Introduction

The Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organization, implemented as a part of the Uruguay Round, sets guidelines regarding the rights of governments to protect against environmental and health risks associated with imported goods (Sumner and Tangermann 2002). Implementation of the SPS Agreement was initiated due to a perception that trade was being disrupted by a large number of technical restrictions and that as tariffs and other trade barriers were reduced, new and more stringent SPS barriers would be implemented as substitute forms of protection (Roberts 2000). Although it prohibits the use of trade instruments as disguised barriers to trade, the SPS Agreement permits importing countries to target SPS trade policies according to commodity and country of origin (Josling et al. 2004).

The ability to implement trade policy which discriminates among commodities and trading partners, combined with the high degree of uncertainty associated with SPS risk, often makes SPS trade policy the subject of controversy. The uncertainty associated with SPS risks is viewed by some as a justification for more stringent trade policy which errs on the side of caution. Alternatively, this uncertainty may facilitate the use of SPS trade barriers for protectionist purposes; the perception that SPS trade barriers are used as protectionist barriers to trade is widespread within the trade policy literature (see Josling et al. 2004 and Victor 2000 for discussions).

This paper presents a theoretical model of the enforcement of an SPS standard – border inspections for invasive non-indigenous species (NIS) – in the presence of both risk-reducing and protectionist motivations. In addition to the use of border inspections to address NIS risk, the model incorporates two motivations for protectionist trade
barriers typically advanced in the trade theory literature: political economy and terms of trade. While the theoretical results concerning the impact of political economy and terms of trade on the formation of tariffs are well known, results concerning border inspections have not been fully developed.

The paper proceeds as follows. The following section presents a brief review of the literature which addresses optimal trade policy and NIS. The theoretical model is presented next. A politically weighted government welfare function is specified followed by specification of equilibrium price and material balance conditions. The equilibrium conditions determine the response of domestic and world prices to inspection intensity. The final section presents comparative static results for three cases: a small country with no political economy, a small country with a politically influential domestic production sector, and a large country with no political economy. The final section provides concluding remarks.

Previous Literature

Previous theoretical work examining preemptive NIS trade policy has considered Pigouvian tariffs, border inspections, and fines. Since damages due to NIS are tied to trade volumes, an import tariff is an efficient means of correcting for the NIS externalities. McAusland and Costello (2004) demonstrate that, in the absence of political economy and terms of trade motivations, the optimal import tariff is always positive in the presence of NIS risk. They further show that there are cases where it is optimal to forego border inspections altogether and simply charge an appropriate tariff rate. Since contaminated shipments are destroyed in the McAusland and Costello (2004) model, inspection intensity may be decreasing in the infection rate at high infection rates.
– if the product is likely contaminated it is optimal to reduce inspection effort and simply charge the appropriate tariff rate.

Margolis, Shogren, and Fischer (2005) adapt the Grossman and Helpman (1994) political economy model of tariff formation to the prevention of NIS introductions; the marginal damages due to an invasive NIS are incorporated into the politically optimal tariff rate. Although the optimal tariff rate derived by Margolis, Shogren, and Fischer incorporates NIS risk, import tariffs set as a function of NIS risk are not observed empirically. As trade negotiations reduce tariff rates the use of less transparent trade barriers are expected to increase.

In a political economy model of border inspections and fines (where contaminated shipments are treated and the infection rate is endogenous), Margolis and Shogren (2007) demonstrate that an increase in inspection stringency due to a reduction in tariff rates may result in a level of effective protection which is greater than the level of protection initially provided by the tariff. The intuition is that tariffs are a more efficient tool for reallocating economic rents according to the political preferences of the government. If the use of a tariff is restricted and the government substitutes with inspection policy the politically optimal level of the effective trade barrier may increase.

US Border Inspections for Non-indigenous Species

In the US, inspection of non-propagative agricultural commodities is performed by Customs and Border Protection (CBP) while inspection of propagative agricultural commodities is performed by the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture. All shipments of agricultural commodities are subject to inspection – up to 2% of the total volume of imports arriving in the US are
sampled for inspection (NRC 2002; Work et al. 2005). APHIS maintains a list of ‘actionable’ pests which are not currently established in the US but if allowed to establish would cause significant harm to domestic agro-ecosystems or natural ecosystems. Large numbers of actionable pests are intercepted: Between 1984 and 2001, APHIS intercepted approximately 42,000 actionable pests per year (McCullough et al. 2006).

If a pest is detected and identified as potentially harmful the contaminated shipment is determined to be ‘actionable’ and is denied entry until further action is taken by the exporter. The exporter may choose to destroy the shipment, re-export the shipment to an alternative destination, or have the shipment treated according to an approved treatment schedule (treatment is typically fumigation by methyl bromide).

The decision to treat, re-export, or destroy contaminated shipments which are detected is at the discretion of the exporter and depends on the condition and type of product, the value of the product, and the availability of an appropriate treatment technology. In the absence of an appropriate treatment technology, goods which are highly perishable or are of low value are more likely to be destroyed. Alternatively, assuming treatment is not an option, goods which may be transported at low cost or are less perishable are more likely to be re-exported to an alternative destination.

In the US, the majority of contaminated shipments of agricultural commodities are treated rather than destroyed or re-exported. As shown in Table 1, approximately three in four actionable shipments of fruits and vegetables, cut flowers, and propagative material have been treated in recent years. If not treated, fruit and vegetable shipments are more likely to be re-exported than destroyed and cut flowers and propagative material are more likely to be destroyed rather than re-exported.
The Model

Consider trade between two countries, Home and Foreign, where Home is a net importer and Foreign is an exporter of a good which is potentially contaminated with damaging NIS. Domestic demand for the good is denoted $D(p)$ where $p$ represents the domestic price of the good. The domestic supply of the good is denoted $y(p)$ and Foreign supply is denoted $x(p_w)$ where $p_w$ denotes the world price. Net imports of the good are written as $m(p) = D(p) - y(p) > 0$.

Damages due to invasive NIS are assumed a linear function of the number of invasive pests admitted into Home. Damages may include reduced agricultural productivity or damage to ecosystems.\(^1\) The per unit damage term is denoted $\delta > 0$ and the number of pests admitted into Home is denoted $N$. In the absence of inspections, the number of admitted pests is equal to the volume of exports from Foreign, $x(p_w)$, multiplied by the exogenous infection rate, denoted $q$.\(^2\) Therefore, if all pests are admitted into Home the number of admitted pests is $N = x(p_w)q$ and total damages are $\delta x(p_w)q$.

Home has two policy instruments at its disposal, a predetermined specific tariff denoted $\tau$ and inspection intensity denoted $I$. The tariff is a markup over the world price charged on the quantity of imports received for consumption in Home. We assume throughout the paper that the tariff rate is set prior to the determination of inspection

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\(^1\) In Paarlberg and Lee (1998) and Wilson and Anton (2005), damage due to the introduction of FMD occurs as a result of reduced productivity in the domestic livestock sector. Damages therefore enter into the supply function of the domestic production sector.

\(^2\) This assumption may be relaxed. In an extension of their base model, McAusland and Costello (2004) allow for an endogenous infection rate. In their model Foreign possesses a pre-export cleaning technology which is a function of the infection rate. Foreign chooses the optimal infection rate in order to maximize domestic profits. Cases where Home moves first and Foreign moves first are considered.
intensity. Inspection of potentially contaminated goods is conducted at the border. Inspections are costly and imperfect. Total inspection costs are \( klx(p_w) \) where \( k \) represents per-unit cost of inspection intensity. The detection rate is determined by the technology \( r(I) \), where \( r \) is increasing and concave in inspection intensity and \( 0 \leq r(I) < 1 \).

When actionable pests are discovered, the exporter has the option of treating, re-exporting, or destroying the shipment. These mitigation activities prevent the detected contaminated goods from entering Home. The number of damaging pests entering home is proportional to the portion of contaminated goods which go undetected \( N = x(p_w)q[1 - r(I)] \). Total damage due to admitted pests is equal to \( \delta x(p_w)q[1 - r(I)] \).

**Government Welfare Function**

The government welfare function consists of domestic consumer surplus, domestic producer surplus, tariff revenue, the cost of border inspections, and damages due to admitted NIS. Consumer and producer surplus are written as \( \int \sum D(p)dp \) and \( \int \sum y(p)dp \) respectively. The model incorporates political economy motivations through an exogenous weight on domestic producer surplus \( \lambda \geq 1 \). This represents the weight the government places on domestic producer surplus relative to other components of the social welfare function. The objective of the government is to maximize the following weighted social welfare function:
where equilibrium price and material balance conditions close the model.

Disposition of detected contaminated exports is at the discretion of the exporter. Three dispositions are available to the exporter: (1) treatment, (2) re-export, and (3) destroy. Shipments for which a treatment technology is available and affordable are treated. Shipments of high value commodities which cannot be treated but which are suitable for transport to another destination are re-exported (may be non-perishable commodities or commodities which are perishable and in good condition). Shipments which cannot be treated and are of lower value or are perishable are destroyed.

In the remainder of the paper we focus on treatment of contaminated shipments which is the most common disposition of agricultural commodities in the US. The disposition of contaminated shipments determines the response of domestic and world prices to changes in inspection intensity. Since the optimal choice of inspection intensity depends on these price responses, we derive them in detail in the next section.

**Equilibrium Price and Material Balance Conditions**

The material balance and price arbitrage conditions are derived as follows. All exports which are either uncontaminated or contaminated and undetected are admitted into Home. Contaminated and detected exports are treated and admitted into Home.³

The material balance condition can therefore be written as:

\begin{equation}
W = \int_{p}^{\infty} D(p) dp + \int_{0}^{\infty} y(p) dp + \bar{m}(p) - kI(p_w) - \delta x(p_w) q\left[1 - r(I)\right]
\end{equation}

³ We assume that there is no ‘shrinkage’ in quantity due to the treatment procedure. We also assume that treatment eliminates all targeted pests.
The price arbitrage condition is derived as follows. If the exporter does not sell to Home it receives the world price on the full quantity of exports. If the exporter sells to Home, it receives the domestic price minus the tariff on the exports which are admitted into Home without treatment and receives the domestic price minus the tariff and the per-unit fumigation cost (denoted $f$) on the exports treated and admitted into Home.\(^4\) The arbitrage condition is written as

\[
p_w x(p_w) = (p - \bar{t}) x(p_w) [1 - qr(I)] + (p - \bar{t} - f) x(p_w) qr(I)
\]

Simplifying and rearranging, the equilibrium price condition is written as follows

(3) \[ p = p_w + \bar{t} + fqr(I). \]

The equilibrium price and material balance conditions hold simultaneously and determine the response of the domestic and world price to a change in inspection intensity. Price responses expressed in elasticity form are:

(4) \[ \frac{dp}{dl} = \frac{qr f x p}{\varepsilon M p_w + \varepsilon X p} \geq 0 \]

(5) \[ \frac{dp_w}{dl} = \frac{-qr f x p_w}{\varepsilon M p_w + \varepsilon X p} \leq 0 \]

where $\varepsilon_X = \frac{\partial X}{\partial p_w} p_w \geq 0$ is the export supply elasticity and $\varepsilon_M = \frac{\partial M}{\partial p} m \geq 0$ is the import demand elasticity.\(^5\)

The impact of inspection intensity on the domestic and world prices is qualitatively similar to the standard results concerning tariff rates: domestic price is increasing in inspection intensity and world price is non-increasing in inspection intensity.

\(^4\) Assume that the fumigation sector is perfectly competitive.

\(^5\) Derivation of these price responses, as well as the response of prices to tariffs and the infection rate, are presented in Appendix A.
intensity. The rate of change of the domestic and world prices depend on the cost of fumigation, the infection rate, and the marginal productivity of inspection intensity as well as elasticities of import demand and export supply. If Home is a small country the world price is unresponsive to inspection intensity and the full marginal cost of treating contaminated exports is passed through in the domestic price, \( \frac{dp}{dl} = qr^*f \).

**Choice of Inspection Intensity**

The first order condition from the maximization of equation (1) yields a solution for the governments’ choice of inspection intensity which is implicitly given by

\[
\frac{dW}{dl} = -x(k - \delta qr^*) + \frac{dp}{dl}[(\lambda - 1)y - m] + \frac{\partial m}{\partial p} \frac{dp}{dl} I - \frac{\partial x}{\partial p_w} \frac{dp_w}{dl} [kI + \delta q(1 - r)] = 0.
\]

Equation (6) is comprised of four terms: (1) the direct marginal benefits and costs of inspections intensity independent of price effects; (2) the political economy component associated with a change in domestic price; (3) the tariff revenue component associated with a change in domestic price and import volumes; (4) the inspection cost and anticipated NIS damage component associated with a change in world price and export volumes.

The first term captures the direct marginal effects of a change in inspection intensity, comprised of marginal inspection costs, \( xk \), and marginal benefits due to avoided NIS damages, \( x\delta qr^* \). This term captures the trade-offs involved in border inspections independent of price responses.

The second term in equation (6) captures the impact of a change in the domestic price on consumer and producer surplus; an increase in domestic price benefits producers and hurts consumers. The overall impact, from the governments perspective, depends on
the size of the import penetration ratio weighted by the political influence of the domestic production sector, \[ (\lambda - 1) \frac{\gamma}{m} - 1 \]. If the weighted import penetration ratio is greater than one, then an increase in domestic price increases government welfare. Alternatively, an import penetration ratio less than one implies that an increase in the domestic price reduces government welfare.

The third term in equation (6) represents the impact of a change in the domestic price, and therefore imports, on the tariff revenue collected by the government. If the domestic price increases in response to an increase in inspection intensity this reduces the domestic demand for the imports. A reduction in the demand for imports reduces the tariff revenue collected by the government and is therefore costly to the government.

Note that if the government is indifferent between consumer and producer surplus \( \lambda = 1 \) then the import penetration ratio from the second term is irrelevant and an increase in the domestic price reduces government welfare due to the combined effect of terms two and three, \[ -m + \frac{\partial m}{\partial p} I \frac{dp}{dl} < 0. \] The more elastic the import demand the greater the distortion required to raise an additional dollar of tariff revenue.

The final term in equation (6) captures the impact of a change in the world price, and as a consequence a change in exports, on the inspection costs and NIS damage incurred as a result of trade with Foreign. If the world price decreases, causing exports to decrease, then total inspection costs and anticipated NIS damages fall. The standard

\[ \text{Seasonality of agricultural production implies that the import penetration ratio will change through the course of a year. The effect of changes in the domestic price will therefore depend on the season of import. For example, imports of some agricultural commodities peak in winter months implying that optimal inspection intensity (through its impact on domestic price) will be lower in the winter months. Of course, other variables, such as the infection rate } q \text{ and damages } \delta \text{ are also influenced by season of production and import.} \]
result from the optimal tariff literature is that an increase in the tariff imposed by a large country pushes down the world price – an improvement in the terms of trade of the large country. If contaminated goods are treated the story from the optimal tariff literature carries over. A comparative static analysis is presented next.

**Comparative Static Analysis**

The comparative static analysis will consider three cases: (1) a small country and no domestic sector; (2) a small country with a politically influential domestic production sector; (3) a large country and no domestic production sector. The first case allows a comparison with the McAusland and Costello (2004) model which assumed contaminated shipments are destroyed. The impact of a politically influential domestic production sector on the governments’ choice of inspection intensity is evaluated in the second case. Finally, the third case relaxes the small country assumption and allows world price to respond to inspection intensity.

**Small country, no domestic production sector:**

In the absence of terms of trade and political economy motivations the governments’ choice of inspection intensity is derived as follows. Substitute equations (4) and (5) into equation (6), simplify, and evaluate at $\varepsilon \to \infty$ and $\lambda = 1$ to derive an implicit expression for the choice of inspection intensity:

$$ (k + qr' (f - \delta)) = -\frac{qr' f}{p} e_m \left[ T - kl - \delta q(1-r) \right] $$

The left hand side of equation (7) represents the direct marginal cost of inspections, $k$, the direct marginal benefit of avoided NIS damage, $-qr' \delta$, and the marginal increase in

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7 Iso-elastic import demand and export supply functions are assumed throughout the comparative static analysis.
domestic price, $qr'f$. The right hand side captures the impact tariff revenue net of inspection costs and NIS damages associated with imports, $\varepsilon_m\varepsilon_x m \left[ T - kI - \delta q (1 - r) \right]$.

First, consider the impact of the predetermined tariff rate on the governments’ choice of inspection intensity. US import tariffs on fruits and vegetables vary across commodities as well as within commodities across seasons. Regional and preferential trade agreements with specific trading partners also generate variability in tariff rates within commodities.\(^8\) Finally, within commodity and country of origin there may be variation in tariff rates over time as tariff rates are negotiated through trade agreements.

The impact of the tariff rate on inspection intensity is written as follows:

\[
\frac{dI}{dt} = \frac{qr'f \varepsilon_m m}{\varepsilon \varepsilon_x^2 \varepsilon_x (p^2)} \left\{ (p - r) + kI + \delta q (1 - r) \right\} \leq 0
\]

**PROPOSITION 1.** If Home is a small country ($\varepsilon_x \to \infty$) and there is no domestic production sector ($y = 0$) then commodities which are subject to higher tariff rates are subject to lower inspection intensity.

This result demonstrates that, independent of terms of trade and political economy motivations, the governments’ optimal choice of inspection intensity is decreasing in the tariff rate. The intuition is as follows. All else equal, an increase in the tariff reduces the volume of imports; this reduces consumer surplus net of tariff revenue, reduces the cost of inspections, and reduces NIS damages. Since domestic price is increasing in inspection intensity, a decrease in inspection intensity (in response to an increase in the tariff rate) increases the volume of imports. This generates increased consumer surplus.

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\(^8\) Consider grape imports as an example. From the United States Harmonized Tariff Schedule (HTS) the tariff on grapes is zero from April 1 to June 30, $1.80/m^3$ from July 1 to February 14, and $1.13/m^3$ from February 15 to March 31. Due to preferential trade agreements, grapes from Mexico and Chile enter with no tariffs at any time of the year.
net of tariff revenue. The increase in the tariff reduced the potential NIS damages and so inspection intensity falls.

APHIS and CBP are responsible for preventing harmful NIS from establishing in the US. Detection priorities vary by commodity and country of origin in response to variation in infection rates and per-unit damages (Work, et al. 2005; McCullough, et al. 2006). A conclusion of the McAusland and Costello (2004) model is that optimal inspection intensity is single-peaked in the infection rate – inspection intensity is increasing in the infection rate at low infection rates and decreasing in the infection rate at high infection rates. The intuition is that at very high infection rates we know that the good is likely contaminated and it is therefore optimal to forgo inspections and simply charge the appropriate tariff rate.

We can evaluate the response of inspection intensity to a change in the infection rate as follows

\[
\frac{dI}{dq} = -\frac{m}{\frac{dM}{dq}} \left\{ \frac{qr \cdot \varepsilon_M f}{p} \left[ f r (T - k I) + (p - f qr) \delta (1-r) \right] + \frac{p k}{q} \right\} \geq 0
\]

**Proposition 2.** If Home is a small country \((\varepsilon_* \to \infty)\), there is no domestic production sector \((y = 0)\), and the tariff is set to at least recover inspection costs, \(t \geq k l\), then it is optimal to inspect commodities that are more likely contaminated with damaging NIS more intensively.

Therefore, if Home is a small country, there is no domestic production sector, and the tariff is set to at least recover inspection costs \((t > k l)\), then optimal inspection intensity is greater for commodities with higher anticipated infection rates. This result confirms the point made by McAusland and Costello (2004) that if a backstop cleaning
technology is available, then inspection intensity is strictly increasing in the infection rate.\textsuperscript{9}

Total anticipated damages are also comprised of the anticipated damages due to the establishment of a pest. These may vary according to commodity and trading partner. The response of inspection intensity to the per-unit damage term, $\delta$, is

$$
\frac{dI}{d\delta} = -qr' \frac{fm}{d\delta \Delta} \left\{ \frac{p}{f} + \varepsilon q (1-r) \right\} \geq 0
$$

\textbf{PROPOSITION 3.} If Home is a small country $(\varepsilon \to \infty)$ and there is no domestic production sector $(\gamma = 0)$, then it is optimal to inspect commodities which harbor highly damaging (anticipated) NIS more intensively.

This result is consistent with expectations. The per-unit damage term does not enter directly into the equilibrium price or material balance conditions. As a result, damages always reduce government welfare and, all else equal, an increase in inspection intensity mitigates these damages.

\textit{Small country, politically influential domestic production sector:}

Next, consider the case where Home is a small country and the domestic production sector is politically influential. Substitute equations (4) and (5) into equation (6), simplify, and evaluate at $\varepsilon \to \infty$ to derive an implicit expression for the choice of inspection intensity in the presence of political economy motives:

$$
\left( k + qr'(f-\delta) \right) = qr' f \left\{ \lambda - 1 \right\} \frac{\varepsilon M}{p} \left[ T - kl - \delta q (1-r) \right]
$$

The left hand side of equation (11) represents the direct marginal cost of inspections, $k$, the direct marginal benefit of avoided NIS damage, $-qr' \delta$, and the marginal increase in

\textsuperscript{9} See footnote 12 in McAusland and Costello (2004).
domestic price, \( qr' f \). The right hand side captures the political economy term, \((\lambda - 1) y\) and the impact tariff revenue net of inspection costs and NIS damages associated with imports, \( \varepsilon_M \varepsilon_y m \left[ T - kl - \delta q (1 - r) \right] \).

First, we consider the impact of the political strength of the domestic production sector on the governments’ choice of inspection intensity. The response of inspection intensity to the weight on domestic producer surplus is as follows

\[
\frac{dI}{d\lambda} = -qr' f y \varepsilon_M m \geq 0
\]

**Proposition 4.** It is optimal to inspect commodities in domestic sector which are more politically influential more intensively.

The inspection intensity is non-decreasing in the weight the government places on domestic producer surplus. Since the domestic price is increasing in inspection intensity, the greater the weight on domestic producer surplus, the greater the incentive to increase inspection intensity.

Next, we consider the impact of the predetermined tariff rate on the governments’ choice of inspection intensity. In the presence of political economy motives, the impact of the tariff rate on inspection intensity is written as

\[
\frac{dI}{dT} = -qr' f y \varepsilon_M m \left[ (p - T) + kl + \delta q (1 - r) \right]
\]

where \( \varepsilon_y = \frac{\partial y}{\partial p} \geq 0 \) is the domestic supply elasticity.

**Proposition 5.** If Home is a small country \((\varepsilon_y \rightarrow \infty)\) and the domestic production sector is politically influential \((\lambda > 1)\) then it is optimal to inspect commodities more or less intensively the higher the tariff rate.
The impact of the tariff rate on inspection intensity is ambiguous. The presence of a politically influential domestic production sector introduces the possibility that inspection intensity may decrease as tariff rates decrease due to, for example, entering into a trade agreement. A reduction in the tariff rate reduces the size of the domestic sector relative to the volume of imports. As the relative importance of the domestic production sector decreases the incentive to increase the domestic price falls. Since the domestic price is increasing in inspection intensity, the incentive to increase inspection intensity in response to a decrease in the tariff rate is reduced in the presence of a domestic production sector.

In this model, the incentive for disguised protection (protection of the domestic production sector for political reasons) is actually reduced as tariff rates fall. This contradicts the common perception that governments will use SPS tariff barriers as substitute forms of protection. Holding all else constant, an increase in inspection intensity in response to a decrease in the tariff rate is more likely the less important the domestic production sector.

As shown in the previous section, in the absence of political economy and terms of trade motivations, the governments’ choice of inspection intensity is strictly increasing in the infection rate so long as inspection costs are covered by the tariff. When we allow for a politically influential domestic sector, the response of inspection intensity to the infection rate is as follows

\[ \frac{dI}{dq} = - \frac{qr^{\prime} f^2 r}{\frac{\sigma^2 w}{\sigma^2 r}} p^2 \left\{ p(\lambda - 1) y (\varepsilon_r + \varepsilon_M) + \frac{\varepsilon_M}{f r} \left[ fr (r - kr) + (p - fqr) \delta (1 - r) \right] + \frac{pk}{q} \right\} \geq 0 \]
PROPOSITION 6. If Home is a small country \((\epsilon_X \rightarrow \infty)\), the domestic production sector is politically influential \((\lambda > 1)\), and the tariff is set to at least recover inspection costs, \(\bar{T} \geq kI\), then it is optimal to inspect commodities that are more likely contaminated with damaging NIS more intensively.

Once again, if the tariff is set at a rate which at least covers inspection costs, inspection intensity is increasing in the infection rate. In the political economy case, the incentive to inspect commodities which are more likely to harbor damaging NIS is greater in sectors with greater political influence. An increase in the infection rate increases the domestic price which increases the importance of the domestic production sector relative to imports. This increases the governments’ incentive to increase domestic price through an increase in inspection intensity.

Next, we evaluate the impact of the anticipated damages due to established NIS on the governments’ choice of inspection intensity. The response of inspection intensity to the per-unit damage term, \(\delta\), is derived as follows

\[
\frac{dI}{d\delta} = -qr' fm \left( \frac{p}{f} + \epsilon_m q (1-r) \right) \geq 0
\]

PROPOSITION 7. If Home is a small country \((\epsilon_X \rightarrow \infty)\) and the domestic production sector is politically influential \((\lambda > 1)\), then it is optimal to inspect commodities which harbor highly damaging (anticipated) NIS more intensively.

This result is equivalent to Proposition 3. The per-unit damage term does not impact the domestic price and as a result there is no incentive to increase inspection intensity in order to increase the domestic price paid to the domestic production sector.

**Large country, no domestic production sector:**

The case of a large country with no domestic production sector is considered next. Since agricultural commodities such as fruits, vegetables, and cut flowers are perishable
they are traded regionally. This implies that the actions of a large country such as the US may influence the price of commodities traded regionally. As demonstrated above, if contaminated shipments are treated and Home has market power in the world market of a certain commodity, then an increase in inspection intensity will decrease the world price. This improves Homes terms of trade and may provide an incentive to inspect those commodities more intensively.

Substitute equations (4) and (5) into equation (6), simplify, and evaluate at \( \varepsilon_x < \infty \) and \( \lambda = 1 \) to derive an implicit expression for the choice of inspection intensity in the presence of a terms of trade motivation:

\[
(16) \quad \left( k + qr'(f - \delta) \right) = \frac{qr'f}{\varepsilon_x p + \varepsilon_M p_W} \left\{ \varepsilon_M p_W - \varepsilon_x [\overline{T} - kl - \delta q(1-r)] \right\}
\]

As in the cases above, the left hand side of equation (16) represents the direct marginal cost of inspections, \( k \), the direct marginal benefit of avoided NIS damage, \( -qr'\delta \), and the marginal increase in domestic price, \( qr'f \). In this case the right hand side captures the terms of trade effect, \( \varepsilon_M p_W \) and the impact tariff revenue net of inspection costs and NIS damages associated with imports, \( \varepsilon_M \varepsilon_x [\overline{T} - kl - \delta q(1-r)] \).

If Home is a large country, the impact of the tariff rate on inspection intensity is written as

\[
(17) \quad \frac{dI}{dT} = \frac{q^r f \varepsilon_M \varepsilon_x m}{\varepsilon_W p_W D^3} \left\{ \left( \varepsilon_x^2 p - \varepsilon_M^2 p_W \right) \left[ \left( p - \overline{T} \right) + kI + \delta q(1-r) \right] + p_W A \right\}
\]

where \( D = \varepsilon_x p + \varepsilon_M p_W \) and \( A = p \left( \varepsilon_x + \varepsilon_M \right) + 2\varepsilon_x \varepsilon_M p + \varepsilon_M^2 \left( p + p_W \right) \geq 0 \).
PROPOSITION 8. If Home is a large country \((\varepsilon_X < \infty)\) and there is no domestic production sector \((v = 0)\) then commodities which are subject to higher tariff rates may be subject to higher or lower inspection intensity.

As in the political economy case, if Home is a large country a reduction in the predetermined tariff rate may cause inspection intensity to increase or to decrease. In the small country case with no political economy inspection intensity is a substitute for reductions in the tariff. If Home can influence its terms of trade then a portion of the tariff and marginal inspection costs are passed through to the world price. This reduces the responsiveness of the domestic price to changes in the tariff rate and inspection intensity. The net effect depends on the elasticity of export supply relative to import demand. If export supply is more elastic than import demand \((\varepsilon_X > \varepsilon_M)\) then inspection intensity is increasing in the tariff rate.

In the previous two cases, inspection intensity was increasing in the infection rate so long as the tariff was set at a level which recovered inspection costs. In the large country case, the response of inspection intensity to the infection rate is as follows

\[
\frac{dI}{dq} = -\frac{1}{p^2} \left\{ qr^2 f^2 r e_m e_x m - \frac{pp_w (e_x + e_M)}{D^2} + \left[ T \left( e_x^2 p - e_M^2 p_w \right) + \delta (1-r) D \right] + \frac{mk}{q} \right\}
\]

where \(T = \bar{T} - kl - \delta q (1-r)\).

PROPOSITION 9. If Home is a large country \((\varepsilon_X < \infty)\), the there is no domestic production sector \((v = 0)\) then it is optimal to inspect commodities that are more likely contaminated with damaging NIS more or less intensively.

When Home is a large country, the impact of the infection rate on inspection intensity is ambiguous. In this case the world price is decreasing in the infection rate and
this reduces the response of the domestic price to the infection rate. As in the 
comparative static result for the tariff, the impact of the infection rate on inspection 
intensity depends on the size of the export supply elasticity relative to the import demand 
elasticity. If the tariff is set at the Pigouvian rate as in McAusland and Costello (2004) 
then the impact of the infection rate on inspection intensity is ambiguous. Therefore 
when terms of trade motivations are included in a model of treatment the inspection 
intensity may be increasing or decreasing in the infection rate.

The impact of the per-unit damage term on inspection intensity carries over from 
the small country case and is not reproduced here.

**Concluding Remarks**

This paper incorporates two motivations for protectionist trade policy – terms of 
trade and political economy – into a model of border inspections for invasive NIS. In the 
US, the majority of contaminated shipments of agricultural commodities are treated. We 
find that the governments’ optimal response to a change in the anticipated damages 
associated with imports is non-decreasing. All else equal, the more politically influential 
the domestic sector, the greater the governments optimal inspection intensity.

The response of inspection intensity to the infection rate is not as straightforward. 
If Home is a small country and there is no domestic production sector the governments’ 
optimal choice of inspection intensity is strictly increasing with the infection rate. The 
same is true if the domestic production sector is politically influential. These results 
contrast the result in McAusland and Costello (2004) wherein inspection intensity is 
single-peaked in the infection rate. Nonetheless, the model demonstrates that if Home is
a large country the relationship between inspection intensity and infection rate is ambiguous.

The comparative static analysis also evaluates the impact of tariff rates on the governments’ optimal choice of inspection intensity. Once again, absent terms of trade and political economy motivations, the optimal inspection intensity is greater for those commodities with lower tariff rates. When political economy and terms of trade motivations are taken into account inspection intensity may be increasing or decreasing in the tariff rate.

The model presented in this paper highlights the importance of protectionist motivations in the determination of border inspection policy. This model generates a number of testable propositions and will serve as a framework for an analysis of US border inspections for NIS. This analysis will test the extent to which US border inspections are targeted according to political economy and terms of trade motivations.
REFERENCES


APPENDIX A: Arbitrage and materials balance conditions

Treatment:

The materials balance and price arbitrage equations form a system of two equations in two unknowns, \( p \) and \( p_w \):

\[
(A1) \quad m(p) - x(p_w) = 0
\]

\[
(A2) \quad p - p_w - \bar{T} - fqr(1) = 0
\]

The response of domestic and world prices to the exogenous variables in this system are derived from the solution to the system presented below:

\[
(A3) \quad \begin{bmatrix}
\frac{\partial m}{\partial p} & -\frac{\partial x}{\partial p_w} \\
\frac{dp}{dt} & \frac{dp}{dt} \\
1 & -1 \\
\frac{dp_w}{dt} & \frac{dp_w}{dt} \\
\frac{dp_w}{dq} & \frac{dp_w}{dq}
\end{bmatrix}
\begin{bmatrix}
\frac{dp}{dt} \\
\frac{dp}{dt} \\
\frac{dp_w}{dt} \\
\frac{dp_w}{dq}
\end{bmatrix}
= \begin{bmatrix}
0 \\
ofr \bar{T} \\
\end{bmatrix}
\]

Tariff rate:

\[
\frac{dp}{dt} = \frac{\varepsilon_x p}{\varepsilon_M p_w + \varepsilon_x p} \geq 0 \quad \frac{dp_w}{dt} = \frac{-\varepsilon_M p_w}{\varepsilon_M p_w + \varepsilon_x p} \leq 0
\]

Infection rate:

\[
\frac{dp}{dq} = \frac{\varepsilon_x p f r}{\varepsilon_M p_w + \varepsilon_x p} \geq 0 \quad \frac{dp_w}{dq} = \frac{-\varepsilon_M p_w f r}{\varepsilon_M p_w + \varepsilon_x p} \leq 0
\]
Table 1: Disposition of actionable shipments

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Fruits &amp; vegetables</th>
<th>Cut flowers</th>
<th>Propagative material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposition:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treat</td>
<td>0.73</td>
<td>0.72</td>
<td>0.77</td>
</tr>
<tr>
<td>Re-Export</td>
<td>0.17</td>
<td>0.20</td>
<td>0.15</td>
</tr>
<tr>
<td>Destroy</td>
<td>0.09</td>
<td>0.08</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: APHIS PPQ 280 database.