Trade policy coordination and food price volatility

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July 18, 2016

Abstract

Many countries adjust their trade policies countercyclically with food prices, to the extent that the use by numerous food exporters of export restrictions has occasionally threatened the food security of food importing countries. These trade policies are inconsistent with the terms-of-trade motivation often retained to characterize the payoff frontier of self-enforcing trade agreements, as they can worsen the terms of trade of the countries that apply them. This article analyzes trade policy coordination when trade policies are driven by terms-of-trade effects and a desire to reduce domestic food price volatility. This framework implies that importing and exporting countries have incentives to deviate from cooperation at different periods: the latter when prices are high and the former when prices are low. Since staple food prices tend to have asymmetric distributions, with more prices below than above the mean but with occasional spikes, a self-enforcing agreement generates asymmetric outcomes. Without cooperation, an importing country uses its trade policy more frequently because of the concentration of prices below the mean but an exporting country has a greater incentive to deviate from a cooperative trade policy because positive deviations from the mean price are larger than negative ones. Thus, the asymmetry of the distribution of commodity prices can make it more difficult to discipline export taxes than tariffs in trade agreements.

Keywords: commodity price stabilization, export restrictions, food security, repeated game, WTO.

JEL classification: F13, Q17, Q18.

*The author thanks the editor Brian Roe and two anonymous referee, as well as Antoine Bouët, Jean-Marc Bourgeon, Quy-Toan Do, Lionel Fontagné, Sébastien Jean, and Will Martin for their helpful comments. This research was generously supported by the Knowledge for Change Program (KCP), and by the European Union's Seventh Framework Programme FP7/2007–2011 under Grant Agreements no 290693 FOODSECURE. The author only is responsible for any omissions or deficiencies. The European Union and European Commission are not accountable for the content of the article.
This is a pre-copyedited, author-produced PDF of an article accepted for publication in the American Journal of Agricultural Economics following peer review. The version of record "Gouel, C. (2016). Trade Policy Coordination and Food Price Volatility. *American Journal of Agricultural Economics*, 98, 1018–1037" is available online at: http://dx.doi.org/10.1093/ajae/aaw020.

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During food price spikes, food exporting countries frequently use export restrictions to insulate their domestic markets from high prices on the world market. Their use can be so widespread that the high levels reached by international prices could be seen as a consequence of these interventions (Dawe and Slayton, 2011), and the restrictions can be so stringent that they can lead to the near disappearance of the world market as happened to the rice market over nine months in 1973 (Timmer, 2010). Food importing countries also act: they decrease their tariffs to protect their consumers but when world prices are low, the situation is reversed and importers raise their import duties. In summary, in food markets, countries routinely adjust their trade barriers to protect their domestic markets from international price variability (Anderson and Nelgen, 2012). The lack of commitment to leaving borders open can reduce trust in the world trade system and lead to costly policies. Importing countries that expect food exporters to restrict their exports in times of scarcity will move away from the specialization consistent with their comparative advantages in order to ensure greater self-sufficiency, or will carry expensive public stocks. For example, the current large-scale public interventions in the Asian countries, through which many countries attempt to achieve self-sufficiency in major staples, can be explained largely by their experience in the 1972/73 food crisis (Rashid et al., 2008).

This article addresses the question of how multilateral trade policy coordination is affected if governments value price stability in their domestic markets in addition to the traditional terms-of-trade motive for trade policy. It also addresses the related question of whether this framework implies a difference in the ability in a cooperative equilibrium to reduce import tariffs versus export taxes, given that both should be reduced by the same amounts if governments are concerned only with terms of trade as in Bagwell and Staiger (1990). The article shows that the price smoothing objective implies that importing and exporting countries have diametrically opposite incentives to deviate from cooperation – this contrasts with trade wars that are motivated by terms of trade which tend to promote symmetrical trade policies. The article shows also that in food commodity markets where prices tend to follow a positively skewed distribution, exporters have a greater incentive than importers to deviate from cooperation which helps to explain why it is more difficult to discipline export taxes than import tariffs within the World Trade Organization (WTO). This is an important policy issue given the recent turmoil in food markets. The widespread use of export restrictions in the 2007/08 food prices spike,[1] and the Russian ban on exports in 2010 following a devastating drought, spurred calls for WTO disciplines on export restrictions (FAO et al., 2011, HLPE, 2011, Bouët and Laborde, 2012). Several food-exporting developing countries judged these proposals unwelcome (Mitra and Josling, 2009), and they were not considered in the agreement reached at the 9th WTO Ministerial Conference held in Bali (WTO, 2013).[2] So far, according to agricultural draft modalities (WTO, 2008), in the case of another agreement there would not be any significant strengthening of the disciplines on export restrictions. Thus, given the importance of export restrictions for influencing trust in world markets, and food policies in the long run, it is essential to understand what is preventing a trade agreement on this issue.

To improve our understanding, this article builds a two-country partial equilibrium trade model, in which governments adjust their trade policies to stabilize their domestic prices. The resulting model is used to characterize the static Nash equilibria, and the nature of a self-enforcing agreement on time-

[1] In a survey of national responses to the food security crisis, Demeke et al. (2009) show that 25 developing and emerging countries from a panel of 81 restricted or banned exports.

[2] This was not a new issue: proposals to regulate export restrictions were rejected by many member countries at the beginning of the Doha Round negotiations (WTO, 2004).

varying trade policies. The current model draws heavily on Bagwell and Staiger's (1990, 2003) work to analyze how self-enforcing agreements can discipline countercyclical trade policies. An agreement is self-enforcing when cooperation is sustained by the threat of future punishment if the cooperation is violated, without the need for an external enforcement mechanism. Bagwell and Staiger (1990, 2003) show that the threat of a return to a non-cooperative situation is sufficient to achieve tacit cooperation among countries involved in repeated interactions. However, this cooperation is not necessarily synonymous with free trade, because when trade shocks are large enough the incentive to deviate from cooperation would become too high in a situation of free trade. This article adapts this model to a setting suitable to analyze trade policies applied to food products. In order to answer the research question, we need to introduce two features absent from Bagwell and Staiger's (1990) model.

Firstly, to investigate the impact of price fluctuations on trade policy coordination, a particular structure must be imposed on the social welfare function. The papers by Bagwell and Staiger focus on trade policies motivated by terms-of-trade gains, and explain changes in trade policies by changes in potential terms-of-trade gains arising from idiosyncratic supply shocks. For food products, terms-of-trade theory may not be sufficient to explain the behavior of trade barriers. Examples of deviations from this theory are the export bans imposed by many countries during the recent food crisis which precluded any gains from trade, and the export subsidies applied by wealthy countries in periods of low prices which deteriorate the terms of trade of the countries using them. In addition, terms-of-trade theory implies that trade policy adjustments are a function of trade volume rather than of the world price because trade volume characterizes the potential gains from manipulating terms of trade. However, Anderson and Nelgen (2012, table 1) show that protection of food products is negatively correlated with deviations from trend in the international price of the products in question. So to account for the extent of trade policy adjustments in food products, and to characterize the payoff frontier of self-enforcing trade agreements, we need a model in which governments are motivated not just by terms-of-trade gains, since exploitation of the terms of trade is not sufficient to explain the offsetting of international price variations by trade policies, but want also to stabilize domestic prices. To introduce the observed reaction of trade policies to the world price, it is necessary to consider other economic and political-economy motivations. When accounting for market failures in risk management (Eaton and Grossman, 1985, Cassing et al., 1986, Gouel and Jean, 2015), countercyclical trade policies can be rationalized as insurance instruments. Their existence might be explained also by political-economy considerations. For example, the loss-aversion framework of Freund and Özden (2008) and Tovar (2009) is applied by Giordani et al. (2014) to account for price-insulating trade policies. Given the variety of potential motivations for these policies (Swinnen, 2010, Anderson et al., 2013), and the focus of the present article on the strategic interactions of countries, we adopt a tractable reduced-form, social welfare function that accounts for the economic and political-economy motivations described above.

Secondly, in contrast to Bagwell and Staiger's (1990) model which is concerned only with idiosyncratic risk (i.e., potential trade volume in free trade due to the difference in supply shocks), we introduce aggregate uncertainty (i.e., potential price in free trade due to the sum of supply shocks) which is crucial to add world price volatility to the model. So in the proposed model, price volatility is driven by stochastic supply shocks in both countries. The two risks correspond also to different motivations for using trade policy. If trade policies are aimed at manipulating the terms of trade, they will vary with trade volume. If they are aimed at smoothing prices, they will vary with the world price. Introducing aggregate uncertainty allows us also to consider the well-known stylized facts that staple food prices tend to have positively skewed distributions (Deaton and Laroque, 1992), with more prices below the mean than above it but with occasional spikes. If the distribution of free-trade world prices is positively skewed, an importing country involved in a trade war will use its trade policy more frequently than an exporting country because of the concentration of prices below the mean; however, an exporting country will have a greater incentive to deviate from a cooperative trade policy because positive deviations from the mean price will be larger than negative ones. So an exporting country is more likely than an importing country to retain in cooperation the right to use its trade policies. This result could explain the difficulty to reach an international agreement which would discipline export restrictions.

These extensions of Bagwell and Staiger's (1990) model come at a cost. The reduced-form social welfare function penalizing price volatility combined with aggregate uncertainty implies that in tacit cooperation equilibria, importing and exporting countries have incentives to deviate from cooperation at different periods: exporters will deviate when prices are high and importers when prices are low. This breaks the symmetry of the model, and we lose the ability to characterize the cooperative solution analytically. Therefore, once the equations characterizing the payoff frontier of self-enforcing trade agreements have been defined, we proceed with numerical simulations. These simulations are central to showing that a positively skewed price distribution makes disciplining export taxes more difficult than disciplining import taxes.

A few recent papers have pointed out that disciplines on export restrictions, although potentially useful at the global level, are unlikely to be achievable within the WTO framework. For Abbott (2012), this is because policy makers will not agree to renounce their right to stabilize their markets. For Cardwell and Kerr (2014), the dispute settlement system cannot enforce such disciplines because export restrictions are of short duration compared to the time taken to settle disputes, and because complainant countries may not be in a position to retaliate owing to insufficient bilateral trade levels. The present article also contributes to the policy discussions on export restrictions. Here, disciplines on export restrictions also proved difficult to achieve. Due to the asymmetric distribution of commodity prices, it may be more difficult to discipline export taxes in trade agreements compared to tariffs, since exporters will occasionally face a greater incentive to deviate from free trade than importers.

1 Model setup

Consider a partial equilibrium model of a global cereal market. There are two countries (Home and Foreign) with identical demand schedules. Foreign is indicated by the superscript "$*$". Production is assumed to be inelastic and is represented by two random variables, ε and ε^*, which are drawn from a known bivariate probability distribution defined on a bounded support, and which are not serially correlated. Production shocks are perfectly observable. For the analytical part of the article, we need only to assume that the bivariate distribution is such that in a situation of free trade Home is always in a position to export to Foreign, so given that countries are symmetric we always have $\varepsilon \geq \varepsilon^*$.

The demand functions are assumed to be linear and identical in both countries $D(P) = a - bP$ and $D^*(P^*) = a - bP^*$. Domestic prices clear the markets: $\varepsilon = D(P) + V$ and $\varepsilon^* = D^*(P^*) - V$, where V refers to the volume of trade.

Countries can apply specific trade policies: τ and τ^*. We allow government to implement only trade taxes. This is not to deny the actual use of subsidies but rather to suggest that for fiscal and institutional reasons their use is likely to be less extensive than the use of taxes. Importing countries cannot be expected to be able to use import subsidies to the extent that they are able to compensate for any level of export taxes. Export subsidies are subject to many WTO disciplines and would be more severely restricted in the case of an agreement based on the current draft modalities. A consequence of this restriction is that it is not possible for one country to perfectly offset another country's trade tax by decreasing its own trade policy. At some point, the restriction to use only taxes will be binding.[3] When trade takes place, domestic prices are defined by combining the world price, P^w, with trade policies:

$$P = P^w + \tau \text{ and } P^* = P^w + \tau^* \text{ with } \tau \leq 0 \leq \tau^*. \tag{1}$$

This definition implies that when Home exports, a negative τ is an export tax; conversely, when Foreign imports, a positive τ^* is an import tax.

By combining the above equations, we can characterize the volume of trade:

$$V = \frac{\varepsilon - \varepsilon^*}{2} + \frac{b(\tau - \tau^*)}{2}. \tag{2}$$

From (2), the free-trade trade volume is defined as $V^f \equiv (\varepsilon - \varepsilon^*)/2$. Trade is strictly positive for

$$\tau - \tau^* > \frac{\varepsilon^* - \varepsilon}{b} \text{ or } \tau^* - \tau < \frac{2V^f}{b}. \tag{3}$$

When (3) holds, the world price is given by

$$P^w = \frac{a}{b} - \frac{\varepsilon + \varepsilon^*}{2b} - \frac{\tau + \tau^*}{2}. \tag{4}$$

In a situation of free trade, the world price would be

$$P^f \equiv \frac{a}{b} - \frac{\varepsilon + \varepsilon^*}{2b}. \tag{5}$$

Let s be the state of the world. It is defined by the two supply shocks ε and ε^*. Another equivalent definition of the state of the world which we exploit later in the article is the aggregate risk, $\varepsilon + \varepsilon^*$, and the difference in idiosyncratic risks, $\varepsilon - \varepsilon^*$, which can also be represented by the free-trade world price, P^f, and the free-trade trade volume, V^f.

2 The static game

In this section, we characterize the Nash equilibria of the static game in which each country applies trade taxes to maximize the social welfare function which in addition to the usual measures of surplus, accounts for the policy-makers' preference for food price stability. The resulting interior trade policies are costly for both countries and will serve as punishments in the repeated game.

[3] The results would be similar if instead of assuming that countries are constrained to use trade taxes, they were constrained to not exceed a certain level of subsidies, because such a constraint would maintain the existence of states of the world in which the smoothing components of trade policies are not mutually offsetting. However, it would introduce the possibility of multiple cooperative equilibria; a refinement of the solution concept and different numerical methods would be required to select the equilibrium where free trade prevails when countries cooperate.

2.1 Social welfare function

To model government preferences with respect to the distribution of domestic prices, we introduce in a traditional welfare function a term accounting for deviations from a price target. This term should lead to trade policies consistent with the observed behavior of governments in response to food price shocks. Year-to-year variations in trade protection are countercyclical to deviations in the world price from its long-run trend, and are similar for upward and downward price spikes (Anderson and Nelgen, 2012, Anderson et al., 2013). Thus, we adopt a tractable reduced-form social welfare function able to account for the various economic and political-economy motivations behind these variations, by assuming that governments maximize their countries' welfare which is defined as the sum of the producer's surplus, the consumer's surplus, and the tariff revenue to which a quadratic term in the domestic price is added to account for the policy-makers' preference for food price stability.[4] The Home and Foreign welfare functions are defined as functions of the state of the world and the trade policies by

$$W\left(s,\tau,\tau^*\right) \equiv \int_{P(s,\tau,\tau^*)}^{a/b} D(p)\,\mathrm{d}p + P\left(s,\tau,\tau^*\right)\varepsilon - \tau V\left(s,\tau,\tau^*\right) - \frac{K}{2}\left[P\left(s,\tau,\tau^*\right) - \bar{P}\right]^2, \tag{6}$$

$$W^*\left(s,\tau,\tau^*\right) \equiv \int_{P^*(s,\tau,\tau^*)}^{a/b} D^*(p)\,\mathrm{d}p + P^*\left(s,\tau,\tau^*\right)\varepsilon^* + \tau^* V\left(s,\tau,\tau^*\right) - \frac{K}{2}\left[P^*\left(s,\tau,\tau^*\right) - \bar{P}\right]^2, \tag{7}$$

where $K \geq 0$ is a parameter characterizing the preference for price stability, and $\bar{P}$ is a target price around which policy-makers want prices to be stabilized. To avoid introducing systematic bias in the policy, $\bar{P}$ is chosen such that the smoothing motivation is inactive in the absence of stochastic shocks in free trade. It means that $\bar{P}$ is the steady-state, free-trade price, or the price when random variables are equal to their mean, and when countries do not use trade policies: $\bar{P} = a/b - \mathrm{E}\left[\varepsilon + \varepsilon^*\right]/(2b)$, where E denotes the mathematical expectations operator. Given the linearity of the model, the steady-state, free-trade price is equal also to the average price without intervention. For simplicity, the preference for price stability and the target price are assumed to be identical in both the Home and Foreign countries.

Although the quadratic term in the social welfare functions is merely a means of introducing (in a tractable way) additional concavity into the social welfare function, it can also be endowed with some micro-foundations by being interpreted as the difference between the second-order approximation of the equivalent variation of a risk-averse consumer and its surplus. Thus, it becomes a welfare term accounting for non-zero risk aversion and income elasticity. Following Turnovsky et al. (1980), in this case K will be equal to $\gamma(R-\nu)D\left(\bar{P}\right)/\bar{P}$, where γ, R, and ν are the values at steady-state of the commodity budget share, relative risk aversion to income, and income elasticity. K will be positive if the risk aversion is higher than the income elasticity which would seem reasonable for staple food products. This would represent an approximation of social welfare for an incomplete-markets economy in which risk-averse consumers cannot insure against food price risk (see Gouel and Jean, 2015, for such a situation). This interpretation is useful when choosing a reasonable value for K for the numerical simulations.

[4] Alternatively, the social welfare function might have penalized deviations toward high prices only. This would be consistent with a focus on social unrest as in Arezki and Brückner (2014) and Bellemare (2015) which find that upward price spikes matter much more than food price volatility for political stability. While this may be consistent with the short-run effects of high food prices for poor urban populations, it is important to bear in mind that the distribution of food prices has mixed effects. Rural populations, even with net food consumers, may benefit from higher food prices because of the associated wage response (Ivanic and Martin, 2014, Jacoby, 2016). These various effects may explain why trade policy interventions are actually related not just to high food prices but to both low and high prices.

2.2 Trade policies as functions of the world price

Before considering the Nash equilibrium, we analyze how trade policies react to the world price when countries maximize their social welfare function as defined above. To obtain the optimal reaction to world price changes, we maximize $W(s,\tau,\tau^*)$ over $\tau \leq 0$, and $W^*(s,\tau,\tau^*)$ over $\tau^* \geq 0$. The welfare functions are strictly concave with respect to their respective domestic trade policies, so the optimal trade policies are given by the first-order conditions which if (3) holds leads to:

$$\tau = \min\left[0, \frac{\overbrace{K\left(\bar{P}-P^w\right)}^{\text{Smoothing}} - \overbrace{\left(\varepsilon - a + bP^w\right)}^{\text{Market power}}}{K+2b}\right], \tag{8}$$

$$\tau^* = \max\left[0, \frac{K\left(\bar{P}-P^w\right) - \left(\varepsilon^* - a + bP^w\right)}{K+2b}\right]. \tag{9}$$

This trade policy has two components. The first component obeys a smoothing motive. It derives from the marginal welfare cost of deviating from the steady-state price corrected by the reaction of world and domestic prices to the trade policy. It is countercyclical and will tend to impose export subsidies (import taxes) when prices are below the target price, and to impose export taxes (import subsidies) when prices are above the target price. The second component exploits the country's market power. If we neglect K in the denominator, this second component is equal to the inverse of the import demand (export supply) elasticity faced by Home (Foreign) as expected for a welfare-maximizing trade policy. K in the denominator reduces this component because exploiting the terms of trade goes against the smoothing motivation. This component leads to the use of export (import) taxes to exploit market power over the world price, and as is clear from the equation, it is proportional to the trade volume at the border price ($\varepsilon - D(P^w)$ or $\varepsilon^* - D^*(P^w)$). For $K=0$, this is the only rationale for intervention.[5]

2.3 The interior Nash equilibrium

Next, we characterize the interior Nash equilibrium and express all results as functions of P^f and V^f. From equations (8) and (9), best-response correspondences are given by

$$\tau_R(s,\tau^*) = \min\left[0, 2\frac{K\left(\bar{P}-P^f\right)-V^f}{K+3b} + \frac{K+b}{K+3b}\tau^*\right], \tag{10}$$

$$\tau_R^*(s,\tau) = \max\left[0, 2\frac{K\left(\bar{P}-P^f\right)+V^f}{K+3b} + \frac{K+b}{K+3b}\tau\right]. \tag{11}$$

For each country, the interior Nash trade policies present three possible regimes. For sufficiently low prices ($P^f \leq \bar{P} - bV^f/K(K+2b)$), the unconstrained policy for the exporter would be to subsidize its exports. Because its policy is constrained to being a tax, it does not impose any trade barrier. In this

[5] With a small country, the optimal trade policy of Home would be $\tau = \min\left[0, K\left(\bar{P}-P^w\right)/(K+b)\right]$. This is similar but slightly different from the smoothing component of (8). With respect to the smoothing objective, a small country reacts more than a big country to a change in the world price because the use of countercyclical trade policies by a big country amplifies the world price movement and hampers its smoothing objective. However, when accounting for the terms-of-trade motivation, a big country will make bigger adjustments than a small country to its trade policy in the context of a change in the world price, because the ratio of the slopes of the trade policy rules with respect to world price is $K(K+2b)/(K+b)^2$, which is always inferior to 1.

case, the importer policy is set by (11) with $\tau = 0$. The opposite is true for sufficiently high prices ($P^f \geq \bar{P} + bV^f/K(K+2b)$): no trade policy on the importer side, and exporter trade policy determined by (10) with $\tau^* = 0$. For intermediate prices, the trade policies in each country account for the intervention in the other country. This is summarized in the following expressions:

$$\tau_N(s) = \begin{cases} 0 & \text{if } P^f < \bar{P} - \frac{bV^f}{K(K+2b)}, \\ \frac{K(\bar{P}-P^f)}{b} - \frac{V^f}{K+2b} & \text{if } \left|\bar{P} - P^f\right| \leq \frac{bV^f}{K(K+2b)}, \\ 2\frac{K(\bar{P}-P^f)-V^f}{K+3b} & \text{if } P^f > \bar{P} + \frac{bV^f}{K(K+2b)}, \end{cases} \tag{12}$$

$$\tau_N^*(s) = \begin{cases} 2\frac{K(\bar{P}-P^f)+V^f}{K+3b} & \text{if } P^f < \bar{P} - \frac{bV^f}{K(K+2b)}, \\ \frac{K(\bar{P}-P^f)}{b} + \frac{V^f}{K+2b} & \text{if } \left|\bar{P} - P^f\right| \leq \frac{bV^f}{K(K+2b)}, \\ 0 & \text{if } P^f > \bar{P} + \frac{bV^f}{K(K+2b)}, \end{cases} \tag{13}$$

where the subscript N designates variables on the Nash equilibrium. Again these expressions include the two components of smoothing and market power. Terms proportional to $\bar{P} - P^f$ relate to smoothing, and terms proportional to V^f relate to market power. These terms behave very differently.

The market power components have opposite signs in the two countries. Using the world price equation (4), this means that for intermediate world price levels, when policies are unconstrained, these components do not change the world price. The exporter tends to tax exports, and the importer tends to tax imports. It reduces trade levels, leaves the world price unchanged, reduces prices in the exporting country, and increases prices in the importing country.

However, for intermediate world price levels, the trade policy component motivated by smoothing is equal across countries and does not affect the domestic price. In a situation of scarcity, each country tries to bid higher for the same commodity: the exporter increases its export tax, and the importer decreases its tariff by the same amount, so the quantities allocated are the same. The exporter's terms of trade improve at the expense of the importer, thus, a transfer takes place from the importing to the exporting country. In a situation of glut, the situation is reversed: the exporter decreases its export tax and the importer increases its tariff, and this smoothing component leads to transfers from the exporting to the importing country. These policy adjustments perfectly offset each other, and so are ineffective. This ineffectiveness of countercyclical trade policies at the global level is highlighted in Bigman and Karp (1993) and Martin and Anderson (2012).

Martin and Anderson (2012) compare this ineffectiveness of the countercyclical component of trade policies to the collective-action problem which arises when a crowd stands up in a stadium to get a better view: when everybody decides to stand, standing up does not result in a better view but remaining seated is no longer an option. In our framework, this zone of compensation does not justify an international cooperative agreement with respect to the smoothing motivation, because the only aggregate welfare cost is related to the terms-of-trade part of the intervention. Since the smoothing parts of trade policies compensate each other, they do not affect domestic prices but create income transfers associated with the terms-of-trade changes. Across time, these transfers compensate because the target price is also the average price. In our welfare framework, given the absence of aversion to income risk, this volatility of income is not costly. The smoothing motivation for trade policies opens up the possibility of a trade agreement precisely if the policies do not compensate: that is, for a low or high free-trade world price when one country is constrained in its trade policy.

Given the use by the two countries of these Nash trade policies, the world price is given by

$$P_N^w = P^f + \begin{cases} \frac{K\left(P^f - \bar{P}\right) - V^f}{K+3b} & \text{if } P^f < \bar{P} - \frac{bV^f}{K(K+2b)}, \\ \frac{K\left(P^f - \bar{P}\right)}{b} & \text{if } \left|\bar{P} - P^f\right| \leq \frac{bV^f}{K(K+2b)}, \\ \frac{K\left(P^f - \bar{P}\right) + V^f}{K+3b} & \text{if } P^f > \bar{P} + \frac{bV^f}{K(K+2b)}. \end{cases} \tag{14}$$

The trade policies amplify movements in the free-trade price, and this amplification depends on K. A stronger preference for domestic price stability entails a more volatile world price (see also Giordani et al., 2014, for an in-depth analysis of this multiplier effect of trade policy). With respect to free trade, the world price will be increased by trade policies if the free-trade price is above the target price, and decreased when it is below (see figure 1, left panel). The world price equals the free-trade price only when the free-trade price equals the target price. These trade policies increase the variance of the world price with respect to the free-trade situation. This increased variance is caused by the smoothing motivation (the world price variance would be the same as in free trade if K equals 0).

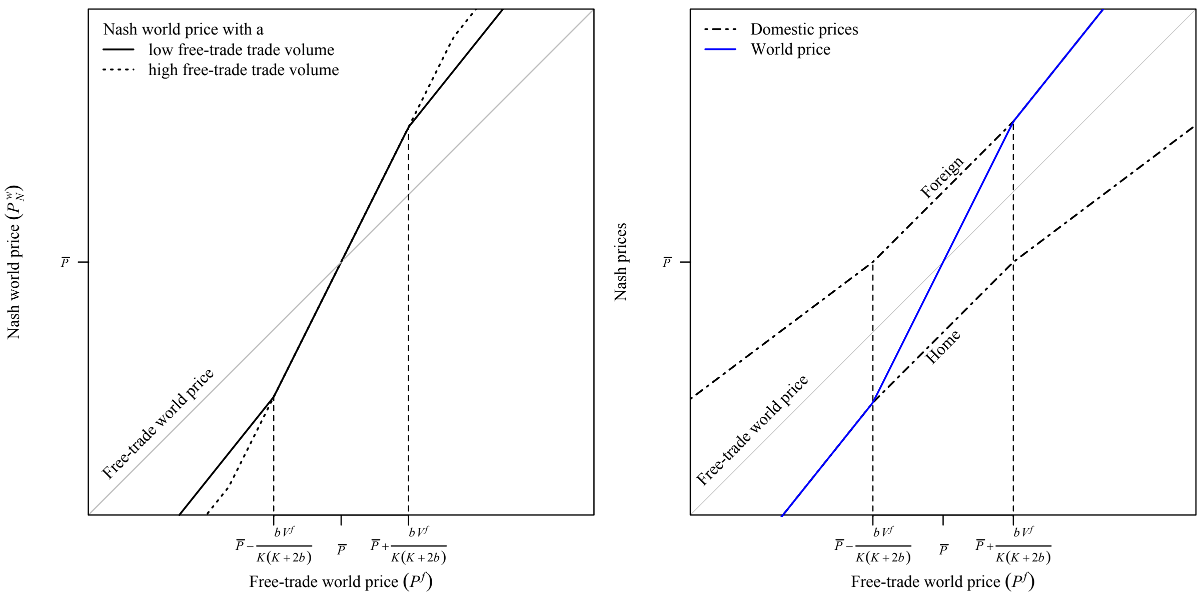

Figure 1. Nash prices as functions of the free-trade world price (P^f)

The increased world price volatility does not translate necessarily into greater domestic price volatility. In the absence of the partner's reaction, one country could achieve some price stabilization with respect to the world price by using its trade policy. However, in the Nash equilibrium which takes account of trade policy reactions such a stabilization is harder to achieve since the partner country tends to offset the stabilization efforts. The effect of Nash trade policies on domestic prices is illustrated in figure 1 (right panel). Nash domestic prices are constructed by combining equation (14) with equations (12) and (13). For prices close to steady state, the countercyclical components of trade policies compensate each other, and the slope of domestic prices with respect to the free-trade price is 1 (this is the zone where countercyclical trade policies are globally ineffective as noted in Martin and Anderson, 2012). For free-trade prices above $\bar{P} + bV^f / [K(K+2b)]$, the slope of the Home domestic price with respect to the free-trade price is lower than 1 ($3b/(K+3b)$). When Foreign is constrained in relation to its use of trade policies, Home achieves some partial protection against world price variations. Conversely, for low prices, the slope of the Home domestic price with respect to the free-trade price is higher than 1 ($(2K+3b)/(K+3b)$), since its domestic price is equal to the world price. These policies increase the severity of upward price spikes in the importing country, and the severity of downward price spikes in the exporting country. Overall, domestic price volatility is decreased for high (low) prices and increased for low (high) prices in the exporting (importing) country. The overall effect is ambiguous and depends on the distribution of supply shocks.

The model has two exogenous variables that define its state: the free-trade world price, P^f, and the free-trade trade volume, V^f (or equivalently ε and ε^*). The free-trade world price represents the aggregate risk since it is determined by the overall production level, that is the sum of production shocks in the two countries. In free trade, for the same world price, there can be different levels of trade volume depending on how production is divided between the countries, thus, the free-trade trade volume represents the idiosyncratic risk. It is worth examining the two special cases of pure aggregate risk and pure idiosyncratic risk since these are situations where the model has only one state variable which simplifies the analysis, and where the smoothing and terms-of-trade motivations can be contrasted which contributes to our understanding of these policies.

Pure aggregate risk In a situation where $\varepsilon - \varepsilon^*$ is a constant, there is only an aggregate supply risk, and no idiosyncratic risk. This means that shocks have a perfect positive correlation and equal variance. This leads to a constant free-trade trade volume but a volatile free-trade price, and according to (12) and (13), changes in trade policy are explained only by the smoothing motivation. However, strategic interactions and market power considerations are present, although their effect is of second order. For intermediate world prices, the slope of the trade policy rule with respect to the free-trade price is $-K/b$, while it would be smaller at $-K/(K+b)$ in a small country. Indeed in the Nash equilibrium, larger countries adjust their trade policies more to the world price than would a small country in an attempt to compensate for their partner's trade policy when this latter is active.

Pure idiosyncratic risk If $\varepsilon + \varepsilon^*$ is a constant, there is no aggregate risk, only idiosyncratic risk (this is the situation analyzed in Newbery and Stiglitz 1984, and Bagwell and Staiger 1990). This is a setting of perfect negative correlation, with shocks of equal variance. The free-trade price and the smoothing component of trade policies are constant. In this situation, the change in trade policies stemming from the terms-of-trade motivation appears to be in conflict with the aim of smoothing domestic prices. Without trade policy intervention, the world price would be constant but potential terms-of-trade gains compel countries to intervene. This creates a trade-off between the smoothing and terms-of-trade motivations. This is shown in equations (12) and (13) in the slope of trade policy with respect to the free-trade trade volume: for an intermediate world price, without the smoothing motivation in the social welfare function, the slope would be $1/2b$, whereas it is actually $1/(K+2b)$. The slope is reduced by the smoothing motive, since pursuit of terms-of-trade gains goes against it.

One intuition about trade policies motivated by price smoothing is that they may hinder international sharing of agricultural production risk. Agricultural production is much more volatile at the country than at the world level, because the pooling of all idiosyncratic weather shocks leads to much more stable aggregate production. The two extreme cases analyzed above show that the smoothing component of trade policies does not try to prevent risk sharing, and it is equal to zero when only idiosyncratic risk is present. Smoothing-related trade policies are motivated only by aggregate shocks.

2.4 The autarky equilibria

We now turn to the Nash equilibria that correspond to autarky. If $-\tau \geq 2V^f/b$ or $\tau^* \geq 2V^f/b$ then whatever the value of the other country's trade policy, condition (3) does not hold and autarky prevails. So there is a set of Nash equilibria without trade for any trade tax pair in which one of the taxes exceeds $2V^f/b$ in absolute value.

2.5 Efficient trade policies

The trade policies that maximize joint welfare, $W(s,\tau,\tau^*) + W^*(s,\tau,\tau^*)$, are defined by

$$\tau = \tau^*, \tag{15}$$

which, since trade policies are constrained to be taxes, is compatible only with free trade. So the interior Nash equilibrium is inefficient, because it features too little trade and too much price volatility.

3 International cooperative agreement

We next consider that the countries interact repetitively which enables them to coordinate on more cooperative policies. In this dynamic game, based on the observed state variables, countries decide their trade policy at each period. They can coordinate on lower protection levels than in the static game, because cooperation is enforced by the threat of forever reverting to the interior Nash equilibrium if one country deviates from cooperation.[6] Since we want to analyze what would be best and could most credibly be achieved by such coordination, we consider trade policies that are subgame perfect.

Even in cooperation, free trade may not always be sustainable, because the long-run gains from cooperation may not exceed the short-run gains from deviation when the world price or trade volumes are very high or very low. To understand when countries could be susceptible to defecting from cooperation, we characterize their incentives to do so. The short-run gains of deviating from the cooperative trade policies $\{\tau_c, \tau_c^*\}$ are represented by $\Omega(s,\tau_c,\tau_c^*) \equiv W_D(s,\tau_c^*) - W(s,\tau_c,\tau_c^*)$ and $\Omega^*(s,\tau_c,\tau_c^*) \equiv W_D^*(s,\tau_c) - W^*(s,\tau_c,\tau_c^*)$, where $W_D(s,\tau_c^*) = \max_{\tau\leq 0} W(s,\tau,\tau_c^*)$ is the welfare in the case of deviation, that is, when the country's trade policy is given by its best-response correspondence (10).

Using the envelope theorem, we can characterize the behavior of the static gains from defection with respect to the state variables. With respect to the free-trade trade volume we have $\mathrm{d}\Omega(s,\tau_c,\tau_c^*)/\mathrm{d}V^f = -[\tau_R(s,\tau_c^*) - \tau_c]/2$ and $\mathrm{d}\Omega^*(s,\tau_c,\tau_c^*)/\mathrm{d}V^f = [\tau_R^*(s,\tau_c) - \tau_c^*]/2$. As in Bagwell and Staiger (1990), provided that the trade policy under deviation is farther from free trade than the cooperative policies (i.e., $\tau_R(s,\tau_c^*) < \tau_c$ and $\tau_R^*(s,\tau_c) > \tau_c^*$), the static gain from deviation increases with the trade volume, because the potential terms-of-trade gains are larger with a larger volume of trade.

[6] Reverting forever to the interior Nash equilibrium is not renegotiation proof. A renegotiation-proof agreement would have to include a return to cooperation after the punishment. This would make the analysis of the dynamic game more complex without affecting substantially the results. A renegotiation-proof agreement would imply less severe punishments following a deviation, and so could not sustain the same level of cooperation as sustained by the threat of forever reverting to the Nash.

For the behavior of the short-run gains from defection with respect to the free-trade world price we have $\mathrm{d}\Omega(s,\tau_c,\tau_c^*)/\mathrm{d}P^f = -K\left[\tau_R(s,\tau_c^*) - \tau_c\right]/2$ and $\mathrm{d}\Omega^*(s,\tau_c,\tau_c^*)/\mathrm{d}P^f = -K\left[\tau_R^*(s,\tau_c) - \tau_c^*\right]/2$. Provided that the trade policy under deviation is farther from free trade than the cooperative policies, the incentives to defect are asymmetrical. The exporting country has a greater incentive to defect when the world price is high, while the importing country has a greater incentive to defect when the world price is low.

Since we focus on subgame perfect trade policies, the cooperative trade policies are functions only of the payoff-relevant variables which are the current state variables, not past history: $\tau_c = \tau_c(s)$ and $\tau_c^* = \tau_c^*(s)$. Given that trade policies are functions only of the state variables, and state variables have no intrinsic dynamics (the state variables, ε and ε^*, are not serially correlated), beyond the current period we can define the expected future welfare gain from cooperation by $\omega(\tau_c(\cdot),\tau_c^*(\cdot)) \equiv \mathrm{E}_s[W(s,\tau_c(s),\tau_c^*(s)) - W(s,\tau_N(s),\tau_N^*(s))]$ and similarly for Foreign.

For each country, there is a trade-off between the short-run gains from deviation and the long-run losses from returning to the Nash equilibrium. To ensure that countries have no incentive to deviate, the following participation constraints have to be respected for all states s:

$$\Omega(s,\tau_c(s),\tau_c^*(s)) \leq \frac{\beta}{1-\beta}\omega(\tau_c(\cdot),\tau_c^*(\cdot)), \tag{16}$$

$$\Omega^*(s,\tau_c(s),\tau_c^*(s)) \leq \frac{\beta}{1-\beta}\omega^*(\tau_c(\cdot),\tau_c^*(\cdot)), \tag{17}$$

where $\beta \in [0,1)$ is the discount factor. These participation constraints convey each country's lack of commitment to respecting cooperative policies whatever the situation. Cooperation is possible as long as in any situation the cooperative policy is such that it satisfies these constraints. The equilibrium has to be self-enforcing.

The set of trade policies satisfying the participation constraints is not empty since Nash trade policies always satisfy them. We can show also that if the discount factor is sufficiently high, free trade is sustainable. Let us define $L(s,\beta) \equiv \Omega(s,0,0) - \omega(0,0)\beta/(1-\beta)$, the discounted future loss of Home from deviating from free trade. We have $L(s,0) > 0$ and $\lim_{\beta\to 1} L(s,\beta) = -\infty$, so by the continuity of $L(s,\beta)$ in β there exists $\overline{\beta} \in (0,1)$ such that $L(s,\beta) \leq 0$ if $\beta \geq \overline{\beta}$. The same applies to Foreign.

Corresponding to the participation constraint of Home, the threshold parameter is the discount factor such that $\Omega(\bar{s},0,0) - \omega(0,0)\beta/(1-\beta) = 0$, where $\bar{s}$ is the state of the world that maximizes $\Omega(s,0,0)$. Given that Ω increases with P^f and increases with V^f, $\bar{s}$ corresponds to a situation of high trade volume and high price. This is similar for the Foreign participation constraint, except that since Ω^* decreases with P^f, the threshold discount factor parameter will be determined by the maximum value of Ω^*, which will be a low price combined with a high trade volume. Except when the distributions of production shocks are symmetric, they are unlikely to be equal and the threshold parameter for both constraints is just the maximum over each one:

$$\overline{\beta} = \max\left[\frac{\Omega(\bar{s},0,0)}{\Omega(\bar{s},0,0)+\omega(0,0)}, \frac{\Omega^*(\bar{s}^*,0,0)}{\Omega^*(\bar{s}^*,0,0)+\omega^*(0,0)}\right]. \tag{18}$$

When the discount factor falls strictly below $\overline{\beta}$, free trade is not sustainable, but there is an infinity of trade policies that satisfy these constraints. We focus on the most cooperative subgame perfect Nash equilibrium, the trade policies that maximize intertemporal joint welfare while satisfying participation constraints. Another way to see this problem is to consider that it is the problem of a planner that tries to find the time-consistent trade policies that maximize joint welfare while satisfying the countries' participation constraints. This amounts to solving at each period t the following maximization problem:

$$\max_{\tau_t \leq 0, \tau_t^* \geq 0} W\left(s_t, \tau_t, \tau_t^*\right) + W^*\left(s_t, \tau_t, \tau_t^*\right) + \frac{\beta}{1-\beta} \mathrm{E}_s\left[W\left(s, \tau_c\left(s\right), \tau_c^*\left(s\right)\right) + W^*\left(s, \tau_c\left(s\right), \tau_c^*\left(s\right)\right)\right] \tag{19}$$

subject to the participation constraints, (16) and (17). Given that the problem has no intrinsic dynamics and that we are focusing on the subgame perfect equilibrium, all expectations terms are in fact constants which are functions of the optimal cooperative policies.

Constraining trade policies to be taxes, and associating positive Lagrange multipliers, μ_t and μ_t^*, to equations (16) and (17), the above problem gives the following first-order necessary conditions:

$$(1+\mu_t)\frac{\partial W\left(s_t, \tau_t, \tau_t^*\right)}{\partial \tau_t} + (1+\mu_t^*)\frac{\partial W^*\left(s_t, \tau_t, \tau_t^*\right)}{\partial \tau_t} - \mu_t^* \frac{\partial W_D^*\left(s_t, \tau_t\right)}{\partial \tau_t} \geq 0, \ = 0 \text{ if } \tau_t < 0, \tag{20}$$

$$(1+\mu_t^*)\frac{\partial W^*\left(s_t, \tau_t, \tau_t^*\right)}{\partial \tau_t^*} + (1+\mu_t)\frac{\partial W\left(s_t, \tau_t, \tau_t^*\right)}{\partial \tau_t^*} - \mu_t \frac{\partial W_D\left(s_t, \tau_t^*\right)}{\partial \tau_t^*} \leq 0, \ = 0 \text{ if } \tau_t^* > 0, \tag{21}$$

$$\Omega\left(s_t, \tau_t, \tau_t^*\right) - \frac{\beta}{1-\beta}\omega\left(\tau_c\left(\cdot\right), \tau_c^*\left(\cdot\right)\right) \leq 0, \ = 0 \text{ if } \mu_t > 0, \tag{22}$$

$$\Omega^*\left(s_t, \tau_t, \tau_t^*\right) - \frac{\beta}{1-\beta}\omega^*\left(\tau_c\left(\cdot\right), \tau_c^*\left(\cdot\right)\right) \leq 0, \ = 0 \text{ if } \mu_t^* > 0. \tag{23}$$

The first-order conditions characterize the trade policies τ_t and τ_t^* only as functions of the cooperative trade policy functions $\tau_c\left(\cdot\right)$ and $\tau_c^*\left(\cdot\right)$ which define the expected future welfare gains from cooperation in equations (22) and (23). The most cooperative subgame perfect trade policies are those that for every t satisfy the first-order conditions (20)–(23) and

$$\tau_t = \tau_c\left(s_t\right) \text{ and } \tau_t^* = \tau_c^*\left(s_t\right). \tag{24}$$

Equation (24) enforces rational expectations about future periods by ensuring that the applied trade policies derive from the same policy functions that will be applied subsequently.

When the discount factor falls below $\overline{\beta}$, given that Nash trade policies and best-response functions present several kinks, and that policies may occasionally be constrained to be taxes, a complete analytical characterization of the policies, including a proof of their existence, is out of reach.[7] Below, we provide an interpretation of these equations in various situations depending on which constraint is binding, and we rely later on numerical simulations to analyze the features of the cooperative solutions and how cooperation is affected by the distribution of the free-trade price, especially its skewness.

The first-order conditions can be interpreted as follows. μ and μ^* play the role of the relative weighting of countries in world welfare. It may change at each period depending on which participation constraint is binding. When one country's participation constraint is binding, its welfare weight becomes positive justifying its deviation from the first-best trade policy (i.e., from free trade).

[7]See Bagwell and Staiger (1990) for an analytical characterization of a similar but simpler problem.

No binding participation constraint With $\mu_t = \mu_t^* = 0$, equations (20) and (21) are identical to what they would be were the maximization not subject to the participation constraints, that is, to globally efficient trade policies. Equation (20) gives $\tau_t^* - \tau_t \leq 0, = 0$ if $\tau_t \leq 0$, which is only compatible with $\tau_t = \tau_t^* = 0$. Thus, when no participation constraint is binding, the cooperative policy is free trade. Note, however, that this is a consequence of restricting the analysis to tax policies. Without this restriction, the solution would be $\tau_t = \tau_t^*$, which is compatible with free trade and also with countercyclical trade policies that perfectly offset each other.

Binding participation constraints For a discount factor below $\overline{\beta}$, the efficient trade policy does not satisfy the participation constraints for every realization of ε and ε^*, so the cooperative trade policies must include some deviation from free trade. These deviations from free trade are governed in the first-order conditions by the Lagrange multipliers that play the role of state-contingent welfare weights: they ensure that trade policies always satisfy the participation constraints. There are three possible situations: participation constraint binding for Home, for Foreign, or for both countries. This contrasts with Bagwell and Staiger (1990) where the situation of both participation constraints being binding was the only possible one, because the only motivation for trade policies was the terms-of-trade gains which similarly affect the temptation to deviate in the two countries. In the present article, we also have the smoothing motivation which has asymmetric effects. The temptation to deviate will be higher for exporters in periods of high prices, and for importers in periods of low prices.

If both welfare weights are strictly positive, the terms $\partial W_D^*(s_t, \tau_t)/\partial \tau_t$ and $\partial W_D(s_t, \tau_t^*)/\partial \tau_t^*$ in equations (20) and (21) may matter. They account for the fact that when a country changes its trade policy, this changes its partner's incentives to deviate. This concern about the partner's incentive to deviate exists only if the partner's participation constraint is binding. If not, the country does not have to worry about its partner's incentive until it becomes binding. Given Nash behavior, we could expect in cooperation both participation constraints to be binding at the same time for intermediate free-trade price levels, and a sufficiently high free-trade trade volume. For a high (low) free-trade price, the deviation will come from the exporter (importer). For an intermediate price level, this is the terms-of-trade motivation that will compel both countries to deviate at the same time (as in Bagwell and Staiger, 1990).

4 Numerical simulations

We next analyze cooperative behavior using numerical simulations. We first illustrate the solution under a symmetric price distribution, then analyze a more realistic setting in which the price distribution is positively skewed, and show how this constrains the nature of the cooperative equilibrium.

Given the absence of endogenous state variables, it is easy to calculate a numerical solution to this problem. It is the solution to a set of complementarity equations defined over a grid of carefully chosen production shocks (through a Gaussian quadrature) which allows us to calculate the terms in expectations. The equations are the first-order conditions (20)–(23), and the equations ensuring that the same cooperative trade policies are applied in subsequent periods (i.e., expectations are rational), (24). See the supplementary appendix online for details of the numerical methods.

We focus our discussion of numerical results on the situation of pure aggregate risk, in which the smoothing motivation for trade intervention is dominant. Since in this case the free-trade price summarizes the state of the system, this facilitates the interpretation of results by allowing diagrammatic representations. In the alternative configuration of pure idiosyncratic risk, the results are very close to Bagwell and Staiger (1990), the only difference being that our static level of protection is less important because the smoothing objective goes against exploitation of terms-of-trade gains. In that case, trade policies are of equal intensity but with opposite signs. In a repeated game, for a sufficiently high discount factor, the threat of retaliations allows coordination over free trade. For a lower discount factor, deviations from free trade cannot be excluded. They occur at the same moment for both countries when free-trade volume is high, because a higher free-trade volume increases the potential terms-of-trade gains and the incentive to deviate.

The social welfare function includes a quadratic term that penalizes deviations of prices from their target. No ready source of information is available for calibrating the weight assigned to price stability. As explained above, the parameter characterizing the social preference for price stability, K, could be interpreted as a second-order approximation of the equivalent variation for a risk-averse consumer, reflecting income and risk-aversion effects. This interpretation is used to guide the choice of a relevant value. We assume $K = 0.3$, which could correspond to a 15% budget share, a relative risk aversion equal to 2, and a null income elasticity (see table 1 for all parameter values).

Table 1. Parameterization

Calibration target		Assigned value
Coefficient of variation of free-trade price		30%
Demand elasticity		-0.2
Steady-state demand $(D(\bar{P}))$		1
Steady-state price $(\bar{P})$		1
Trade volume $\left(V^f\right)$		0.2
Parameter	**Economic interpretation**	**Assigned value**
a	Intercept of demand function	1.2
b	Slope of demand function	0.2
K	Preference for price stability	0.3
ε	Distribution of Home supply shock	Four-parameter beta distribution with second shape parameter equal to 3, first shape parameter varying from 3 to 30, and location parameters adjusted to maintain constant the mean and variance.
ε^*	Distribution of Foreign supply shock	$\varepsilon^* = \varepsilon - 0.4$

The other parameters are chosen such that at steady state in both countries demand is equal to 1 and trade to 0.2. The steady-state price is taken to be 1 and demand elasticity -0.2. In what follows, the results will differ in the assumed distributions for production shocks. Production shocks are assumed to be either symmetric or skewed. Since we focus on a situation of aggregate risk where V^f is constant, ε^* can be defined from ε and is equal to $\varepsilon - 0.4$. For the distribution of ε, we need a distribution supported on a bounded interval, with skewness as well as mean and variance that can be parameterized easily. The beta distribution satisfies these constraints and is also a popular distribution for yield shocks (Babcock and Hennessy, 1996, Claassen and Just, 2011), thus, ε is assumed to follow a beta distribution. The distribution is translated and rescaled so that ε has a mean of 1.2 and a standard deviation of 0.06. The supply shocks map into a price distribution through the definition of free-trade price in equation (5), in such a way that the variance of the free-trade price is equal to the variance of the aggregate supply shock divided by $(2b)^2$, and the skewness of the free-trade price is equal to the opposite of the skewness of the aggregate supply shock divided by $2b$. With these parameters and production shocks distribution, the coefficient of variation of the free-trade price is equal to 30%. For the symmetric case, the beta distribution has shape parameters 3 and 3. For the asymmetric cases, the second parameter is maintained at 3, while the first is adjusted to change the skewness of the aggregate supply shock and of the free-trade price (the location and scale parameters are also adjusted to maintain the mean and standard deviation constant).

4.1 Cooperation under a symmetric price distribution

This example illustrates the extent of trade policy coordination when the free-trade price distribution is symmetric around the steady-state price. Figure 2 depicts the cooperative and non-cooperative trade policies as functions of the free-trade price for various discount factors. To put the results into perspective in relation to the assumed distribution, the top x-axis displays the cumulative distribution of the free-trade price. The positive values of trade policies represent the policy of the importing country, while the negative values represent the policy of the exporting country. When a trade policy is zero, it confounds with the zero axis and is not plotted. At a distance of the steady-state price ($\bar{P}$), the non-cooperative Nash policies (dot-dash curves) are constrained by their restriction to being taxes. For high world prices, the importing country would want to apply an import subsidy. When this constraint binds, the import tariff is zero, and the slope of the exporting country trade policy decreases with respect to the world price because it does not need to react so strongly to the world price since its policy is no longer offset by its partner. This change in slope when only one country is using its trade policy also occurs in repeated games. A key parameter characterizing the shape of the Nash trade policies is K (see equations (12) and (13)). For a lower K, the slopes with respect to the world price decrease, and the trade policies become flatter, which leads to a larger overlap of the exporting and importing country trade policies. At the extreme of $K = 0$, without smoothing motivation, trade policies would not vary with P^f and would be constant. This behavior is illustrated in a sensitivity analysis in the supplementary appendix.

When the game is repeated, policies that are more cooperative are sustainable, although it is not possible always to exclude deviations from free trade for high and low free-trade prices. Cooperative policies (solid lines in figure 2) for various discount factors display three possible regimes. (i) For a sufficiently high discount factor, $\beta \geq \bar{\beta} = 0.80$, free trade can be sustained by the threat of retaliation whatever the level of free-trade prices. (ii) For a lower value of the discount factor (in this example for $\beta = 0.5$, 0.6, and 0.7), participation constraints start to bind for low and high world prices. However, they are not binding at the same time; each country is allowed to deviate from free trade at different moments. The exporter deviates when the world price is high by taxing exports, and the importer deviates when the world price is low by taxing imports. Outside the regions where participation constraints are binding, the cooperative trade policy is free trade. These trade policies affect the distribution of world price with respect to free trade. The world price will be identical to the free-trade price when this latter is close to the steady state. When it is far from the steady state, and the incentives to deviate from free trade are too high to make it sustainable in cooperation, the world price will be above (below) the free-trade price if the free-trade price is above (below) its steady state. Cooperation reduces the volatility of world price but mainly close to the steady state, and less so for low and high world prices. For example, for $\beta = 0.7$, free trade is sustainable for 84% of the distribution of shocks but for supply shocks leading to the 8% lowest and highest free-trade prices, the cooperative policy entails some deviation from free trade. (iii)

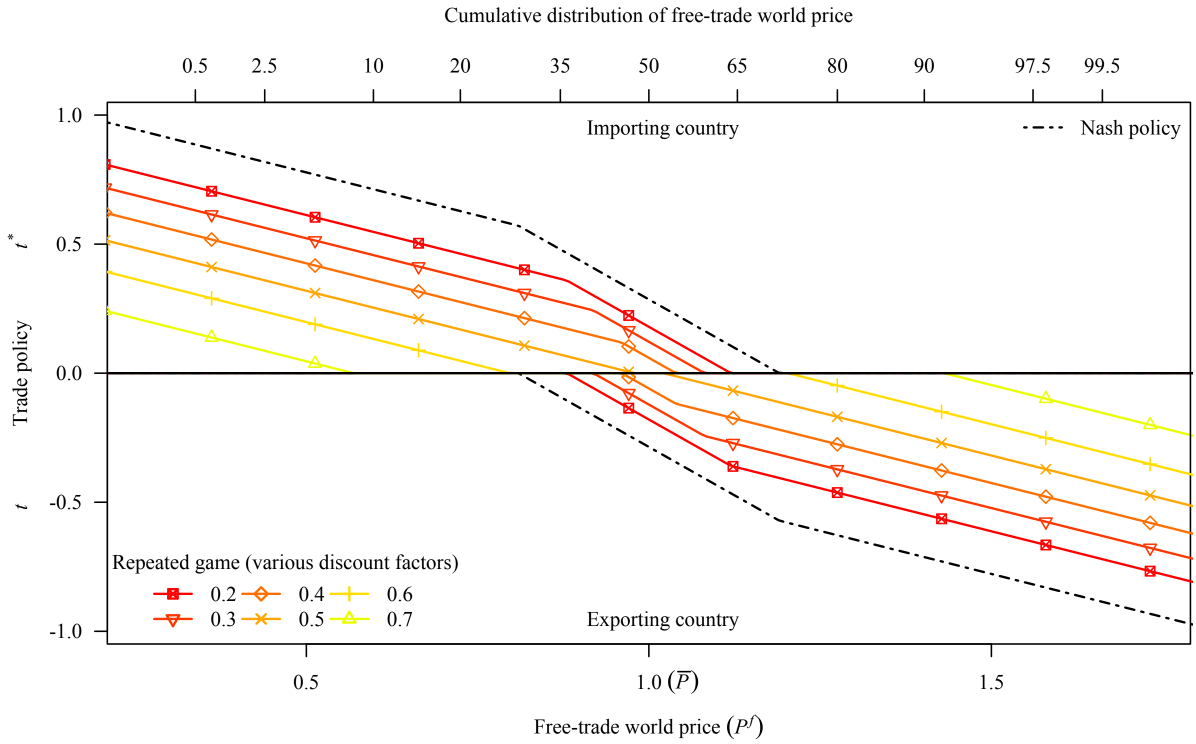

Figure 2. Cooperative and non-cooperative trade policies under a symmetric price distribution

For lower values of the discount factor (in figure 2 for $\beta \leq 0.4$), participation constraints bind more often, and can be binding at the same time for the two countries. This situation is qualitatively closer to the Nash situation than the other two. Trade policies are less interventionist than in Nash, but one of the countries is always applying a policy, making free trade unsustainable for such low discount factors. Note that the discount factor should be interpreted not as a market discount factor but as the policy-makers' discount factor for whom the future may not extend much farther than the next election.

4.2 Cooperation under a positively skewed price distribution

Some of the previous results are a consequence of the symmetry of the problem. Beyond the perfect symmetry of the countries, what seems crucial is the symmetry of the price distribution, which itself is an outcome of many assumptions. In reality, commodity prices are positively skewed (Deaton and Laroque, 1992), a feature often explained by the effect of competitive storage, which would have been too challenging to integrate in a repeated-game approach. Price skewness can also be explained in other ways. For example, a convex demand function could create skewness in the price distribution. This is precisely the effect of storage, which convexifies demand by adding to final demand, demand for stocks at low prices (Wright and Williams, 1982). Positive price skewness could also arise from a negatively skewed yield, which we assume here for convenience since it does not require any changes to the model.

We want to show that the skewness of the price distribution is crucial because it affects the distribution of welfare between the two countries, and consequently, what can be expected from cooperation ensured by the threat of retaliation. In particular, we show that if the distribution of the free-trade price is positively skewed, it is more difficult to make the exporting country cooperate, and export taxes are more often retained than import tariffs in a cooperative equilibrium.

To analyze this we introduce an asymmetry by assuming that yields are negatively skewed. This does not involve any changes to the equations. They hold equally for symmetric and asymmetric shocks. We focus on negatively skewed yields because they imply positively skewed prices, as observed in the price data. However, given that all equations are symmetric for the importing and the exporting countries about the steady-state price, the results with positively skewed yields are symmetric to the results with negatively skewed yields. To generate negatively skewed yields, ε is assumed below to follow a beta distribution with the first shape parameter varying from 3 to 30, and the second parameter equal to 3, which results in a skewness of the free-trade price varying from 0 to 0.95, a value comparable to that observed for staple food markets (Deaton and Laroque, 1992).

Let us first illustrate how cooperative and non-cooperative trade policies are affected by a positively skewed price distribution. This is reported in figure 3 for a free-trade price skewness equal to 0.95. Since upward price spikes are more common than downward price spikes, we more often observe large trade policy interventions from the exporter compared to the importer. However, much of the price distribution is concentrated in prices below the target price, so the importing country will be using its trade policy more often. In this example, we observe that for $\beta = 0.8$, the importing country cooperative policy is free trade for all possible free-trade world prices, while the exporting country retains the right to use export taxes when prices spike.

To show that under a positively skewed price distribution export restrictions are more difficult to discipline than tariffs, we examine the relationship with respect to price skewness of the threshold discount factor and of the magnitude of trade policies for the lowest and highest percentiles. The threshold discount factor above which free trade can be sustained in cooperation is defined (equation (18)) as the maximum between the discount factor that makes the participation constraint of the exporting country hold with an equality at the highest price, and the discount factor that makes the participation constraint of the importing country hold with an equality at the lowest price. For a symmetric price distribution, these two parameters are identical but if the distribution becomes positively skewed, they will start to differ (figure 4). The threshold discount factor corresponding to the exporting country increases with price skewness as the maximum price gets further away from the target price. The threshold discount factor corresponding to the importing country decreases with price skewness as the minimum price gets closer to the target. This behavior holds if, instead of using the discount factor sustaining free trade in all states, we use the discount factor sustaining free trade in all states except the 1% lowest and highest prices. So, in this setting where production shocks are governed by a beta distribution, increasing skewness while keeping the first two moments constant makes free trade more difficult to sustain in cooperation, because of the asymmetry in the short-run incentives for the exporter and the importer to deviate.

However, the sustainability of free trade is a very stringent criterion to apply to analyze cooperation. Figure 5 depicts how the intensity of the trade policies evolves with price skewness for the 1%, 5% and 10% highest and lowest free-trade prices. We can see from figure 5 that even if the discount factor is increased there exists a percentile of free-trade prices (high prices for Home and low prices for Foreign) above which the export tax, in absolute value, is above the import tax. This may not hold for the percentiles in the middle of the distribution but these are the lowest and highest prices for which the incentives to deviate from cooperation are highest. In the example for $\beta = 0.6$ and the 10% lowest and highest prices, the import taxes are higher than the export taxes for any level of skewness above 0, while for lower β or less frequent prices, the export taxes become higher than the import tariffs when skewness

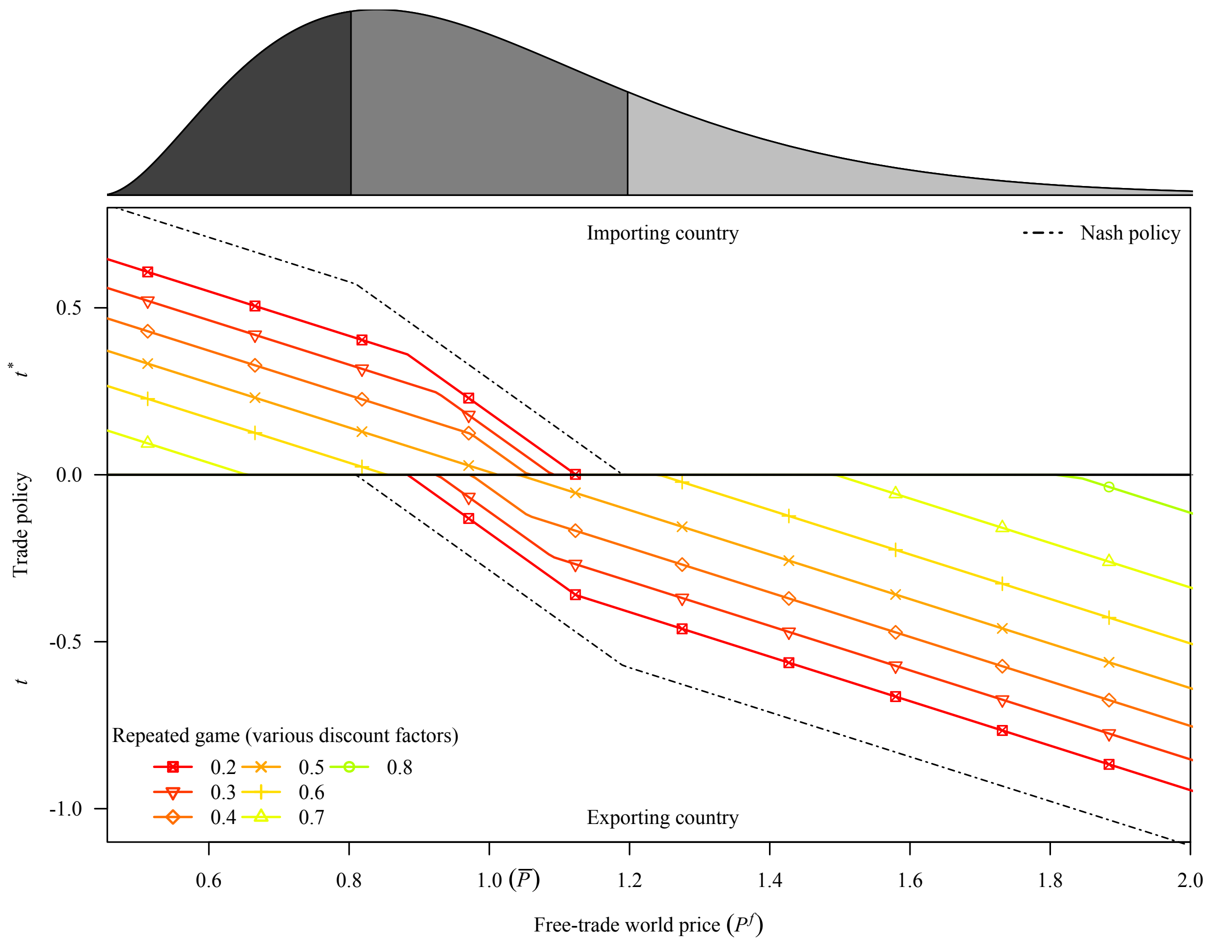

Figure 3. Trade policies under a positively skewed price distribution
Note: Density of free-trade world price above the plot, with a distinction between the regions where, in the Nash, only the importing country intervenes, where countries both intervene, and where only the exporting country intervenes.

increases.

Overall these numerical simulations show that the exporting country is more reluctant than the importing country to cooperate given that the occasional price spikes make it more compelling for it to maintain some trade policy. So the exporting country will be the last to accept free trade. Even if we discount free trade, the exporting country in cooperation retains the right to use higher trade policies than the importing country.

5 Conclusion

Considering that governments care about domestic food price volatility and use trade policy instruments to stabilize their food markets, this article analyzes the extent of international trade policy cooperation that is enforced by the threat of a return to the static interior Nash equilibrium. The analysis in this article differs from the related literature (Bagwell and Staiger, 1990, 2003) by considering that governments adjust trade policy in order to manipulate their terms of trade and also to stabilize their domestic food prices. It stresses the important distinctions between aggregate and idiosyncratic supply shocks for trade

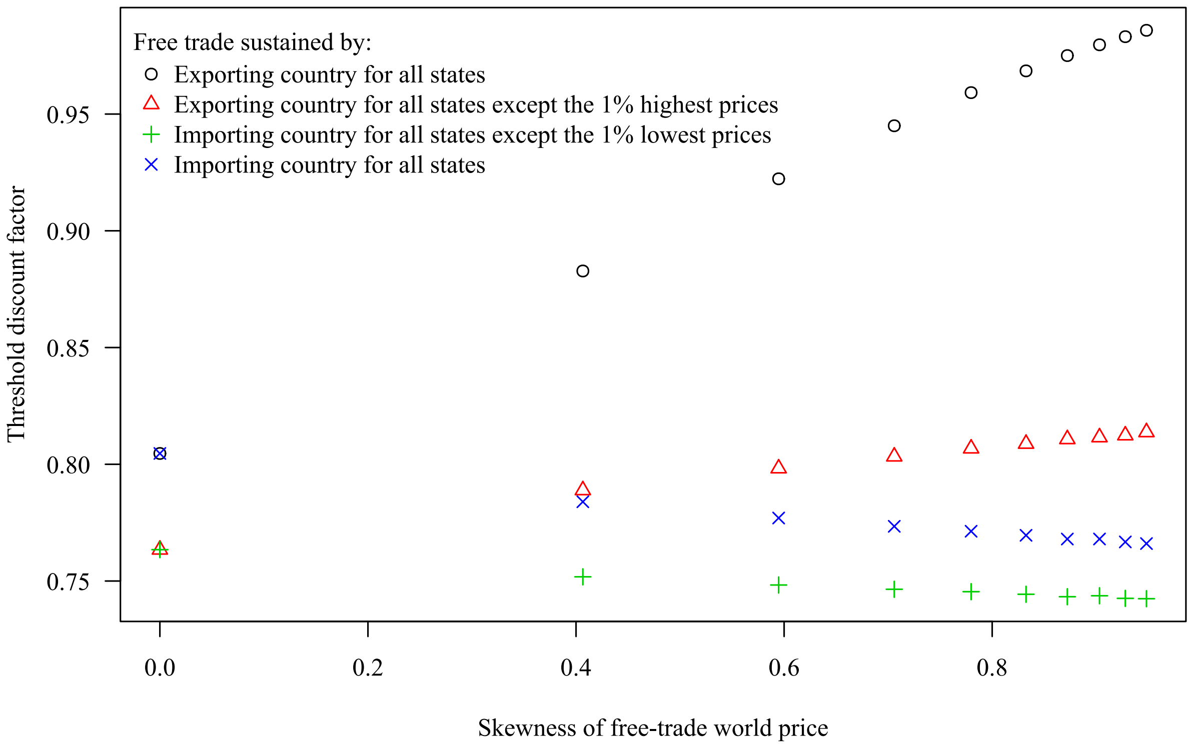

Figure 4. Threshold discount factors sustaining free trade for various levels of price skewness
Note: Price skewness is adjusted by increasing the first shape parameter in the beta distribution of ε by increment of 3.

policy interventions. The terms-of-trade motivation is related only to idiosyncratic shocks (i.e., shocks to free-trade trade volumes) and does not lead to any trade policy adjustments in the case of aggregate shocks (i.e., shocks to the free-trade world price), which are an important driver of actual trade policy adjustments for food products (Anderson and Nelgen, 2012). On the contrary, the smoothing motivation is related only to aggregate shocks and would not hinder risk sharing of idiosyncratic supply shocks.

This work demonstrates a standard feature of self-enforcing trade agreements: the need for active trade policies in periods of severe shocks to maintain the incentives to cooperate in every state of nature. While repeated interactions allow countries to coordinate over cooperative trade policies, periods of unusually high trade volumes, or very low or very high prices, are periods of deviation from free trade. So even in a cooperative agreement, it may not be possible to alleviate completely countercyclical trade policies. These deviations from first best differ from the literature in that, because of the smoothing motivation deviations are asymmetric: exporters deviate when the world price is high, and importers deviate when the world price is low. This implies that even in cooperation, exporters may be able to shift the burden of adjustment to high prices to importers, and conversely importers may limit the impact of low prices on their economy by applying tariffs.

Export restrictions and their role in recent food price spikes have been the object of much attention in policy discussions. To prevent future price spikes, many authors advocate the adoption of WTO disciplines on export restrictions which currently are very weakly regulated. In this article, we made no formal distinction between export restrictions and tariffs. The former are the policy used by exporters to protect themselves from international scarcity, and the latter are the policy used by importers but both

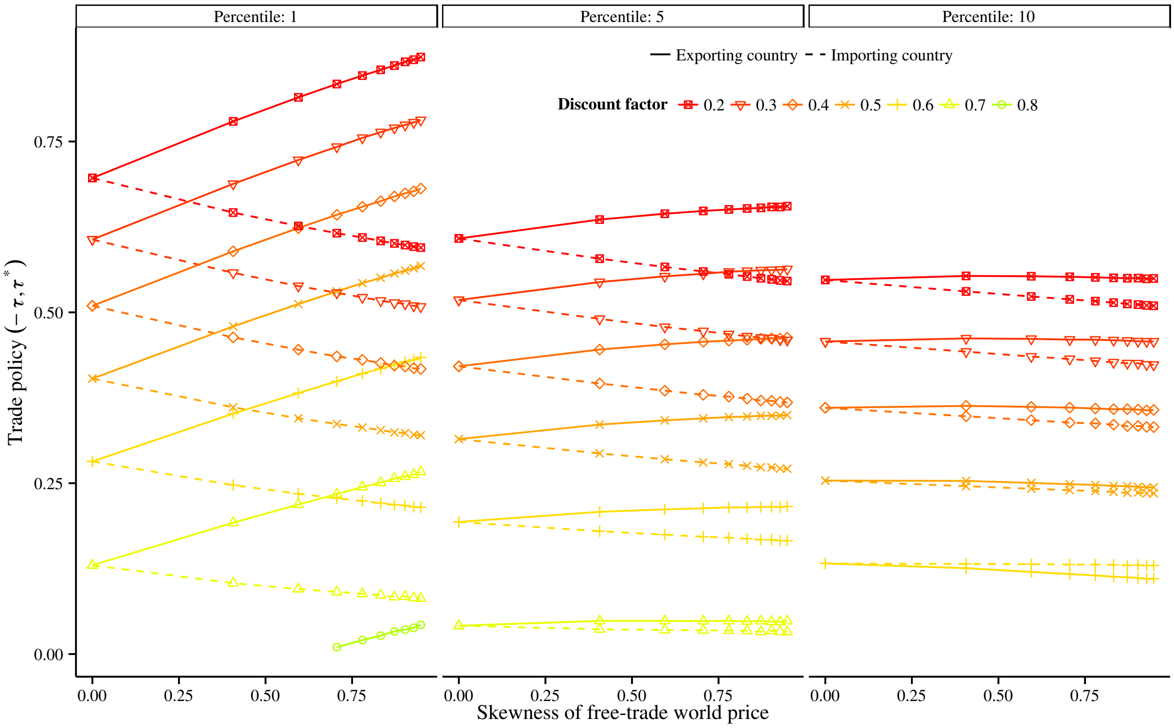

Figure 5. Cooperative trade policies for various levels of price skewness
Note: Each panel corresponds to the trade policies applied for the 1%, 5% and 10% highest (lowest) free-trade prices by the exporting (importing) country.

contribute to shifting volatility to partners' markets. The contribution of this article is to show that, despite this apparent symmetry between trade policy instruments, export restrictions under repeated interactions may be more difficult to avoid than tariffs because of asymmetry in the price distribution. Commodity prices are positively skewed, and prices are concentrated below the mean but with occasional spikes. This matters a lot in self-enforcing agreements because it means that the exporter will have a bigger incentive than the importer to deviate from free trade.

Thus, we have shown that export restrictions are more difficult to discipline in trade agreements than tariffs, and the reluctance of food exporting countries to open negotiations on this issue may be a sign of their inability to commit to not using export restrictions given the incentives they are offered during food price spikes. This does not mean that cooperation that would significantly reduce export taxes cannot be sustained. Given that WTO negotiations operate under the principle of a "Single undertaking" – an approach that precludes separate agreements on some of the negotiation items – other areas of negotiation could bring sufficient incentives for the exporters to cooperate.[8] However, the fact that exporting countries have refused to include the topic in the Doha agenda shows that the stakes related to this issue are very high, and progress on this front is unlikely considering the stalemate at the Doha Round negotiations.

The theory developed in this article opens opportunities for some empirical investigations, for example, related to the value of K, the parameter characterizing the preference for price stability. K is calibrated

[8]The notion of single undertaking is reminiscent of the pooling of incentives allowed to colluding firms by multimarket contact. Bernheim and Whinston (1990) show that as long as there is sufficient heterogeneity across the distinct contact markets (heterogeneity of discount factor, marginal costs, fixed costs, ...), the possibility of transferring the slack in the incentives constraints in one market to another market facilitates collusion.

applying the theory proposed in Turnovsky et al. (1980) but could also be estimated, given that along with the slope of the demand function it is a key parameter characterizing the extent of transmission of world to domestic prices which is a frequently investigated topic. Another prediction of our theory is that the skewness of the price distribution should be different between exporting and importing country. Exporting countries are able to protect themselves from high world prices which will tend to decrease the skewness of their domestic prices; while the converse applies to importing countries which are able to protect themselves from low prices, increasing the skewness of their domestic prices. This difference in price distribution could be the foundation for empirical tests.[9]

[9] See Pieters and Swinnen (2014) for other empirical applications of a closely related model.

Online appendix

A Computational details

This section gathers all the equations that define the cooperative policies and describes how the model is solved numerically. Since all the variables on the interior Nash equilibrium are characterized analytically by equations (1), (6)–(7), and (12)–(14), this appendix focuses on the dynamic game. The problem is implemented numerically in GAMS version 24.5.4 and solved on a PC running Windows 7 (64 bit) using the mixed complementarity solver `PATH` (Dirkse and Ferris, 1995), with a precision of 10^{-7}.[10] Since the model has no intrinsic dynamics, there is no need to consider several periods. However, the model has to be solved over various supply shocks to allow for the calculation of expectations. The shocks on which the model is solved are chosen through 55-node Gaussian quadratures,[11] which define sets of pairs $\{(\varepsilon_i, \varepsilon_i^*), w_i\}$ in which $(\varepsilon_i, \varepsilon_i^*)$ represents a possible realization of shocks and w_i the associated probability. In the following, except for the time index which is substituted by i or j, the mathematical notations mostly follow the article. i and j index possible shocks realizations. The superscript D is used to designate situations of deviation from the cooperative policies.

The expected welfare under Nash ($\mathrm{E}W_N$ and $\mathrm{E}W_N^*$) is calculated by replacing the expectations operators by sums using the Gaussian quadrature and using the analytical expressions of welfare, (6) and (7), and Nash trade policies, (12) and (13). Other variables solve the following set of complementarity equations, in which for compactness some functions are introduced and defined later:[12]

$$P_i^f : P_i^f = \frac{a}{b} - \frac{\varepsilon_i + \varepsilon_i^*}{2b}, \tag{A1}$$

$$V_i^f : V_i^f = \frac{\varepsilon_i - \varepsilon_i^*}{2}, \tag{A2}$$

$$P_i^w : P_i^w = P_i^f - \frac{\tau_i + \tau_i^*}{2}, \tag{A3}$$

$$P_i : P_i = P_i^w + \tau_i, \tag{A4}$$

$$P_i^* : P_i^* = P_i^w + \tau_i^*, \tag{A5}$$

$$W_i : W_i = \int_{P_i}^{a/b} D(p)\,\mathrm{d}p + P_i\varepsilon_i - \tau_i\left[\varepsilon_i - D(P_i)\right] - K\frac{\left(P_i - \bar{P}\right)^2}{2}, \tag{A6}$$

$$W_i^* : W_i^* = \int_{P_i^*}^{a/b} D^*(p)\,\mathrm{d}p + P_i^*\varepsilon_i^* - \tau_i^*\left[\varepsilon_i^* - D^*(P_i^*)\right] - K\frac{\left(P_i^* - \bar{P}\right)^2}{2}, \tag{A7}$$

$$\tau_i : \tau_i \le 0 \perp (1+\mu_i)\frac{\partial W(s_i,\tau_i,\tau_i^*)}{\partial \tau_i} + (1+\mu_i^*)\frac{\partial W^*(s_i,\tau_i,\tau_i^*)}{\partial \tau_i} \ge \mu_i^*\frac{\partial W_D^*(s_i,\tau_i)}{\partial \tau_i}, \tag{A8}$$

$$\tau_i^* : \tau_i^* \ge 0 \perp (1+\mu_i^*)\frac{\partial W^*(s_i,\tau_i,\tau_i^*)}{\partial \tau_i^*} + (1+\mu_i)\frac{\partial W(s_i,\tau_i,\tau_i^*)}{\partial \tau_i^*} \le \mu_i\frac{\partial W_D(s_i,\tau_i^*)}{\partial \tau_i^*}, \tag{A9}$$

$$\mu_i : \mu_i \ge 0 \perp W_i + \frac{\beta}{1-\beta}\sum_j w_j W_j \ge W_i^D + \frac{\beta}{1-\beta}\mathrm{E}W_N, \tag{A10}$$

[10] Programs are available as online appendix.

[11] Gaussian quadrature are generated using the functions available in the MATLAB toolbox `CompEcon` (Miranda and Fackler, 2002).

[12] Complementarity conditions in what follows are written using the "perp" notation ($\perp$). This means that both inequalities must hold, and at least one must hold with equality.

$$\mu_i^* : \mu_i^* \geq 0 \perp W_i^* + \frac{\beta}{1-\beta} \sum_j w_j W_j^* \geq W_i^{*D} + \frac{\beta}{1-\beta} \mathrm{E} W_N^*, \tag{A11}$$

$$W_i^D : W_i^D = \int_{P_i^D}^{a/b} D(p) \,\mathrm{d}p + P_i^D \varepsilon_i - \tau_i^D \left[\varepsilon_i - D\left(P_i^D\right)\right] - K \frac{\left(P_i^D - \bar{P}\right)^2}{2}, \tag{A12}$$

$$W_i^{*D} : W_i^{*D} = \int_{P_i^{*D}}^{a/b} D^*(p) \,\mathrm{d}p + P_i^{*D} \varepsilon_i^* - \tau_i^{*D} \left[\varepsilon_i^* - D^*\left(P_i^{*D}\right)\right] - K \frac{\left(P_i^{*D} - \bar{P}\right)^2}{2}, \tag{A13}$$

$$\tau_i^D : \tau_i^D \leq 0 \perp \tau_i^D \leq 2 \frac{K\left(\bar{P} - P_i^f\right) - V_i^f}{K + 3b} + \frac{K+b}{K+3b} \tau_i^*, \tag{A14}$$

$$\tau_i^{*D} : \tau_i^{*D} \geq 0 \perp \tau_i^{*D} \geq 2 \frac{K\left(\bar{P} - P_i^f\right) + V_i^f}{K + 3b} + \frac{K+b}{K+3b} \tau_i, \tag{A15}$$

$$P_i^D : P_i^D = P_i^{wD} + \tau_i^D, \tag{A16}$$

$$P_i^{*D} : P_i^{*D} = P_i^{w*D} + \tau_i^{*D}, \tag{A17}$$

$$P_i^{wD} : P_i^{wD} = P_i^f - \frac{\tau_i^D + \tau_i^*}{2}, \tag{A18}$$

$$P_i^{w*D} : P_i^{w*D} = P_i^f - \frac{\tau_i + \tau_i^{*D}}{2}. \tag{A19}$$

From equations (6) and (7), we have

$$\frac{\partial W\left(s_i, \tau_i, \tau_i^*\right)}{\partial \tau_i} = \frac{-K\left(P_i - \bar{P}\right) - b\left(P_i - P_i^w\right) - \varepsilon_i + D\left(P_i\right)}{2}, \tag{A20}$$

$$\frac{\partial W^*\left(s_i, \tau_i, \tau_i^*\right)}{\partial \tau_i} = \frac{K\left(P_i^* - \bar{P}\right) + b\left(P_i^* - P_i^w\right) - \varepsilon_i^* + D^*\left(P_i^*\right)}{2}, \tag{A21}$$

$$\frac{\partial W\left(s_i, \tau_i, \tau_i^*\right)}{\partial \tau_i^*} = \frac{K\left(P_i - \bar{P}\right) + b\left(P_i - P_i^w\right) - \varepsilon_i + D\left(P_i\right)}{2}, \tag{A22}$$

$$\frac{\partial W^*\left(s_i, \tau_i, \tau_i^*\right)}{\partial \tau_i^*} = \frac{-K\left(P_i^* - \bar{P}\right) - b\left(P_i^* - P_i^w\right) - \varepsilon_i^* + D^*\left(P_i^*\right)}{2}. \tag{A23}$$

Using the envelope theorem

$$\frac{\partial W_D^*\left(s_i, \tau_i\right)}{\partial \tau_i} = \frac{\partial W^*\left(s_i, \tau_i, \tau_R^*\left(s_i, \tau_i\right)\right)}{\partial \tau_i}, \tag{A24}$$

$$= \frac{K\left(P_i^{*D} - \bar{P}\right) + b\left(P_i^{*D} - P_i^{w*D}\right) - \varepsilon_i^* + D^*\left(P_i^{*D}\right)}{2}, \tag{A25}$$

and similarly

$$\frac{\partial W_D\left(s_i, \tau_i^*\right)}{\partial \tau_i^*} = \frac{K\left(P_i^D - \bar{P}\right) + b\left(P_i^D - P_i^{wD}\right) - \varepsilon_i + D\left(P_i^D\right)}{2}. \tag{A26}$$

The expectations of welfare under cooperation should be consistent with the cooperative trade policies actually chosen. This is ensured numerically by equations (A10) and (A11), where the expressions $\sum_j w_j W_j$ and $\sum_j w_j W_j^*$ represent the welfare expectations discretized by the Gaussian quadrature. So in the solution process the expectations change endogenously with the cooperative trade policies.

B Sensitivity analysis

The parameter characterizing the preference for price stability, K, has important implications for the quantitative analysis. It governs the importance of the smoothing motivation for trade policies and so how much the policies react to movements in world price. In the article, it is calibrated at $K = 0.3$ by assuming a 15% budget share, a relative risk aversion equal to 2, and a null income elasticity and applying a formula from Turnovsky et al. (1980). Here we analyze the sensitivity of the results to two different values of K: 0.15 and 0.6, i.e., halving and doubling the risk aversion.

Figures A1 and A2 correspond to figure 2 and present the trade policies under a symmetric price distribution for the two different values of K. Figures A3 and A4 correspond to figure 3 and present the trade policies under a positively skewed price distribution.

According to equations (12) and (13), decreasing K has two effects on Nash trade policies: it decreases the slope of trade policies with respect to the world price, and increases the slope of trade policies with respect to trade volume (the intercept at $\bar{P}$ in the figures). So it makes the trade policies flatter. If there is no concern over price volatility, at the extreme of $K = 0$, policies would be constant and equal in Nash in absolute value to $V^f/(2b) = 0.5$. Because trade policies are flatter with a lower K, the region where the trade policies of the exporting and importing countries overlap is larger. In figure A3 for example, the exporting country applies export taxes in almost all of the price distribution. Given that the cooperative policies qualitatively follow the behavior of Nash policies, the effects on them of K are the same.

In contrast, for a high K as in figures A2 and A4, the slope of trade policies is higher; the smoothing motivation becomes dominant, and the region where both countries apply trade policies is very limited. This region is symmetric about $\bar{P}$. When K increases, this region decreases and at the limit would collapse

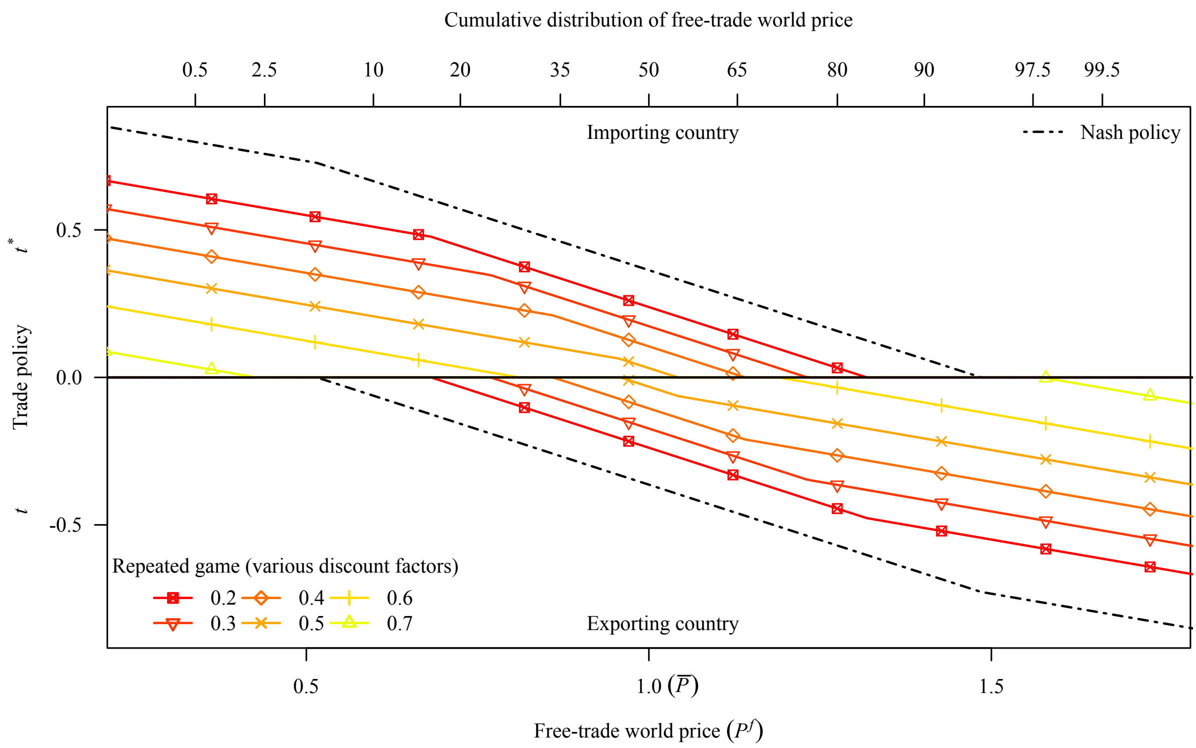

Figure A1. Cooperative and non-cooperative trade policies under a symmetric price distribution if $K = 0.15$

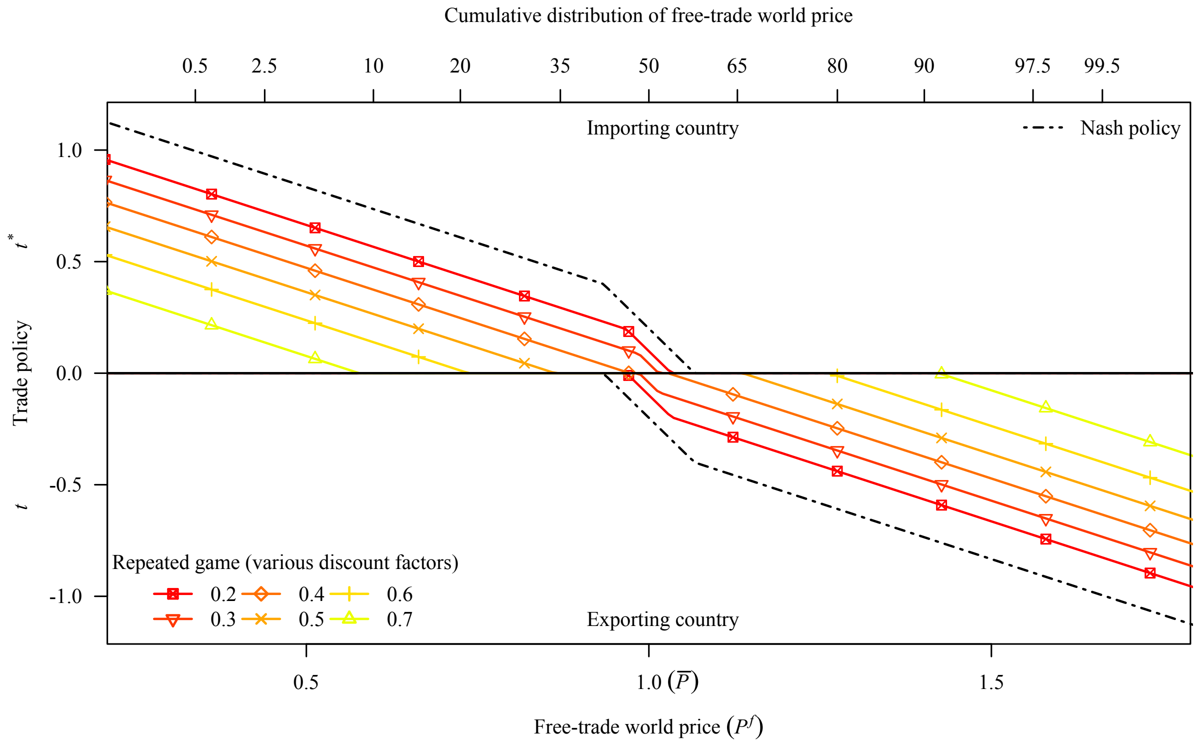

Figure A2. Cooperative and non-cooperative trade policies under a symmetric price distribution if $K = 0.6$

to just one point: $\bar{P}$. Since it increases the welfare cost of deviating from the target price, increasing K has important effects on the reaction of the exporting country policy to high prices when prices have an asymmetric distribution.

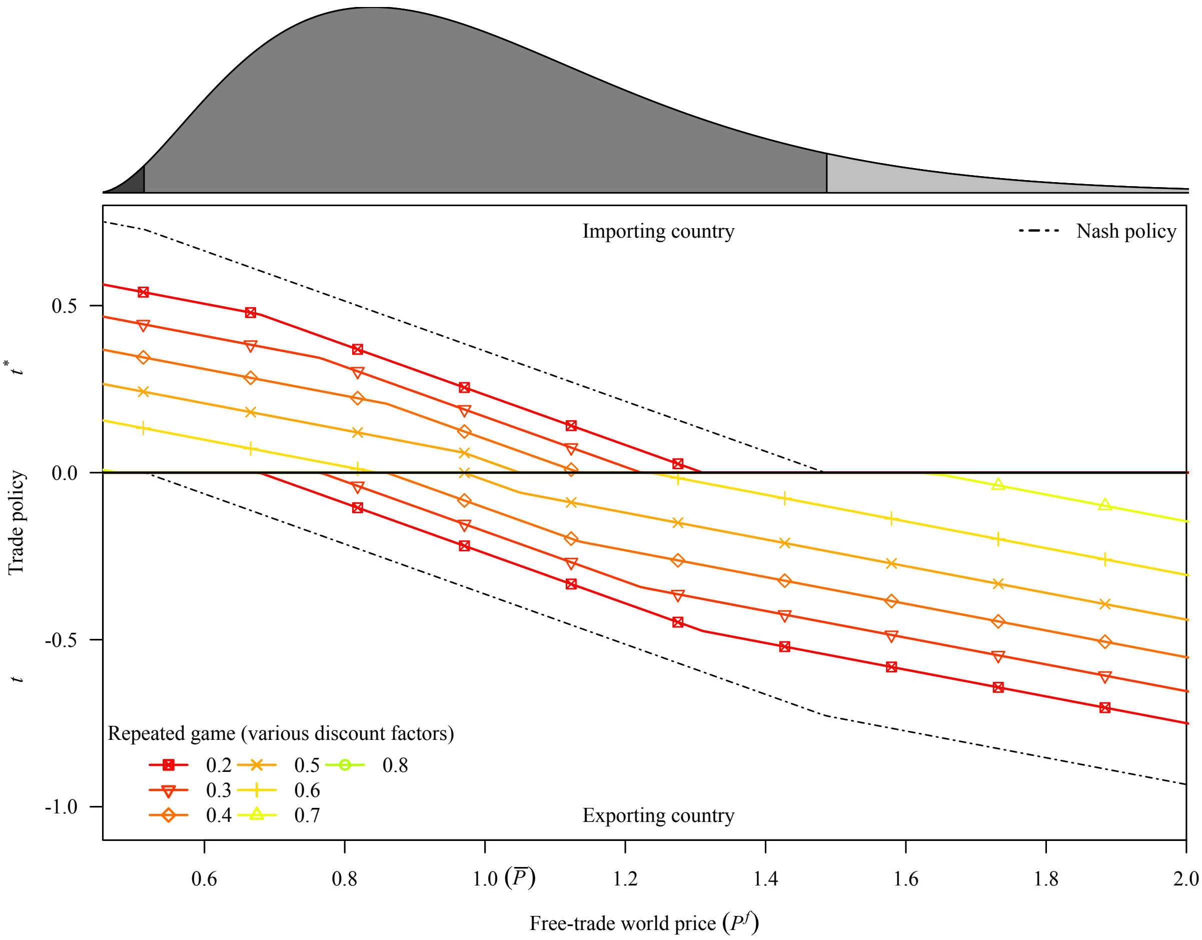

Figure A3. Trade policies under a positively skewed price distribution if $K = 0.15$
Note: Density of free-trade world price above the plot, with a distinction between the regions where, in the Nash, only the importing country intervenes, where countries both intervene, and where only the exporting country intervenes.

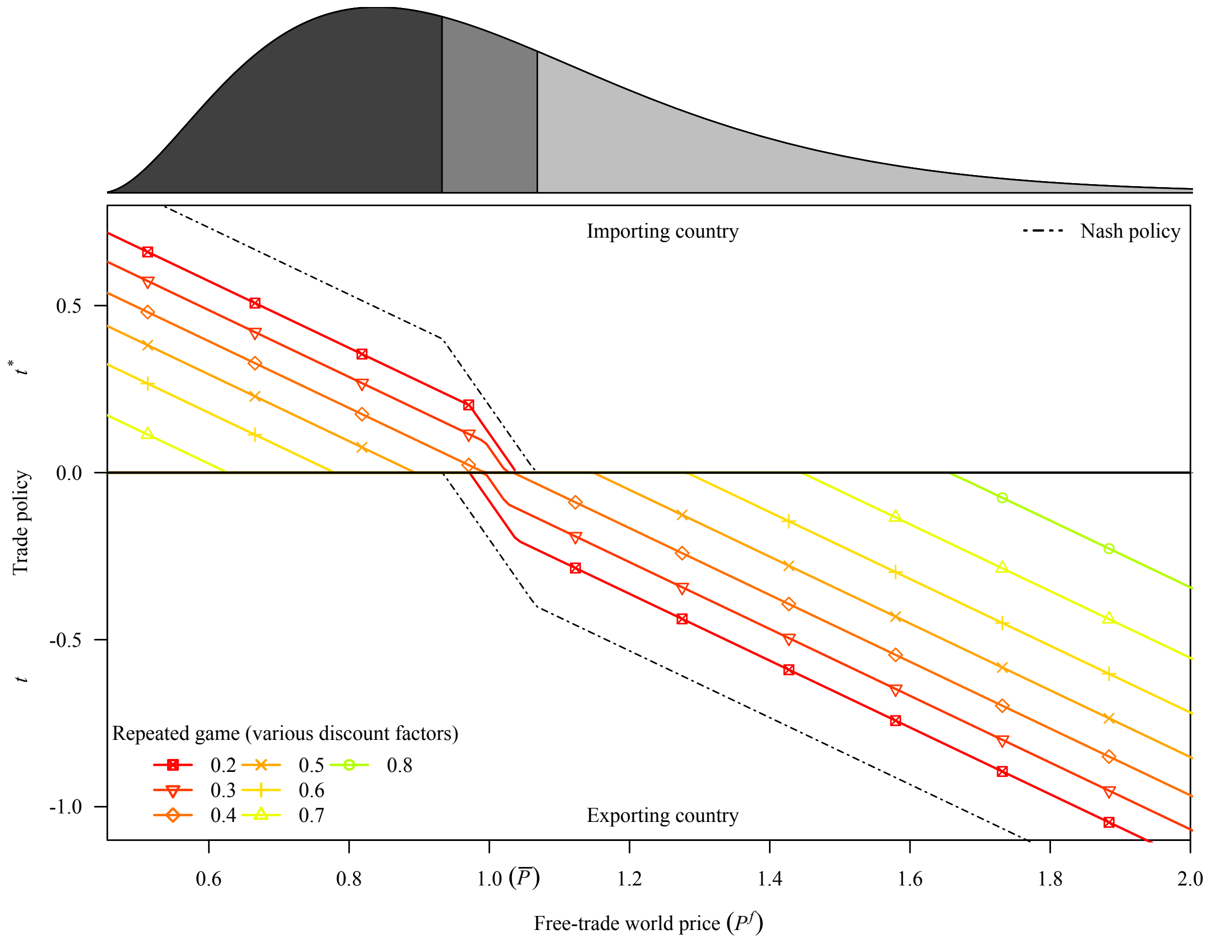

Figure A4. Trade policies under a positively skewed price distribution if $K = 0.6$
Note: Density of free-trade world price above the plot, with a distinction between the regions where, in the Nash, only the importing country intervenes, where countries both intervene, and where only the exporting country intervenes.

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