$, with $g_q \equiv \partial g / \partial q > 0$, $g_{qq} \equiv \partial^2 g / \partial q^2 \geq 0$ and $g_\psi \equiv \partial g / \partial \psi < 0$. The export supply function may become flatter after a shock such that $g_{q\psi} < 0$. Without a theoretical prior, we set $g_{\psi\psi} = 0$. As for import demand shocks, we assume that the export supply shocks have finite bounds, $\psi_{\min}$ and $\psi_{\max}$ and a density υ.

We will focus first on import demand shocks. If the importing country relies on a specific tariff, then $f(q^t,\varepsilon) = g(q^t) + t$ as long as some trade occurs, $q^t > 0$. It can be shown that $q_t^t \equiv \partial q^t / \partial t = \dfrac{1}{f_q - g_q} < 0,$ and that:

$$q_\varepsilon^t \equiv \partial q^t / \partial \varepsilon = \frac{-f_\varepsilon}{f_q - g_q} > 0 \qquad (1)$$

As for curvature, it can be shown that $q_{tt}^t \equiv \dfrac{\partial^2 q}{\partial t^2} = -\left(f_q - g_g\right)^{-2}\left(f_{qq} - g_{qq}\right) q_t \gtrless 0$, $q_{t\varepsilon}^t = -\left(f_q - g_q\right)^{-2}\left(\left(f_{qq} - g_{qq}\right) q_t^t + f_{q\varepsilon}\right) \gtrless 0$, and:

$$q_{\varepsilon\varepsilon}^t = f_\varepsilon \left(f_q - g_q\right)^{-2}\left(f_{qq} - g_{qq}\right) q_\varepsilon^t \gtrless 0. \qquad (2)$$

Under the linearity assumption, $f_{qq} = g_{qq} = 0$, $q_{tt}^t = 0$ and $q_{t\varepsilon} \leq 0$. The quantity traded under the specific tariff is increasing with the size of import demand shocks, but the quantity traded can increase at a decreasing rate, linearly or at an increasing rate with shocks depending on the sign and magnitude of $f_{qq} - g_{qq}$. More specifically, the quantity traded is convex (concave) in ε-shocks if the import demand is more (less) convex than the export supply.

The gains from trade for the exporting country facing a specific tariff are simply:

$$w^t = g\left(q^t\right)q^t - \int_0^{q^t} g\left(q\right)dq. \tag{3}$$

They are increasing with the quantity traded because $g_q > 0$. It is easy to verify that the exporting country is adversely impacted by an increase in the specific tariff: $w_t^t \equiv \partial w^t / \partial t = \left(g_q q^t\right)q_t < 0$. On the other hand, an import demand shock increases the gains of the exporting country:

$$w_\varepsilon^t = g_q q^t q_\varepsilon^t = \frac{-g_q q^t f_\varepsilon}{f_q - g_q} > 0. \tag{4}$$

It is apparent that the exporting country's gains from trade are more convex in ε when $f_{qq} > g_{qq} \geq 0$.

$$\frac{\partial^2 w^t}{\partial \varepsilon^2} = \left[\frac{-\left(g_q + g_{qq}q\right)f_\varepsilon - 2g_q q^t f_{q\varepsilon}}{f_q - g_q} + \frac{g_q q^t f_\varepsilon\left(f_{qq} - g_{qq}\right)}{\left(f_q - g_q\right)^2}\right]q_\varepsilon^t \tag{5}$$

Under an ad valorem tariff, the equilibrium quantity is also decreasing in the tariff, $q_\tau^\tau \equiv \partial q / \partial \tau = \frac{g}{f_q - g_q\left(1+\tau\right)} < 0$ and an import demand shock has a positive effect:

$$q_\varepsilon^\tau \equiv \partial q^\tau / \partial \varepsilon = \frac{-f_\varepsilon}{f_q - g_q\left(1+\tau\right)} > 0 \tag{6}$$

It follows that:

$$q_{\varepsilon\varepsilon}^\tau = f_\varepsilon\left(f_q - g_q\left(1+\tau\right)\right)^{-2}\left(f_{qq} - g_{qq}\left(1+\tau\right)\right)q_\varepsilon^\tau \gtrless 0. \tag{7}$$

We can readily see that the export response to an import demand shock is weaker when an ad valorem tariff is being used. This is so because the demand-increasing triggers an automatic increase in the spread between domestic and border prices under the ad valorem tariff. Gains from trade are increasing in import demand shocks:

$$\frac{\partial w^\tau}{\partial \varepsilon} = \frac{-g_q q f_\varepsilon}{f_q - g_q\left(1+\tau\right)} \tag{8}$$

and convex:

$$\frac{\partial^2 w^\tau}{\partial \varepsilon^2}=\left[\frac{-\left(g_q+g_{qq}q\right)f_\varepsilon-2g_q q f_{q\varepsilon}}{f_q-g_q\left(1+\tau\right)}+\frac{g_q q f_\varepsilon\left(f_{qq}-g_{qq}\left(1+\tau\right)\right)}{\left(f_q-g_q\left(1+\tau\right)\right)^2}\right]q_\varepsilon^\tau . \quad (9)$$

Under a TRQ, in-quota imports are predetermined by the choice of a quota *R*. These imports are typically taxed at very low rates or not taxed at all. For simplicity, we will assume that in-quota tariffs are zero. Over-quota imports are generally taxed at very high levels/rates that are prohibitive for a wide range of shocks or the entire range of possible shocks.[6] Let $T^p\left(\varepsilon\right)$ be the minimum prohibitive tariff for shock ε. If the over-quota tariff is prohibitive over all possible shocks (i.e., $g\left(R\right)+T\geq f\left(R,\varepsilon^{\max}\right)$ where $\varepsilon^{\max}$ is the largest possible shock) and $T\geq T^{pp}\equiv T^p\left(\varepsilon_{\max}\right)$ with the latter satisfying $g\left(R\right)+T^{pp}=f\left(R,\varepsilon^{\max}\right)$, then $q^T=R\,\forall\varepsilon$ and the quantity imported does not vary at all and the same goes for the gains for the exporting country. In this case, all of the adjustments fall on the domestic price which becomes quite volatile. However, if $t^c<T<T^{pp}$, some shocks are large enough to trigger over-quota imports and there is a critical shock $\varepsilon^R\left(T\right)$ level such that $g\left(R\right)+T\geq f\left(R,\varepsilon\right)$, $q^T=R\,\forall\varepsilon\leq\varepsilon^R<\varepsilon^{\max}$ and $g\left(R\right)+T<f\left(R,\varepsilon\right)$, $q^T>R\;\forall\varepsilon>\varepsilon^R$. It follows that $\varepsilon^R\to\varepsilon_{\max}$ as $T\underset{-}{\to}T^{pp}$ and that $\varepsilon^R\to 0$ as $T\underset{+}{\to}t^c$. As for negative shocks, we assume that $g\left(R\right)\leq f\left(q,\varepsilon_{\min}\right)$ such that the exporting country has an incentive to supply the quantity *R* even under the worst possible import demand. Thus, imports under a TRQ are weakly increasing in ε-shocks. As a result, the gains from trade for the exporting country are:

$$w^T\left(R,T,\varepsilon\right)=\begin{cases} g\left(R\right)R-\int_0^R g\left(q\right)dq\;\forall\varepsilon_{\min}\leq\varepsilon<\varepsilon^R \\ g\left(q^T\right)q^T-\int_0^{q^T} g\left(q\right)dq\;\forall\varepsilon^R\leq\varepsilon\leq\varepsilon_{\max}\end{cases} \quad (10)$$

Under perfect competition, the rents from the licenses are captured by the importing country. The gains from trade for the exporting country are weakly increasing with respect to import demand shocks and convex. Put differently, the gains from trade are invariant to shocks except when shocks are large enough to exceed the ε^R threshold. Once the threshold is exceeded, the quantity traded is increasing with shocks, but the quantity traded remains lower than under the tariffs because of the greater restrictiveness of the over-quota tariff T. Accordingly , the gains from trade increase under a TRQ in response to a large shock, but less so than under a tariff.

[6] Over-quota exports are often subjected to a mixed tariff that applies an ad valorem tariff rate if the border price exceeds a given threshold. A specific tariff is applied if the border price falls under the threshold. This way, rapid border price declines cannot continue reducing the spread between domestic and border prices once the border price threshold has been reached.

Let us now discuss the implications of volatility caused by import demand shocks on the quantity traded. Under a specific tariff, the quantity traded denoted $q^t(t,\varepsilon)$ is conditioned by the tariff and the observed import demand shock. The quantity traded under an ad valorem tariff is $q^\tau(\tau,\varepsilon)$ while under a TRQ we have $q^T(R,T,\varepsilon)$. Let us assume that the tariffs t^c and τ^c are set to achieve the same volume of trade in the absence of shocks (i.e., $\varepsilon = 0$): $q^t(t^c,0) \equiv q^{t^c} = q^{\tau^c} \equiv q^\tau(\tau^c,0)$. Market access is at the heart of negotiations involving sensitive agricultural products and it is natural to anchor our comparisons of trade policy instruments around a quantity. The quantity traded has been used extensively to anchor in trade policy comparisons (e.g., Bhagwati, 1965; Larue and Lapan, 2002). We now compare this quantity under certainty or without volatility to the expected quantity traded in the presence of import demand shocks. For the TRQ, If $q^T(R^c,T,0) = q^{t^c}$, then $E\left[q^T(R^c,T)\right] \geq q^{t^c}$, with equality if $T \geq T^{pp}$. It is a more complex to ascertain the relative sizes of the expected quantities under the specific tariff, $E\left[q^t(t^c)\right]$, and the ad valorem tariff, $E\left[q^\tau(\tau^c)\right]$.

PROPOSITION 1: *Considering shocks that affect only the intercept of the import demand (i.e.,* $f_{q\varepsilon} = 0 < f_\varepsilon$*), A)* $E\left[q^t(t^c)\right] > E\left[q^\tau(\tau^c)\right] > q^{t^c}$ *when* $f_{qq} > g_{qq}(1+\tau^c)$. *B)* $E\left[q^t(t^c)\right] > q^{t^c} > E\left[q^\tau(\tau^c)\right]$ *when* $g_{qq}(1+\tau^c) > f_{qq} > g_{qq}$. *C)* $\mathrm{Max}\left(E\left[q^t(t^c)\right], E\left[q^\tau(\tau^c)\right]\right) < q^{t^c}$ *when* $g_{qq} > f_{qq}$. *D) If* $f_{qq} = g_{qq} = 0$*, then* $E\left[q^t(t^c)\right] = E\left[q^\tau(\tau^c)\right] = q^{t^c}$. E) If $T < T^{pp}$, then $E\left[q^T(R^c,T)\right] > Max\left(E\left[q^\tau(\tau^c)\right], E\left[q^t(t^c)\right]\right)$ if q^t and q^τ are concave or linear in ε, otherwise the expected quantity under the TRQ can be larger or smaller than both tariffs or larger than the ad valorem tariff but smaller than the specific tariff.

PROOF: It should be recalled that $g_{qq} \geq 0$, $f_{qq} \geq 0$. Rewriting (2), q^t is increasing and convex in ε if : $\frac{\partial^2 q^t}{\partial \varepsilon^2} = \frac{2 f_{q\varepsilon} f_\varepsilon (f_q - g_q) - f_\varepsilon^2 (f_{qq} - g_{qq})}{(f_q - g_q)^3} > 0$. The denominator is negative and when $f_{q\varepsilon} \approx 0$, convexity requires that $f_{qq} - g_{qq} > 0$. From (7), convexity is obtained when $\frac{\partial^2 q^\tau}{\partial \varepsilon^2} = \frac{2 f_{q\varepsilon} f_\varepsilon \left(f_q - g_q(1+\tau^c)\right) - f_\varepsilon^2 \left(f_{qq} - g_{qq}(1+\tau^c)\right)}{\left(f_q - g_q(1+\tau^c)\right)^3} > 0$ or $f_{qq} > g_{qq}(1+\tau^c)$ when $f_{q\varepsilon} \approx 0$. By Jensen's inequality, $E\left[q^k\right] > q^{kc}$ if $\frac{\partial^2 q^k}{\partial \varepsilon^2} > 0$. Similarly, $E\left[q^k\right] = q^{kc}$ if

$\frac{\partial^2 q^k}{\partial \varepsilon^2} = 0$ while $E\left[q^k\right] < q^{kc}$ if $\frac{\partial^2 q^k}{\partial \varepsilon^2} < 0$ for $k = t, \tau$. This proves parts A) to D). As for part E), the possibility of over-quota imports implies that $E\left[q^T\left(R^c, T\right)\right] > R^c \geq Max\left(E\left[q^t\left(t^c\right)\right], E\left[q^\tau\left(\tau^c\right)\right]\right)$ when $\frac{\partial^2 q^k}{\partial \varepsilon^2} < 0$ for $k = t, \tau$. When $\frac{\partial^2 q^k}{\partial \varepsilon^2} > 0$, $E\left[q^t\left(t^c\right)\right] > E\left[q^\tau\left(\tau^c\right)\right] > E\left[q^T\left(R^c, T\right)\right] \rightarrow R^c$ as $T \underset{-}{\rightarrow} T^{pp}$ and over-quota imports are too small to make up for the convexity of the tariffs. If $T \underset{+}{\rightarrow} t^c$, then $E\left[q^T\left(R^c, T\right)\right] > E\left[q^t\left(t^c\right)\right] > E\left[q^\tau\left(\tau^c\right)\right]$. $\exists T^s \in \left(t^c, T^p\right)$ such that $E\left[q^T\left(R^c, T^s\right)\right] \equiv E\left[q^t\left(t^c\right)\right]$. Similarly, $\exists T^a > T^s$ such that $E\left[q^T\left(R^c, T^s\right)\right] \equiv E\left[q^\tau\left(\tau^c\right)\right]$. Thus, for $T \in \left(T^s, T^a\right)$, $E\left[q^t\left(t^c\right)\right] > E\left[q^T\left(R^c, T\right)\right] > E\left[q^\tau\left(\tau^c\right)\right]$. **QED**

COROLLARY: *The expected level of trade is larger (lower) when import demand shocks are such that* $f_{q\varepsilon} > (<) 0$.

PROOF: When the slope of the import price function becomes less (more) steep, $f_{q\varepsilon} > (<) 0$, $\frac{\partial^2 q^t}{\partial \varepsilon^2}$ and $\frac{\partial^2 q^\tau}{\partial \varepsilon^2}$ increases (decreases), all else equal. **QED**.

Like exchange rate shocks,[7] volatility due to import demand shocks can induce increases or decreases in the expected quantity exported and this does not hinge on risk attitude. Convexity in the import demand makes the quantity traded under the specific tariff relatively larger than under the ad valorem tariff. The intuition revolves around the spread between the domestic price in the importing country and the border price. This spread gets larger under the ad valorem tariff as the import demand shocks get larger. As a result, the foreign export function distorted by the ad valorem tariff induces a smaller increase in exports than under the specific tariff. Volatility can also have an adverse effect on the volume traded. This tends to occur when the price received by exporters increase at an increasing rate with the level of trade. This is likely when individual exporters start facing capacity constraints. In this light, Case D with volatility having no effect on the quantity traded, supported by linear export supply and import demand functions and shocks affecting only the intercept of the import demand, is a special case.

[7] Bonroy, Gervais and Larue (2007) derive conditions for exports to increase under exchange rate volatility. The cited empirical literature offers mixed results.

Figure 1 illustrates a case with a convex import demand and a linear export supply. The TRQ is set such that $R = q^{t^c} = q^{\tau^c} \ \forall \varepsilon$ which implies that all three instruments are quantity-equivalent in the absence of volatility. This is why the quantities under all three instruments cross at $\varepsilon = 0$. The quantities exported under the tariffs are convex in shocks, and more so for the specific tariff. Table 1 shows the expected quantities exported for each instruments for different distributions. The largest expected quantities are observed when import demand shocks are uniformly distributed. In this instance the large quantities resulting from large positive shocks get more weight than under the symmetric triangular distribution. The skewed triangular distributions put low probabilities on large positive shocks and this is why the expected export quantities are lower. Under the negatively skewed distributions, shocks in excess of 1.25 have a zero probability while under the positively skewed distributions large shocks have low probabilities.

Increases in exports following import demand shocks are less likely to trigger protectionist responses on the part of importing countries than export surges resulting from export supply shocks. When there are unexpected shortfalls in domestic supply in importing countries, consumers may even pressure their government to lower tariffs. Accordingly, the greater variations in quantities traded under the tariffs as opposed to TRQs ought to please importers. Finally, because trade statistics often report only trade values and not traded quantities, we can show that the above results hold also for trade values since $\frac{\partial g q^k}{\partial \varepsilon} = \left(g + g_q\right) q_\varepsilon^k,\ k = t, \tau, T$.

The exporting country's gains from trade are increasing and convex in the quantity traded (i.e., $\frac{\partial w^k}{\partial q^k} = g_q q^k > 0$, $\frac{\partial^2 w^k}{\partial q^{k2}} = g_q + g_{qq} q^k > 0$, $k = t, \tau, T$) and this tends to make the gains from trade more responsive to volatility than the volume of trade.

PROPOSITION 2: A) If $q^{k^c} = E\left[q^k\left(k^c\right)\right]$, $E\left[w^k\left(k^c\right)\right] > w^k\left(k^c, 0\right) \ \forall k = t, \tau$. B) For import equivalent barriers without volatility $q^{t^c} = q^{\tau^c} = R^c$, $E\left[w^t\left(t^c\right)\right] > E\left[w^\tau\left(\tau^c\right)\right]$ and $E\left[w^\tau\left(\tau^c\right)\right] > E\left[w^T\left(q^{t^c}, T^p\right)\right]$. However, if $T < T^p$, the TRQ admits some over-quota imports in the presence of large shocks, and the ranking of instruments is ambiguous.

PROOF: A) The gains from trade for the exporting country are the same in the absence of volatility (i.e., at $\varepsilon = 0$) for all three instruments. Proposition 1D) spells out the condition under which the expected quantity exported is equal to the quantity exported without volatility. However, we have shown that under these conditions that the gains from trade increase faster with import demand shocks under the specific tariff, $\partial w^t / \partial \varepsilon > \partial w^\tau / \partial \varepsilon$, and since the gains from trade are also more convex under the specific tariff, $\partial^2 w^t / \partial\varepsilon^2 > \partial^2 w^\tau / \partial\varepsilon^2$, it follows from Jensen's inequality that $E\left[w^t\left(t^c\right)\right] > E\left[w^\tau\left(\tau^c\right)\right] > w^t\left(t^c,0\right) = w^\tau\left(\tau^c,0\right)$. Volatility makes the expected gains from trade for the exporting country larger. If $T \geq T^p, q^T = R^c \; \forall\varepsilon$, $E\left[w^T\left(R^c,T\right)\right] = w^T\left(R^c,T\right) = w^t\left(t^c,0\right) = w^\tau\left(\tau^c,0\right)$. The TRQ is then the worst instrument from the perspective of the exporting country because volatility does not generate any additional gains from trade. However, if $T \to t^c$, then the gains from trade under the TRQ when $\varepsilon > 0$ are roughly the same as under the specific tariff, $\int_0^{\varepsilon_{\max}} w^T\left(R^c,T\right)\phi d\varepsilon \approx \int_0^{\varepsilon_{\max}} w^t\left(t^c\right)\phi d\varepsilon$, but the gains are much larger for the downside risk: $\int_{\varepsilon_{\min}}^0 w^T\left(R^c,T\right)\phi d\varepsilon > \int_{\varepsilon_{\min}}^0 w^t\left(t^c\right)\phi d\varepsilon$. **QED**

Figure 2 illustrates the above results. The comparisons are anchored such that the quantities and gains from trade with no volatility are the same for the two tariffs and the first TRQ : $q^t\left(t^c,0\right) = q^\tau\left(\tau^c,0\right) = q^T\left(R^0,T^0\right) = R^0$. Because the import demand and export supply are linear, the quantities exported in the absence of volatility under both tariffs are equal to the expected quantities in the presence of shocks. Even though the quantities are linear in shocks, the gains from trade are not and the greater convexity under the specific tariff makes the expected gains from trade larger than under the ad valorem tariff and larger than under a TRQ with $T \geq T^{pp}$. Figure 2 also shows two TRQs with a lower minimum access (i.e., $R^1 = R^2 = 3.9 < 4 = R^0$). $TRQ\left(R^1,T^1\right)$ has a low enough over-quota tariff to generate the same level of exports as the two tariffs and the first TRQ, assuming a symmetric triangular distribution. This shows that expected market access can be maintained by lowering the over-quota tariff to compensate for the reduction in guaranteed market access. Even though both TRQ produce the same expected level of market access, exporters concerned with expected gains from trade should prefer the TRQ allowing over-quota exports in the presence of large shocks. Still, the expected level of over-quota exports remains too low to match the expected gains from trade under the tariffs. With an additional reduction in the over-quota tariff, the TRQ can match the specific tariff in terms of expected welfare. In our example with a symmetric triangular distribution, $E\left[w^T\left(R^2,T^2\right)\right] = E\left[w^t\left(t^c\right)\right]$.

3. Export Supply Volatility under Perfect Competition

The exporting country's domestic market may face demand or supply shocks impacting on export supply. The incidence of an export supply shock on exports is obtained by differentiating the arbitrage conditions. Keeping in mind that $g_\psi < 0$, the quantity exported increase in response to an export supply shock when the importing country uses a specific tariff:

$$q_{\psi}^{t} = g_{\psi}\left(f_q - g_q \right)^{-1} > 0. \qquad (11)$$

For the ad valorem tariff, we have:

$$q_{\psi}^{\tau} = g_{\psi}\left(1+\tau\right)\left(f_q - g_q\left(1+\tau\right)\right)^{-1}. \qquad (12)$$

PROPOSITION 3: A) *Export supply shocks have a larger incidence under an ad valorem tariff than under a specific tariff, unlike import demand shocks. B)* $E\left[q^{t}\left(t^{c}\right)\right] > q^{t^{c}} > E\left[q^{\tau}\left(\tau^{c}\right)\right]$ *if* $g_{q\psi} = 0 < g_{gg} < f_{qq} < g_{qq}\left(1+\tau\right)$. *C)* $E\left[q^{\tau}\left(\tau^{c}\right)\right] < E\left[q^{t}\left(t^{c}\right)\right] < q^{t^{c}}$ *if* $g_{q\psi} = f_{qq} = 0 < g_{qq}$ *D)* $E\left[q^{\tau}\left(\tau^{c}\right)\right] > E\left[q^{t}\left(t^{c}\right)\right] > q^{t^{c}}$ *if* $g_{q\psi} < 0 = g_{gg} = f_{qq}$.

PROOF: From (12) and (11), $q_{\psi}^{\tau} > q_{\psi}^{t}$ while from (1) and (6), $q_{\varepsilon}^{\tau} < q_{\varepsilon}^{t}$. This proves part A. The other parts are about the curvature of exports when facing different types of tariff:

$$\frac{\partial^2 q^t}{\partial \psi^2} = \frac{2 g_{q\psi} g_{\psi}\left(f_q - g_q\right) - g_{\psi}{}^2\left(f_{qq} - g_{qq}\right)}{\left(f_q - g_q\right)^3} \qquad (13)$$

$$\frac{\partial^2 q^{\tau}}{\partial \psi^2} = \frac{2 g_{q\psi} g_{\psi}\left(1+\tau\right)^2\left(f_q - g_q\left(1+\tau\right)\right) - g_{\psi}{}^2\left(1+\tau\right)^2\left(f_{qq} - g_{qq}\left(1+\tau\right)\right)}{\left(f_q - g_q\left(1+\tau\right)\right)^3}. \qquad (14)$$

Parts B) and C) assume that shocks affect only the intercept and not the slope of the export supply curve. Under the conditions in part B), exports are convex (concave) in shocks when facing a specific (ad valorem) tariff $\frac{\partial^2 q^t}{\partial \psi^2} > 0 > \frac{\partial^2 q^{\tau}}{\partial \psi^2}$, while for part C) $0 > \frac{\partial^2 q^t}{\partial \psi^2} > \frac{\partial^2 q^{\tau}}{\partial \psi^2}$. For part D, it is easy to see that exports are more convex under the ad valorem tariff. **QED**

Part A) of the above proposition is important because export surges induced by export supply shocks are not likely to be as well received in importing countries as export increases resulting from import demand shocks. The effects of export supply shocks on trade values are more complex than for import demand shocks because export supply shocks affect the export price directly and indirectly through the quantity exported: $\frac{dgq^k}{d\psi} = g_{\psi} q^k + \left(g + g_q q^k\right) q_{\psi}^k$, $k = t, \tau, T$. In the case of the specific tariff, this reduces to $\frac{dgq^t}{d\psi} = \frac{g_{\psi}\left(f_q q^t + g\right)}{f_q - g_q} \gtrless 0$ while for the ad valorem tariff we have $\frac{dgq^{\tau}}{d\psi}=\frac{g_{\psi}\left(f_q q^{\tau}+g\left(1+\tau\right)\right)}{f_q-g_q\left(1+\tau\right)} \begin{smallmatrix}>\\-\\<\end{smallmatrix} 0$. In both cases, the sign depends on the term in parentheses in the numerator. For a TRQ that remains prohibitive after the shock, $q_{\psi}^{T}=0$ and $\frac{dgq^{T}}{d\psi}<0$.

The effect of an export shock on the gains from trade for the exporting country when the importing country restricts trade with a specific tariff is given by:

$$\frac{\partial w^{t}}{\partial \psi}=g_q q^{t} g_{\psi}\left(f_q-g_q\right)^{-1}+g_{\psi}q^{t}-\int_{0}^{q^{t}} g_{\psi}dq. \tag{15}$$

The first component is a gain arising from the increase in the quantity exported while the second term reflects the loss of revenue from a lower price and the third component measures the reduction in export cost stemming from the export supply shock. When the importing country relies on an ad valorem tariff, an export supply shock has the following effect on the gains from trade:

$$\frac{\partial w^{\tau}}{\partial \psi}=g_q q^{\tau} g_{\psi}\left(1+\tau\right)\left(f_q-g_q\left(1+\tau\right)\right)^{-1}+g_{\psi}q^{\tau}-\int_{0}^{q^{\tau}} g_{\psi}dq. \tag{16}$$

PROPOSITION 4: *Export supply (import demand) shocks have a larger (smaller) effect on the gains from trade for the exporting country when the importing country relies on an ad valorem tariff as opposed to a specific tariff:* $\frac{\partial w^{\tau}}{\partial \psi}>\frac{\partial w^{t}}{\partial \psi}$ vs $\frac{\partial w^{\tau}}{\partial \varepsilon}<\frac{\partial w^{t}}{\partial \varepsilon}$.

PROOF: The first inequality results from comparing (16) to (15). Intuitively, the spread between the domestic price and the exporters' price decrease with the export supply shock when the importing country relies on ad valorem tariff and the larger quantity effect makes the gains from trade larger. When the shocks are associated with the import demand, their effects of the exporting country's gains from trade are simpler to compute. Glancing at (4) and (8), it is easy to verify that: $\frac{\partial w^{t}}{\partial q^{t}}\frac{\partial q^{t}}{\partial \varepsilon}>\frac{\partial w^{\tau}}{\partial q^{\tau}}\frac{\partial q^{\tau}}{\partial \varepsilon}$. **QED**

As for curvature of the gains from trade, we have for the specific tariff:

$$\begin{aligned}\frac{\partial^2 w^{t}}{\partial \psi^2}=&\left(\left(g_q+g_{qq}q\right)g_{\psi}+2g_q q g_{q\psi}\right)g_{\psi}\left(f_q-g_q\right)^{-2}-g_q q g_{\psi}^2\left(f_{qq}-g_{qq}\right)\left(f_q-g_q\right)^{-3}\\&+2g_{q\psi}qg_{\psi}\left(f_q-g_q\right)^{-1}\end{aligned} \tag{17}$$

The first term is positive, the third one is negative and the second is positive (negative) if $f_{qq} > (<) g_{qq} \geq 0$. If shocks do not impact on the slope of the export supply ($g_{q\psi} = 0$) and f and g are linear, then $\frac{\partial^2 w^t}{\partial \psi^2} = g_q g_\psi^2 \left(f_q - g_q \right)^{-2} > 0$. For the ad valorem tariff, we have:

$$\frac{\partial^2 w^\tau}{\partial \psi^2} = \left(\left(g_q + g_{qq} q \right) \left(g_\psi \left(1+\tau \right) \right)^2 \right) \left(f_q - g_q \left(1+\tau \right) \right)^{-2} + 2 g_q q g_{q\psi} g_\psi \left(1+\tau \right)^2 \left(f_q - g_q \left(1+\tau \right) \right)^{-2}$$
$$- g_q q \left(g_\psi \left(1+\tau \right) \right)^2 \left(f_{qq} - g_{qq} \left(1+\tau \right) \right) \left(f_q - g_q \left(1+\tau \right) \right)^{-3} + 2 g_{q\psi} q g_\psi \left(1+\tau \right) \left(f_q - g_q \left(1+\tau \right) \right)^{-1}$$

(18)

PROPOSITION 5: A) If $f_{qq} = g_{gg} = g_{q\psi} = 0, E\left[w^\tau \left(\tau^c \right) \right] > E\left[w^t \left(t^c \right) \right] > w^\tau \left(t^\tau, 0 \right) = w^t \left(t^c, 0 \right)$.
Thus the ranking is reversed relative to

PROOF: If $g_{q\psi} = f_{qq} = g_{gg} = 0$, the curvature checks in (17) and (18) reduce to: $\frac{\partial^2 w^t}{\partial \psi^2} = \left(g_q + g_{qq} q \right) \left(g_\psi \right)^2 \left(f_q - g_q \right)^{-2} < \frac{\partial^2 w^\tau}{\partial \psi^2} = g_q \left(g_\psi \left(1+\tau \right) \right)^2 \left(f_q - g_q \left(1+\tau \right) \right)^{-2}$. The gains from trade are convex but more so under the ad valorem tariff. **QED**

The ranking of instruments is reversed compared to that of proposition 2 for volatility arising from import demand shocks. Thus, if volatility is due to shocks arising in the exporting country, the latter is better off if the importing country relies on an ad valorem tariff than on a specific tariff. In this instance, a trade-increasing shock decreases the border price which decreases the spread between the border and domestic prices under the ad valorem tariff. Unlike for import demand shocks, the automatic spread adjustment under the ad valorem tariff is an advantage in the presence of export supply shocks.

What about the gains from trade for the exporting country when it is facing a TRQ? Clearly, an export supply shock that induces a downward shift in the export supply must weakly increase the probability of over-quota exports. If the over-quota tariff is prohibitive over all possible shocks, then the exporting country's gain from trade does not change as shocks move up and down the export supply. In this instance, the shocks do not impact the domestic price in the importing country as the value of import licenses absorbs the shocks and hence is volatile. If some shocks trigger large enough downward shifts to induce over-quota exports, the expected gains from trade under a TRQ in the presence of shocks exceed the gains in the absence of volatility, but they cannot be unambiguously ranked vis-à-vis the expected gains under the tariffs.

4. Risk Preferences

The results from propositions 2 and 5 indicate that the choice of instrument by the importing country matters to exporters. This issue is particularly important in the context of tariff simplification in the current Doha Round of multilateral negotiations and in the context of regional trade liberalization. Tariff simplification calls for the replacement of complex tariffs by ad valorem equivalents. The negotiations of regional trade agreements provide opportunities for some countries to negotiate over the type of trade barriers as well as about the level of existing trade barriers. For example, Canada agreed to phase out its TRQs on whey powder over a 10-year period in the TPP negotiations, but questions remain about how the quotas and over-quota tariffs change. Because expected improvements in market access can be obtained by quota enlargements and over-quota tariff reductions, exporting countries are likely to make their preferences known and the latter may be influenced by their risk attitudes.

The gains from trade tend to be convex in shocks which means that expected gains from trade tend to be larger than gains from trade without volatility. However, the convexity can be tamed by risk preferences. In a mean-variance model, a larger expected gain can be offset by a larger variance. It follows that a ranking based on the expected value of the gains from trade may not be robust to the introduction of risk preferences. Going back to the numerical example of Figure 2 where the shocks were due to unexpected changes in import demand, the expected gains from trade for the exporting country for the pair of quantity-equivalent specific and ad valorem tariffs and shock drawn from a symmetric triangular distribution are 6.13 and 6.11. If we posit that the government in the exporting country displays constant relative risk aversion such that $U = w^{\zeta}; \zeta \in (0,1)$, then the expected utility of the gains from trade is the same under both instruments if $\zeta = 0.5$. The ranking between tariffs changes as the risk parameter goes up or down. The best quantity-equivalent instrument with this amount of risk aversion and the parameters used for Figure 2 is the TRQ. If relative risk aversion was declining with the level of gains, the ranking could change.

Under loss aversion, utility decreases more rapidly than it increases around a reference level. The choice of a reference level is often arbitrary and questionable. For example, Tovar (2009) use the gains from the preceding year. One could assume that some agents might discard information from a highly unusual year or downplay it by resorting to a moving average to construct their reference point. Alternatively, a highly unusual year might have a lasting impression on some agents who might use it as a reference point for some years, and in the process end up putting a weight on such an outcome that far exceeds its probability. Figure 3 illustrates the incidence of a changing reference level. The top plot considers the gains in the absence of volatility as the reference level. Small negative deviations bring about much disutility and have large probabilities of occurrence in our computation of expected utility which is based on a symmetric triangular distribution. Accordingly loss aversion more than offsets the greater convexity of gains from trade under the specific tariff. The same rationale applies when the reference level is based on a particularly good year that makes negative deviations highly likely. However, a very bad year when the import demand shock was close to its minimum value makes negative deviations improbable and this restores the advantage of the specific tariff. The effect of loss aversion can be quite different from those of constant relative risk aversion.

5. Firm-level shocks and imperfect competition

Shocks can be industry-specific (e.g., a health scare about a food), country-specific (e.g., weather, strong aggregate demand…) or firm-level (e.g., a mechanical failure at a plant). Until recently, it was assumed that firm-level shocks cannot have aggregate effects. Gabaix (2011) showed that firm-specific shocks are not likely to cancel each other when the distribution of firm size has fat tails, that is when there are few huge firms and a great many small ones. In such cases, shocks on small firms would have to be aligned to offset a large shock on one of the large firms, an unlikely event. A key characteristic of food processing is the high level of concentration. Concentration ratios tend to be high even in large countries like the United States. We can then analyze the effect of volatility and import barriers on aggregate exports and the gains from trade when an exporting country has only a few firms. We assume Cournot competition between *n* exporting firms and *m* domestic firms in an importing country, a setup that is similar to Salant and Schaffer's (1999) model. Keeping in line with the previous analysis, it is assumed that firms produce a homogenous product. We assume that half of the exporting firms experience a shock that reduces their per unit cost by ψ while the other half see their per unit cost increase by ψ. The profit of an exporting firm facing a specific import tariff is:

$$\pi_s^{\ k} = \left(p\left(\sum_{i=1}^{n/2} q_i^{\ +} + \sum_{j=1}^{n/2} q_j^{\ -} + \sum_{k=1}^{m} q_k \right) - t \right) q_s^{\ k} - c^k \left(q_s^{\ k}, \psi \right) \tag{19}$$

where the subscript *k*=+ designates firms that face a profit-increasing/cost reducing shock while *k*=– designates firms that are dealt a profit-decreasing/cost increasing shock. We assume that shocks impact only the intercepts of the marginal costs of exporting firms such that $\frac{\partial^2 c^+}{\partial q^+ \partial \psi} = \frac{-\partial^2 c^-}{\partial q^- \partial \psi} < 0$ and $\frac{\partial^3 c^+}{\partial \left(q^+\right)^2 \partial \psi} = \frac{-\partial^3 c^-}{\partial \left(q^-\right)^2 \partial \psi} = 0$. A typical domestic firm has a similar cost function and its profit:

$$\pi_v = p\left(\sum_{i=1}^{n/2} q_i^{\ +} + \sum_{j=1}^{n/2} q_j^{\ -} + \sum_{k=1}^{m} q_k \right) q_v - c\left(q_v\right) \tag{20}$$

Taking the first order conditions and imposing symmetry amongst the n/2 + firms, the n/2 – firms and the m domestic firms (i.e., $\sum_{i=1}^{n/2} q_i^{\ k} = \frac{n}{2} q^k$, $\sum_{k=1}^{m} q_k = mq, Q = \frac{n}{2}\left(q^+ + q^-\right) + mq$), interesting comparative statics are generated. The second order conditions require that:

$$\frac{1}{2}\left(p_Q - c_{qq}\right)^2 \left(2\left(1+m+n\right) p_Q - 2c_{qq} + p_{QQ}\left(2mq + n\left(q^+ + q^-\right)\right)\right) < 0$$

Since $p_{QQ} \geq 0$, it is assumed that $-p_Q\left(m+n+1\right) > Max\left(-c_{qq}, -p_{QQ}\left(mq+\frac{n}{2}\left(q^+ + q^-\right)\right)\right)$.

This is automatically satisfied under linear cost and demand functions, but more generally economies of size cannot be too large and marginal revenue must be declining with the volume marketed. The effects of volatility on the quantity chosen by + and - firms is stronger when marginal cost is decreasing with the level of output :

$$\frac{\partial q^+}{\partial \psi} = \frac{-1}{p_Q - c_{qq}}, \ \frac{\partial q^-}{\partial \psi} = \frac{1}{p_Q - c_{qq}} \tag{21}$$

PROPOSITION 6: *Economies of size are not sufficient for firm-level shocks to increase aggregate exports. However, even if exports remain unaffected by shocks, aggregate profit from exporting increases when there are shocks. If $c_{qqq} < (>) 0$, aggregate exports are increasing (decreasing) in firm level shocks.*

PROOF: From (21), p_Q is the same for all firms in the market. The same goes when c_{qq} is a negative constant. Consider the cost functions $c^+\left(q^+\right) = \beta_0 + \left(\beta_1 - \psi\right)q^+ - 0.5\beta_2\left(q^+\right)^2$ and $c^-\left(q^-\right) = \beta_0 + \left(\beta_1 + \psi\right)q^- - 0.5\beta_2\left(q^-\right)^2$. In such a case, the positive effect of the shocks on the output of the + firms is exactly offset by the negative effect of the shocks on the output of the – firms as $c_{qq} = \beta_2$. As a result, the level of aggregate exports is not affected by firm-level shocks. Because exports do not change and the cost of firms in the importing country is not subject to shocks, their output is unaffected and the same can be said about total output marketed. However the aggregate costs of exporting firms fall and profit increases. The incidence of firm-level shocks on aggregate cost is: $\frac{n}{2}\frac{\partial c^+}{\partial \psi} + \frac{n}{2}\frac{\partial c^-}{\partial \psi}$ = $\frac{n}{2}\left(-\psi\frac{\partial q^+}{\partial \psi} + \psi\frac{\partial q^-}{\partial \psi} - \beta_2\left(q^+\frac{\partial q^+}{\partial \psi} + q^-\frac{\partial q^-}{\partial \psi}\right)\right)$ = $\frac{n}{2}\left(-2\psi - \beta_2\left(q^+ - q^-\right)\right)\frac{\partial q^+}{\partial \psi}$ < 0 since $\frac{\partial q^+}{\partial \psi} = \frac{-\partial q^-}{\partial \psi}$. Thus, volatility makes exporting more profitable in aggregate, even when it does not impact on the level of aggregate exports. Consider now the case where c_{qq} varies with the level of output of firms. If $c_{qqq} < 0$, $-c_{qq}\left(q^+\right) > -c_{qq}\left(q^-\right)$ and $\frac{\partial q^+}{\partial \psi} > \frac{-\partial q^-}{\partial \psi}$. The last inequality is reversed if $c_{qqq} > 0$. **QED**

The above result is quite similar to that of proposition 5 under perfect competition in the sense that shocks in the exporting country need not boost export to increase the expected gains from trade. The above result can also be construed as an extension of Salant and Shaffer's (1999) analysis which discusses ways by which governments can create cost asymmetries amongst symmetric domestic firms with constant marginal cost ($c_{qq}=0$) to increase industry profit. In their paper, the government distributes per unit subsidies/taxes so that the sum of the marginal cost of the firms remains unchanged. Individual subsidies and taxes cancel one another, but total industry cost is concave in the per unit subsidy/tax and aggregate profit increases even though the price and the aggregate output levels do not change. In our case, cost asymmetries are due to firm-level shocks. Aggregate exports increase if the slope of the marginal cost of + firms decreases faster than that of – firms in shocks.

Interestingly, the incidence of the volatility on exports and on the aggregate profit of export firms is not affected by the specific tariff when c_{qq} is a constant and shocks impact only the intercept of the marginal cost of firms. If the importing country relies on an ad valorem tariff instead, then the profit of a type k firm can be depicted by:

$$\pi_s{}^k = \left(p\left(\sum_{i=1}^{n/2} q_i{}^+ + \sum_{j=1}^{n/2} q_j{}^- + \sum_{k=1}^{m} q_k \right)(1+\tau)^{-1} \right) q_s{}^k - c^k\left(q_s{}^k, \psi\right) \qquad (22)$$

where k=+,- as before. It is easy to show that the incidence of firm-level shocks on the quantities exported by + and – firms is given by:

$$\frac{\partial q^+}{\partial \psi} = \frac{-(1+\tau)}{p_Q - c_{qq}},\ \frac{\partial q^-}{\partial \psi} = \frac{(1+\tau)}{p_Q - c_{qq}} \qquad (23)$$

PROPOSITION 7: *Export profits increase more under volatility when the importing country relies on an ad valorem tariff than on a specific tariff. Export profits do not change if the importing countries relies on a TRQ and export licenses are tied to export firms and are non-transferable.*

PROOF: Profit increase more under the ad valorem tariff because the variations in quantities exported between + and – firms is largest under an ad valorem tariff. This can be readily seen by comparing (23) to (21). Under the TRQ and fixed licenses, quantities sold by + and – firms cannot change and as a result nor does aggregate export profit. **QED**

Intuitively, the effect of volatility on aggregate profit in the exporting country is exacerbated under an ad valorem tariff because the effects of shocks on the marginal cost are magnified by the ad valorem tariff. To see this, an exporting firm's first order condition takes the general form $(p+p'q)=c_q(q,\psi)(1+\tau)$ and it is clear that the shocks are amplified.

6. Empirical evidence

Our theoretical results show that greater volatility may increase, decrease or leave constant the volume of exports and the gains from trade for exporting countries depending on the nature of the shocks, the type of protection used by importers and market structure. While we derived conditions supporting various outcomes, it remains to be seen how shocks interacts with different trade policy instruments in affecting the volume of trade. Our objective is to measure the effects of demand and supply shocks in importing and exporting countries on the volume of trade and to see whether these effects are mitigated or exacerbated by the type of import barriers used by importing countries. Our theoretical model lends itself to an empirical specification that can be construed as a commodity gravity model. Our application focuses on bilateral flows of corn. Trade flows involving 63 countries are from the World Bank's World Integrated Trade Solution (WITS) website. The list of countries (see Appendix 1) includes the main importers and exporters. The trade flows are reported on an annual basis, covering the 1996-2015 period. The same source and the WTO website offer tariff data, including information about the type of tariff. The variable *lntariff* is simply the log of one plus the ad valorem equivalent tariff. Because our theoretical model posits that the type of trade barrier conditions the effect of volatility on trade, we construct of an interaction variable, *lnvol2_spec* that is simply the product of volatility (in logs) and an indicator variable that equals one when the tariff is not an ad valorem one. Corn is a widely traded commodity whose volatility can be measured by the standard deviation of the daily price of the nearby (nearest-to-maturity) futures contracts. As pointed out by Isengildina, Irwin and Good, 2006), nearby contracts are the most heavily traded and liquid contracts and as a result daily variations in nearby prices are likely to accurately reflect market reactions to various shocks. The data was downloaded from the USDA's Agricultural Marketing Service website.

Demand shocks impacting the import demand of the importing countries and the export supply of the exporting countries are captured by real GDP of importing and exporting countries, denoted respectively *lnGDPimp* and *lnGDPexp*. The import demand and export supply functions can be affected by variations in domestic corn production and this is why the *lnprodimp* and *lnprodexp* variables enter our specificiation. The data on corn production by country was collected from the FAO website. As shown by Magee (2008), regional trade agreements, rta's, condition the volume of trade and it might be necessary to include lagged indicator variables to properly estimate their incidence on trade. Hence, we use *rta* and its lagged values *L1rta* and *L2rta*. Because tariff levels are already controlled for, the interpretation of *rta* differs from the usual one as the inclusion of this variable is meant to capture the incidence of non-tariff provisions in rta's. These are particularly important for trade in agricultural goods and in some cases more restrictive than tariff barriers (Ghazalian, Larue and Gervais, 2011). The usual concerns over endogenous rta's (e.g., Magee, 2008) do not apply because it is highly unlikely that the value of corn traded might have increased the likelihood of rta's. The data on regional trade agreements was collected from the website of Jose de Sousa. Natural barriers like transport costs continue to have a strong adverse effect on trade (Disdier and Head, 2008). We proxy such cost with the CEPII's distance variable. Other variables like indicators for contiguity, a common official language and a colonial relationship complete our empirical specification. To summarize, our theoretical model rationalizes the introduction of time-varying importing and exporting countries-specific variables (i.e., *lntariff*, *lnGDPimp*, *lnGDPexp*, *lnprodimp*, *lnprodexp*), year-specific effects (i.e., *lnvol2*, *lnvol2_spec*), time-varying pair-specific variables (*rta*, *L1rta*, *L2rta*) and time-invariant pair-specific variables (i.e., distance, common language, contiguity. Because some countries do not make tariff changes very often, importing and exporting countries' fixed effects are not indicated.

Two specifications are estimated with the PPML estimator advocated by Santos Silva and Tenreyro (2006). This estimator is often portrayed as a natural fix for zero trade flows and heteroscedasticity. The first specification is more parsimonious, including only the variables suggested by our theoretical model while the second specification borrows from the empirical literature on gravity models by adding dynamic rta effects and variables controlling for the thickness of borders like contiguity, common language and colonial relationships indicators. Clustered standard errors are computed to allow for intra-dyad correlation between observations.

Descriptive statistics about the level of the variables are presented in Table 1. As one could expect there is much variation in domestic production, GDP and trade across countries. To have a better sense of the volatility of the corn market, daily nearby prices in our sample varied between $1.75/bushel to $8.31/bushel and the largest daily decrease and increase were -9.48% and +19.69%. Regression results are presented in Table 2. As one would expect, distance is a natural barrier that significantly reduces trade between countries. The coefficient of -0.82 in the first model implies that increasing the distance from 1000km to 2000km would reduce trade by a multiple of 1.766.[8] Corn is a bulk commodity that does not require to be refrigerated like meats and this estimate seems reasonable. Our prior is that artificial trade barriers also reduce trade and this is confirmed by the adverse effect of tariffs. Our theory indicates that the sign of daily volatility is ambiguous. The coefficient for daily volatility is positive and significant at the 1% level. Furthermore, the coefficient about its interaction with the specific tariff indicator indicates that the positive effect of volatility on trade is augmented when importers rely on specific tariffs. Corn is harvested once a year and one would expect that domestic production in exporting (importing) countries increases (decreases) export supply (import demand). As per our prior, the coefficient on *lnprodexp* is positive and statistically significant while that of *lnprodimp* is negative and also statistically significant. Domestic demand shocks are proxied by *lngdpexp* and *lngdpimp*. They are expected to have opposite effects: increases in national income in importing countries increase import demand and hence trade all else equal while increases in national income in exporting countries augment domestic demand for corn, reduce export supply and hence trade. The coefficients reported in Table 2 support this argument.

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[8] 1.766=exp(-0.82*(ln(1000)-ln(2000)). Our distance coefficients (-0.82 and -0.68) fall in the interval of distance coefficients reported in Sun and Reed (-1.4 to -0.5) who aggregated all agricultural products.

The effect of regional trade agreements extend beyond tariff reductions. This is reflected by the positive and statistically significant *rta* coefficient in the first model. The coefficient suggests that regional trade agreements increase trade by as much as 57%. As argued by Magee (2008), this estimate is likely to be biased because it does not allow for dynamics. The second model addresses this problem by introducing lagged *rta* variables. These variables are correlated and their individual effect are difficult to assess with precision, but Goldbeger (1991, p.219) point out that the sum of the coefficients might be estimated more precisely due to collinearity. The aggregate *rta* effect by summing up the coefficient is exp(-0.94+0.92+0.41)-1=48%. Magee (2008) report an effect that is roughly twice as large, but his model does not control separately for tariff reductions and it is for all goods combined, not a single commodity. Finally, the coefficients on the contiguity, colonial relationships and common language indicators are all positive, as expected, but only common is language is significant.

7. Conclusion

Large price variations over short periods of time (like days or weeks) create opportunities and hurdles for firms engaged in international trade and this is likely to be reflected in annual trade flows between pairs of countries. Naturally, the effect of volatility on trade is conditioned by the level and nature of trade restrictions and by the degree of competition between firms. There is a literature on the optimal trade restrictions in the presence of volatility from the point of view of importing countries (e.g., Young and Anderson, 1982; Anderson and Young, 1982; Freund and Ozden, 2008), but less has been written from the perspective of exporters. The first part of our analysis is about the incidence of import demand and export supply shocks on the gains from trade for exporters in the presence of different trade barriers that are equivalent (welfare-wise for exporting countries) in the absence of volatility. The volume of trade can be convex or concave in shocks and hence higher or lower in the presence of volatility relative to a stable benchmark depending on functional forms, the type of shocks, the type of trade barrier used and attitude toward risk/losses. The same is generally true for the gains from trade. For example, the expected gains from trade are larger under a specific tariff than under an ad valorem tariff or a TRQ in the presence of shocks impacting the intercept of the import demand if the import demand is sufficiently more convex than the export supply. Intuitively, the export response is stronger when the export supply is less convex and the spread between domestic and border prices is not affected by shocks. Thus, starting from a stable benchmark at which an exporting country is indifferent toward the type of policy instrument used by the importing country, the introduction of volatility will generally give rise to a definite ranking of policy instruments. When the perfect competition assumption is replaced by Cournot competition and firms in the exporting country are subject to firm-level shocks decreasing or increasing their marginal costs, we show that the trade gains from volatility for the exporting country when the importing country relies on an ad valorem tariff. This is so because the cost asymmetries are amplified by the ad valorem tariff. These gains from trade can arise even when aggregate exports remain constant.

Our theoretical framework provides a solid foundation for what could be construed as a commodity gravity model that could be estimated to gain empirical insights and resolve the aforementioned theoretical ambiguities. We used annual data on corn trade between 63 countries between 1996 and 2015 and regressed trade in corn on factors giving rise to import demand and export supply shocks, like ad valorem tariff equivalents, transport costs (proxied by distance), national income and domestic corn production in exporting and importing countries, and non-tariff provisions of trade agreements. Other variables influencing the thickness of borders like common languages and colonial links were also added. More importantly, we included a measure of market volatility using daily observations about the nearby futures price and had it interact with an indicator variable about the use of non-ad valorem tariffs. We found that volatility exerts a positive and significant influence on trade. This positive relationship is stronger when importing countries rely on non-ad valorem tariffs. Therefore, volatility creates opportunities that exporting and importing firms can exploit to magnify the expected level of trade and more so when importing countries rely on specific and other non-ad valorem tariffs.

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Figures

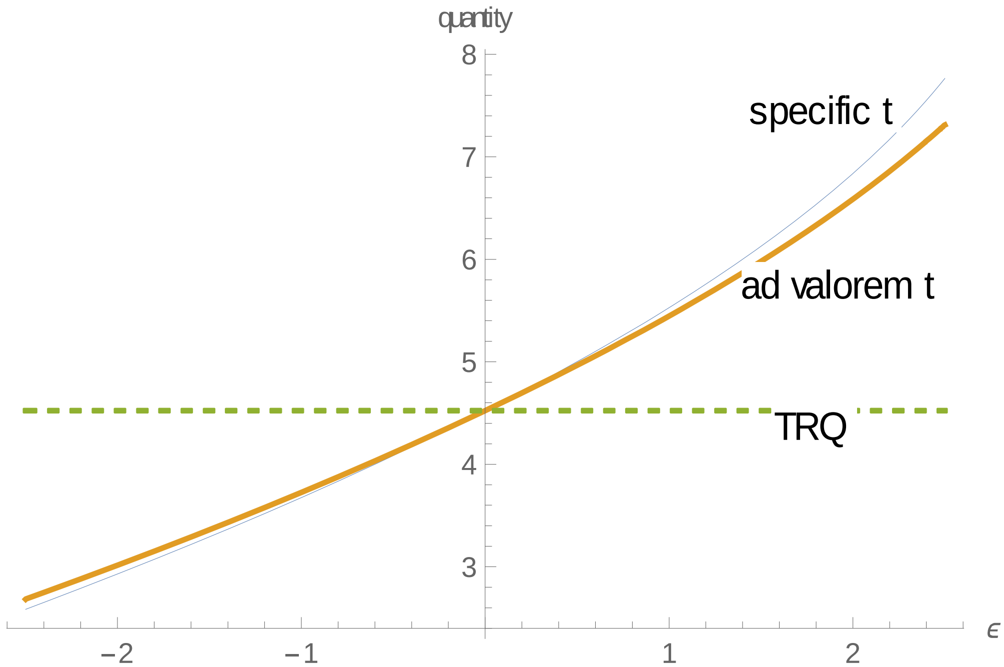


Figure 1. State-contingent quantities under different policy instruments for policy instruments that are quantity-equivalent in the absence of volatility. The above quantities are based on the following functional forms and parameters: $f = 10 + \varepsilon - 1.75q + 0.1q^2$, $g = 2 + 0.25q$, $t = 1, \tau = 0.3194$, $R = 4.52$, $T \geq 3.5$.

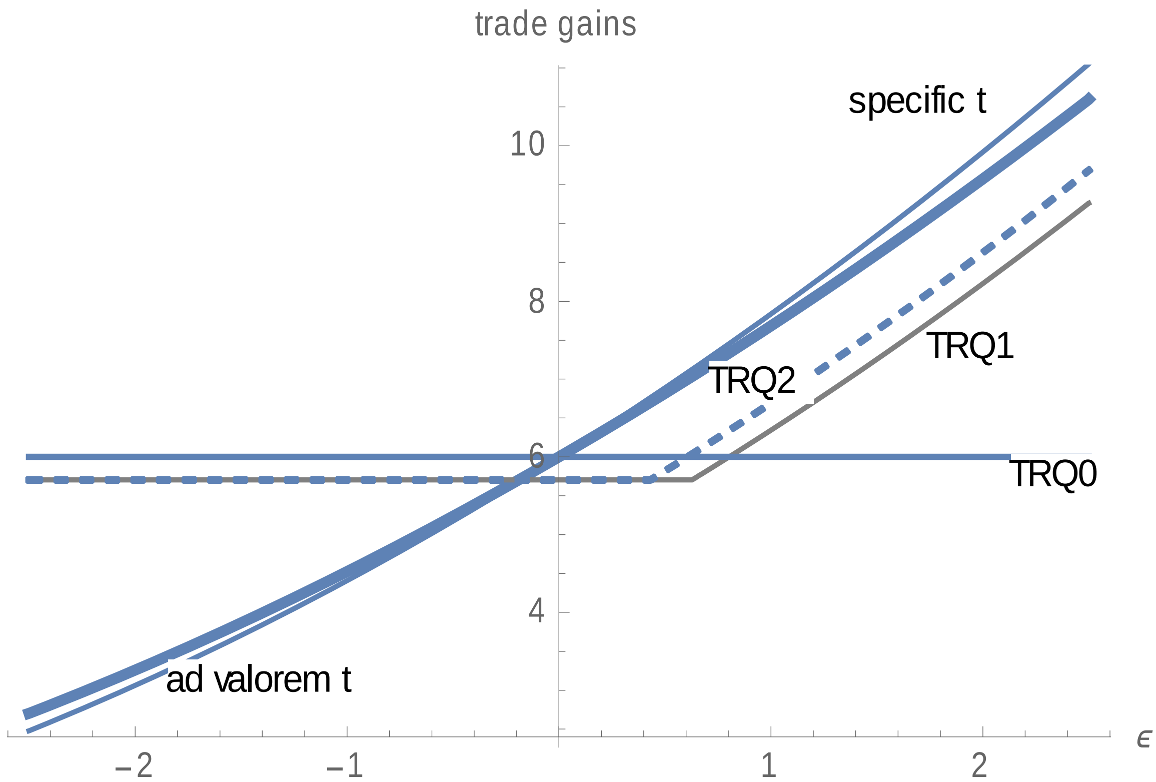
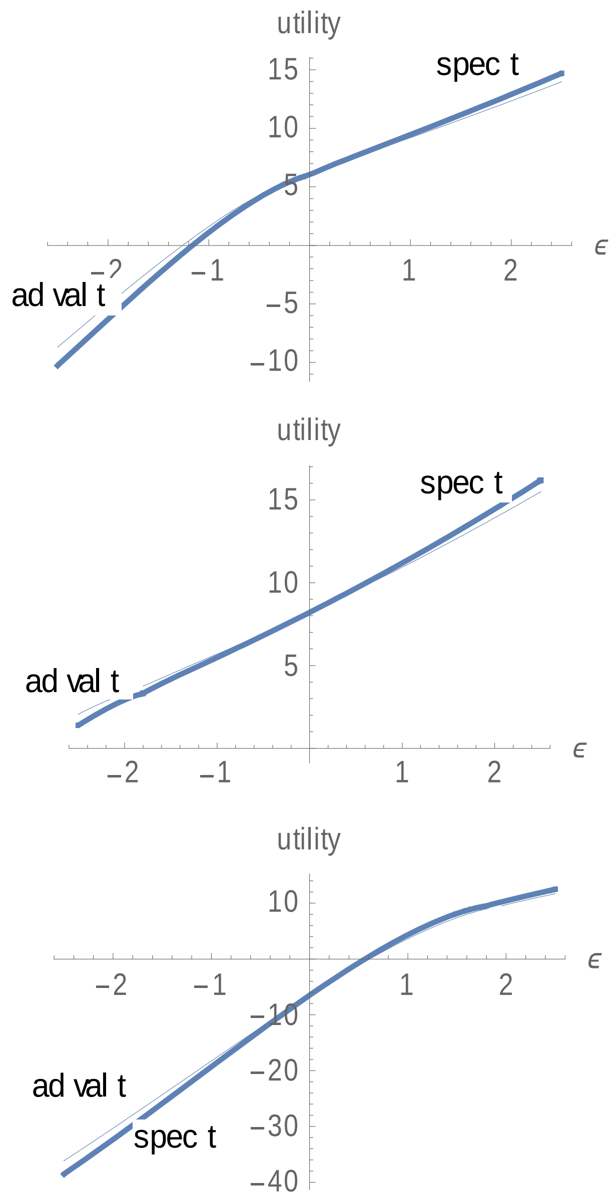


Figure 2. Exporting country's trade gains in the presence of import demand shocks. Note that $q^{t^c} = q^{\tau^c} = R^0 = E\left[q^t\left(t^c\right)\right] = E\left[q^T\left(R^1, T^1\right)\right] = E\left[q^\tau\left(\tau^c\right)\right]$, $E\left[w^t\left(t^c\right)\right] = E\left[w^T\left(R^2, T^2\right)\right] > E\left[w^\tau\left(\tau^c\right)\right] > E\left[w^T\left(R^1, T^1\right)\right] > E\left[w^T\left(R^0, T^0\right)\right]$. The above gains from trade are based on the following specifications and parameters: $f = 10 - q$, $g = 2 + 0.75q, t = 1, \tau = 0.2$, $R^0 = 4$, $T^0 \geq 3.5$, $R^1 = 3.9 = R^2, T^1 = 1.8028, T^2 = 1.6074$.



Utility from trade gains given loss aversion for different reference levels and $E\left[w^{\tau}\right] > E\left[w^{t}\right]$. The expected utilities and expected gains are computed using a symmetric triangular distribution $\varepsilon \in [-2.5, 2.5]$ and $U = w^{k}(k,\varepsilon) - 1.5\left(w^{f} - w^{k}(k,\varepsilon)\right)^{1.7} \; \forall w^{k} < w^{f}$, $U = w^{k}(k,\varepsilon) + \left(w^{k}(k,\varepsilon) - w^{f}\right)^{0.8} \; \forall w^{k} \geq w^{f}$, $k = t^{c}, \tau^{c}$. For the top plot, $w^{f} = w^{k}(k,0)$, $E\left[U\left(w^{\tau}\right)\right] > E\left[U\left(w^{t}\right)\right]$. For the middle plot, $w^{f} = w^{k}(k,-1.8)$, $E\left[U\left(w^{\tau}\right)\right] < E\left[U\left(w^{t}\right)\right]$ and for the bottom plot, $w^{f} = w^{k}(k,1.8)$, $E\left[U\left(w^{\tau}\right)\right] > E\left[U\left(w^{t}\right)\right]$.

Table 1. Expected quantity exported under various distributions

Distributions	Specific tariff	Ad valorem tariff	TRQ
Uniform $\varepsilon \sim [-2.5, 2.5]$	4.71	4.66	4.52
Triangular Symmetric $\varepsilon_{\min} = -2.5 = -\varepsilon_{\max}; \varepsilon_{\text{mode}} = 0$	4.61	4.59	4.52
Triangular Pos.Skewed $\varepsilon_{\min} = -1.25 = \varepsilon_{\text{mode}}; \varepsilon_{\max} = 2.5$	4.59	4.57	4.52
Triangular Neg.Skewed $\varepsilon_{\max} = 1.25 = \varepsilon_{\text{mode}}; \varepsilon_{\min} = -2.5$	4.58	4.57	4.52

The above results are based on the following functional forms and parameters: $f = 10 + \varepsilon - 1.75q + 0.1q^2$, $g = 2 + 0.25q$, $t = 1, \tau = 0.3194$, $R = 4.52$, $T \geq 3.5$.

Table2 . Summary statistics about trade in maize and volatility

Variable	Obs	Mean	Std. Dev.	Min	Max
Trade	78,120	3806.252	62583.66	0	5501105
Dist	75,640	7411.531	4840.627	59.61723	19772.34
Tariff	78,120	14.83048	53.34671	0	467.07
Vol2	78,120	.4419914	.3258596	.0934138	1.207303
Prod_imp	55,552	7575515	2.21e+07	142	2.18e+08
Prod_exp	55,552	7575515	2.21e+07	142	2.18e+08
Gdp_imp	78,058	7.62e+11	1.91e+12	3.40e+09	1.79e+13
Gdp_exp	78,058	7.62e+11	1.91e+12	3.40e+09	1.79e+13
Rta	78,120	.2626984	.4401028	0	1
Nbrofnalines	78,120	.2607655	.4390550	0	1
Contig	75,640	.0401904	.1964068	0	1
Comlang_off	75,640	.0951877	.293476	0	1
Colony	75,640	.0253834	.1572877	0	1

Table 2. Changes in pork exports in response to shocks and type of import tariff

	ppml1	ppml2
lndist	-0.8235**	-0.6829**
	(0.1313)	(0.2020)
lntariff	-1.5261*	-2.0355*
	(0.7468)	(0.8459)
lnvol2	0.4363**	0.2890**
	(0.0807)	(0.0984)
lnvol2_spec		0.5324**
		(0.2051)
lnprodimp	-0.0751+	-0.0875*
	(0.0436)	(0.0420)
lnprodexp	0.9897**	1.0283**
	(0.0923)	(0.1071)
lngdpimp	0.3806**	0.4494**
	(0.0685)	(0.0669)
lngdpexp	-0.2599**	-0.3206**
	(0.0839)	(0.0877)
rta	0.4513+	-0.9544*
	(0.2437)	(0.4186)
l1rta		-0.9374*
		(0.4112)
l2rta		0.4058
		(0.6490)
contig		0.4178
		(0.5173)
comlang_off		0.7127+
		(0.4008)
colony		0.2691
		(0.5256)
_cons	-2.5812	-4.5038+
	(2.7092)	(2.6719)
N	41968	37644

Clustered standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Appendix 1: List of countries

Algeria, Argentina, Australia, Austria, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Denmark, Ecuador, Egypt, Arab Rep., Finland, France, Germany, Greece , Guatemala, Hungary, India, Indonesia, Iran, Islamic Rep., Ireland, Israel, Italy, Japan, Kenya, Korea, Rep., Luxembourg, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Paraguay, Peru, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, Ukraine, United Kingdom, United States, Uruguay, Vietnam, Zambia, Zimbabwe.