Tariffs and the Risk of Invasive Pest Introductions

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Tariffs and the Risk of Invasive Pest Introductions

Current policy relies on inspecting cargoes, treating or rejecting those containing organisms that are known/suspected exotic pests.

McAusland/Costello (JEEM 2004): Optimal to use tariffs as Pigouvian taxes in combination with inspection.

- Reduces introductions by reducing import volume, creating incentives for pretreatment.
- Inspection may not be optimal for shipments with very low or very high infestation rates.

Our question: Would it be practical to use tariffs to prevent introductions of invasive pests?

Theory:

- Optimal choice of volume, pest infestation level by an exporter sending an individual shipment; inspection strategy constant.
- Optimal choice of inspection intensity for an individual shipment by importing country; volume, quality, tariff constant.

Empirical analysis:

- Data from inspections of individual import shipments of fruits and vegetables, FY2005-2007 used to estimate logit model of probability of introduction, response of volume and number of shipments to tariff status.
- Estimated coefficients used to calculate elasticity of probability of introduction, expected number of introductions with respect to tariff status.

Preventing Introduction of Invasives via Inspection

Plant Protection Act (2000) gives the Animal and Plant Health Inspection Service, US Department of Agriculture (APHIS) authority to inspect all incoming perishable materials (including packaging) for plant and animal pests, weeds, diseases.

2003—authority for all imports but plant propagative materials delegated to Customs and Border Protection (CBP).

Standard protocol: Binomial sampling $\Rightarrow$ inspect 2% of shipment.
Inspection intensity can be varied by:

- Adjusting sample size for perceived risk.
- Sampling cargo in interior of container rather than at tailgate.
- Inspecting each sample more carefully.

Cargoes with exotic pests must be treated before entry; if the pest cannot be treated, the cargo is denied entry.

Theory

Exporter choosing shipment volume y and the pest infestation level q to maximize profit:

$$\max_{y,q}[\,p - k\phi(q,y;i) - t]y - C(q,y)$$

Importing country chooses inspection intensity i to minimize expected damage from invasive pest introductions plus expenditures on inspection:

$$\min_{i} H[z(i,q,y)] + E(i,y)\,.$$

- p = price in the importing country
- t = importing country tariff
- k = the expected costs of treatment (including losses from delivery delays/quality degradation)
- i = the importing country's inspection strategy
- $\phi(q,y,i)$ = probability invasive pests are discovered in the shipment, increasing and concave in all arguments. At low infestation rates (as in our sample), ϕ_{iq}, ϕ_{yq} < (>) 0 when y is large (small); $\phi_{iy} < 0$ in all cases.
- C(q,y) = production cost, C_y, C_{yy}, $C_{qq} > 0$; C_q, $C_{yq} < 0$.
- $z(i,q,y) \equiv [1-\eta\phi(i,q,y)]y$ = total volume of invasive pest introductions
- η = probability that treatment eliminates invasives/share of invasives killed
- H, E increasing and convex, $E_{iy} > 0$

Nash Equilibrium

Choice of shipment volume equates marginal production cost and expected marginal losses from treatment if invasive pests are discovered with the expected net price of the product:

$$C_y + k\phi_y y = p - k\phi - t .$$

Choice of infestation rate balances reductions in production cost against expected marginal losses from treatment if invasive pests are discovered:

$$-C_q = k\phi_q y$$

Choice of inspection intensity balances marginal cost of inspection against the expected avoided marginal damage from invasive pest introductions:

$$E_i = -H_z \eta \phi_i .$$

Nash Equilibrium—Qualitative Characteristics Depend on Relative Strength of Importer, Exporter Reactions

$$\frac{di}{dt} > (<) 0 \; as \; \frac{\theta_q}{\theta_y} > (<) -\frac{\tau_q}{\tau_y}$$

$$\frac{dq}{dt} > (<) 0 \; as \; \theta_y > (<) \frac{\omega_y}{\omega_i}$$

$$\frac{dy}{dt} > (<) 0 \; as \; \theta_q > (<) \frac{\omega_q}{\omega_i}$$

θ_q = elasticity of importer inspection intensity w/r/t/ quality
θ_y = elasticity of importer inspection intensity w/r/t/ volume
τ_q = elasticity of exporter quality w/r/t/ tariff
τ_y = elasticity of exporter volume w/r/t/ tariff
ω_q = elasticity of exporter marginal cost of quality $k\phi_q y + C_q$ w/r/t/ quality
ω_y = elasticity of exporter marginal cost of quality $k\phi_q y + C_q$ w/r/t/ volume
ω_i = elasticity of exporter marginal cost of quality $k\phi_q y + C_q$ w/r/t/ inspection intensity

$$\frac{di}{dp} = -\frac{di}{dt}, \; \frac{dq}{dp} = -\frac{dq}{dt}, \; \frac{dy}{dp} = -\frac{di}{dt}$$

Data

APHIS Forms 264/280—all propagatable and non-propagatable plant material entering US during FY 2005-2007.

Type, port of entry, date of entry, volume.
Whether cargo was inspected, inspection result, and disposition of cargo (includes pre-clearance, pre-treatment, etc.).
926,600 fruit and vegetable shipments inspected.
Actionable pests found in 1.96%.

US Customs data:

Customs data used to calculate average unit value and tariff by commodity, country, month.

Commodities grouped by Harmonized Tariff Schedule at the 6-digit level.

Descriptive Statistics of the Sample Used in the Econometric Model

Variable	Mean	Standard Deviation	Minimum	Maximum
Full Sample: N = 926,600				
Actionable Pest Detected (0/1)	0.0196	0.1385	0	1
Shipment Volume (1000 Metric Tons)	0.0256	0.3886	0	178.6681
Unit Value ($/metric ton)	2.5981	38.7612	0	2868.2
Unit Duty ($/metric ton)	0.0136	2.0111	0	849
Unit Value Missing (0/1)	0.0382	0.1917	0	1

Positive Tariff Subsample: N = 239,130				
Actionable Pest Detected (0/1)	0.0175	0.1312	0	1
Shipment Volume (1000 Metric Tons)	0.0179	0.2393	0	32.1732
Unit Value ($/metric ton)	1.5454	18.1110	0	2152.316
Unit Duty ($/metric ton)	0.0526	3.9586	0	849
Unit Value Missing (0/1)	0.1480	0.3551	0	1
Duty Free Subsample: N = 678,470				
Actionable Pest Detected (0/1)	0.0203	0.1409	0	1
Shipment Volume (1000 Metric Tons)	0.0282	0.4285	0	178.6681
Unit Value ($/metric ton)	2.9643	43.7084	0	2868.2

Econometric Model of Pest Detection

Pr{At least one actionable pest detected in shipment j} = $\phi_j = \Lambda(a_0 + \Sigma_n a_{1n}\text{Commodity Type}_{jn} + \Sigma_m a_{2m}\text{Origin}_{jm} + \Sigma_t a_{4t}\text{Season}_{jt} + \Sigma_r a_{5r}\text{Port}_{jr} + a_6 p_j + a_7 y_j + a_8 t_j + a_9\text{Duty Free}_j + a_{10}\text{Missing Unit Value}_j)$.

$$a_7 = \frac{d\phi_j}{dy_j} = \phi_y + \phi_i \frac{\partial i}{\partial y}$$

$$a_6 = \frac{d\phi_j}{dp_j} = \phi_q \frac{dq}{dp} + \phi_i \frac{di}{dp}$$

$$a_8 = \frac{d\phi_j}{dt_j} = \phi_q \frac{dq}{dt} + \phi_i \frac{di}{dt},$$

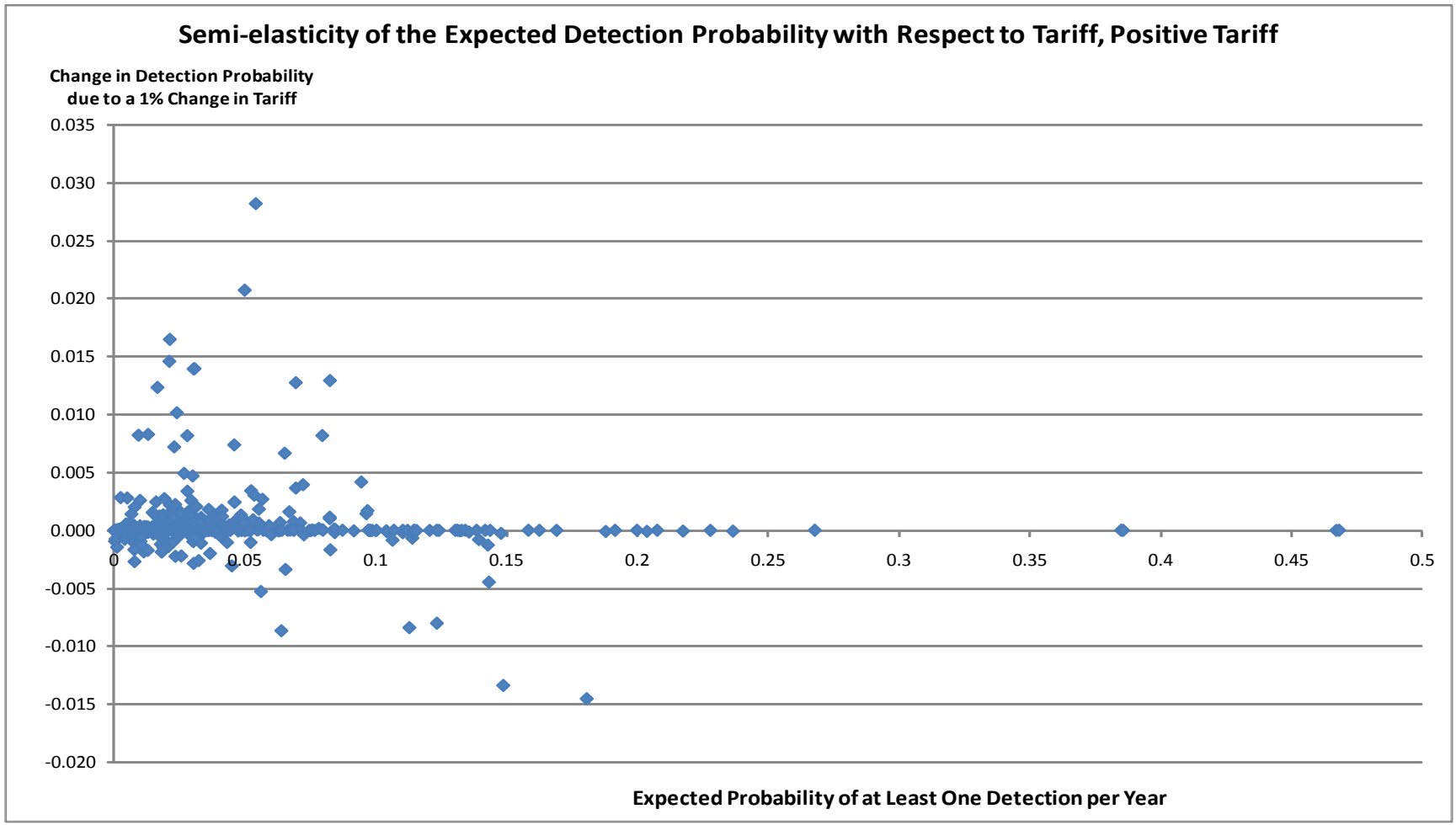
- All are indeterminate in sign.
- Price, tariff effects should be opposite in sign.

Table 3. Estimated Coefficients of the Logit Model

Dependent Variable = At Least One Actionable Pest Detected in Shipment (0/1)	
Variable	**Coefficient (t-statistic)**
Shipment Volume (1000 metric tons)	-0.993*** (-9.074)
Unit Value ($/metric ton)	0.00117*** (3.501)
Unit Duty ($/metric ton)	-0.0587 (-0.669)
Unit Value Missing = 1	0.725*** (18.27)
Duty Free = 1	0.258*** (8.772)
N	926,044
*** denotes significantly different from zero at a 1% level. ** denotes significantly different from zero at a 5% level.	

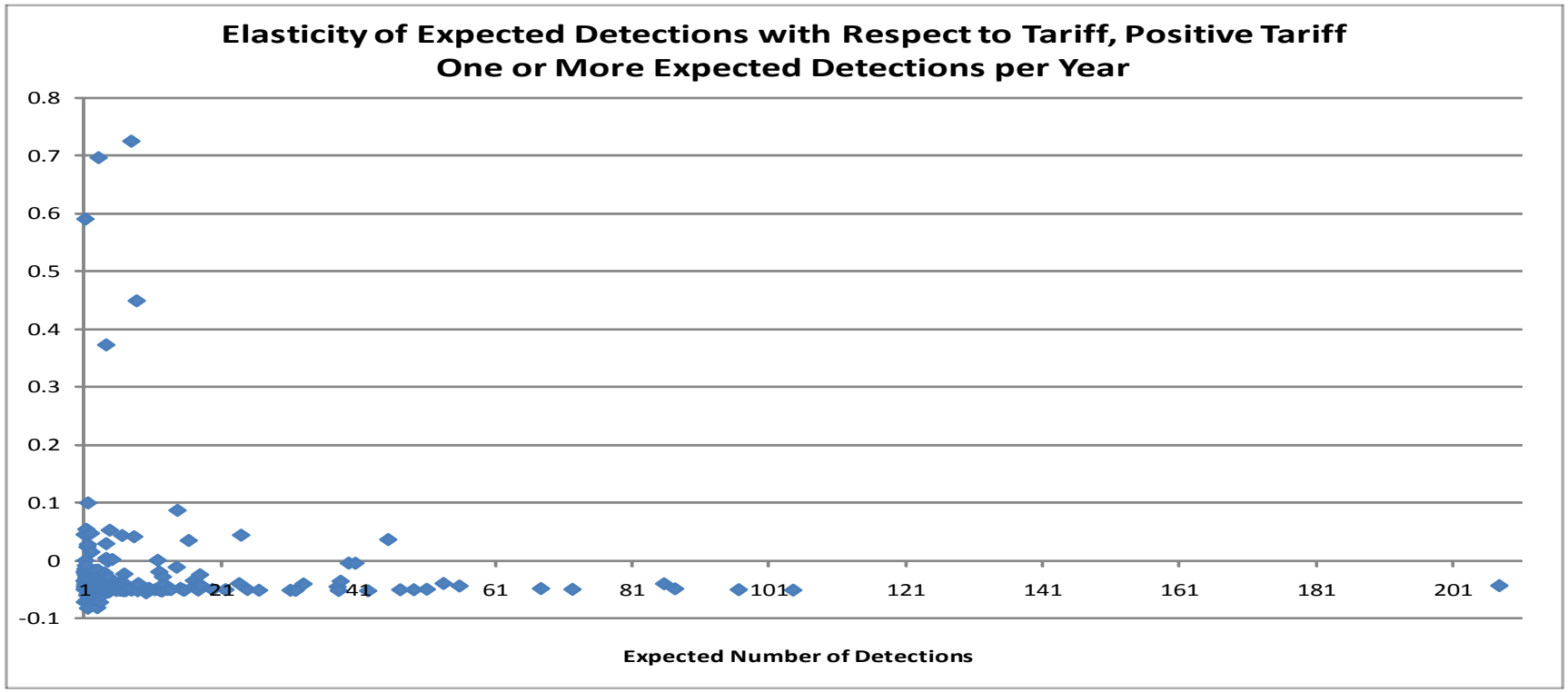
Included: Fixed effects for commodity group, region of origin, production season, and region of entry.

Higher Tariffs Increase the Probability of Detection for a Number of Commodities



Elasticity of volume y with respect to tariff = -0.7, estimated from log-log regression of volume on price, tariff, duty-free status, commodity/region of origin/season/region of entry fixed effects.

Higher Tariffs Increase the Expected Number of Detections for Some Commodities



Elasticity of shipments S with respect to tariff = -0.0501, estimated from log-log regression of the number of shipments on price, tariff, duty-free status, commodity/region of origin/season/region of entry fixed effects.

- Tariff elasticity of expected detections ≈ -0.05 for most commodities.
- But tariff elasticity of expected detections > 0 for some commodities

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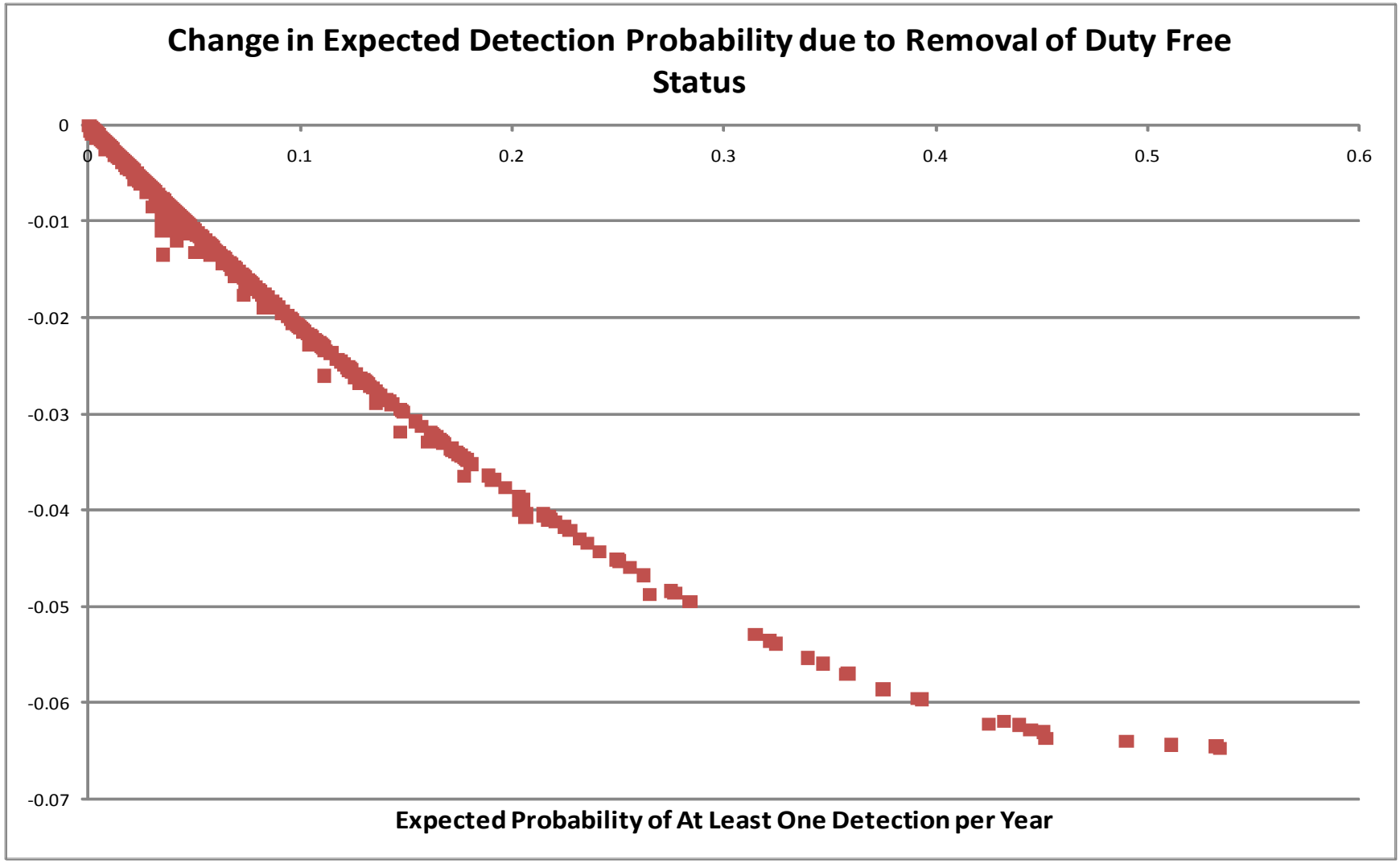
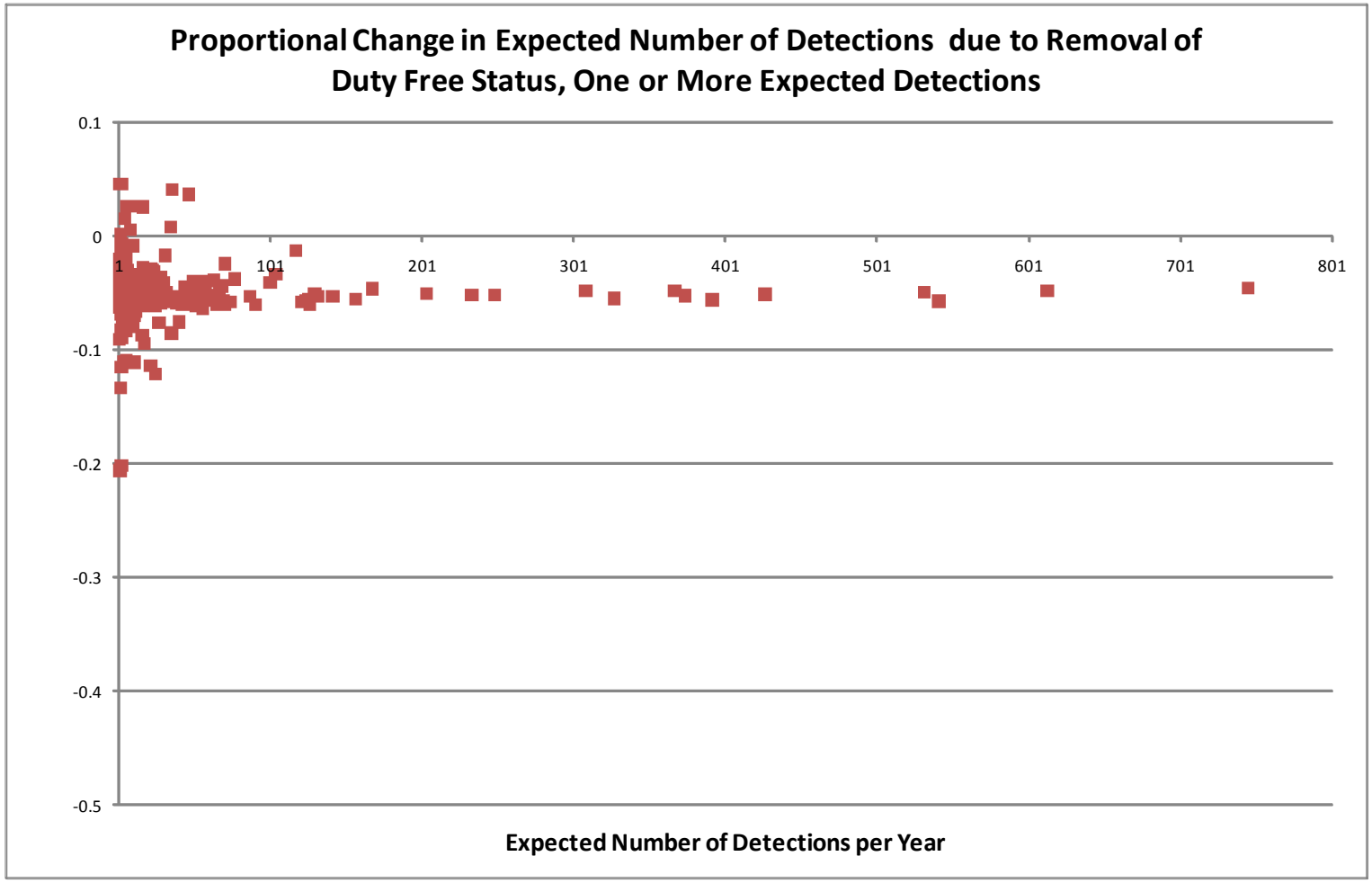
Removing Duty Free Status Reduces the Probability of Detection



Removing Duty Free Status Reduces the Expected Number of Detections for Some but not All Commodities



- For most commodities, the removing duty free status reduces the expected number of detections per year by ~ 5%

Conclusion: Using tariffs as Pigouvian taxes to deter invasive pest introductions is not an attractive option.

The deterrent effect of tariffs on invasive species introductions is generally small.

- For commodities facing a positive tariff, the elasticity of detections with respect to the tariff rate ≈ - 0.05.
- Removing duty free status reduces the expected annual number of detections by about 5%.

Due to the indirect effect of tariffs on shipment volume, raising tariff rates/removing duty free status would actually increase the risk of invasive introductions for commodity/region combinations such as:

- Lemons and limes (Central America, South America, Africa, the Caribbean).
- Watermelons, other melons (Central America, South America).
- Avocados (South America, the Caribbean).
- Grapes (South America, Mexico, the Caribbean).
- Pineapples (Central America, South America).
- Stone fruits, pears, mangos (South America).

Supplemental Material

Exporter Reaction Functions

	Shipment Volume	Pest Infestation
Commodity Price	$\frac{\partial y}{\partial p} = \Omega^{-1} C_{qq} > 0$	$\frac{\partial q}{\partial p} = -\Omega^{-1}\left[k\phi_q\left(1+\frac{\phi_{qy}y}{\phi_q}\right)+C_{yq}\right]$
Tariff Rate	$\frac{\partial y}{\partial \tau} = -\Omega^{-1} C_{qq} < 0$	$\frac{\partial q}{\partial \tau} = \Omega^{-1}\left[k\phi_q\left(1+\frac{\phi_{qy}y}{\phi_q}\right)+C_{yq}\right]$

$$\Omega \equiv [ky\phi_{qq} + C_{qq}]\left[k\phi_y\left(2+\psi_y\right)+C_{yy}\right]-\left[k\phi_q\left(1+\psi_q\right)+C_{yq}\right]^2 > 0$$

- Price, tariff effects are opposite in sign.
- Effects of price, tariff on pest infestation involve tradeoff between lower marginal production costs (C_{yq}) but possibly higher losses from treatment when invasive pests are detected ($k\phi_q[1+\phi_{qy}y/\phi_q]$).
- $\phi_{qy} < 0 \Rightarrow \partial q/\partial p > 0$, $\partial q/\partial \tau < 0$; $\phi_{qy} > 0 \Rightarrow$ both indeterminate.

Importing Country Reaction Function

Inspection intensity is decreasing in the infestation rate:

$$\frac{\partial i}{\partial q} = Z^{-1}\left(H_z \eta \phi_{iq} - H_{zz} \eta^2 y \phi_q \phi_i\right) < 0,$$

where $Z \equiv E_{ii} y + H_{zz} \phi_i^2 \eta^2 y - H_z \eta \phi_{ii} > 0$.

Effect of shipment volume is indeterminate, since it increases the marginal cost of inspection but can also increase expected marginal damage from invasive pest introductions:

$$\frac{\partial i}{\partial y} = Z^{-1}\left(H' \eta \phi_{iy} - H'' \eta \phi_i [1 - \eta \phi (1 - \phi_y y / \phi))] - E_{iy}\right)$$

Impact of Tariff Rate on the Expected Probability of Detection ϕ

Commodities facing a positive tariff:

$$\frac{t}{\phi}\frac{d\phi}{dt} = \varepsilon_t + \varepsilon_y \eta_y$$

$\varepsilon_t = \frac{t}{\phi}\frac{\partial \phi}{\partial t}$, elasticity of expected probability with respect to the tariff rate

$\varepsilon_y = \frac{y}{\phi}\frac{\partial \phi}{\partial y}$, elasticity of expected probability with respect to volume

$\eta_y = \frac{t}{y}\frac{\partial y}{\partial t}$, elasticity of volume with respect to the tariff rate

Commodities entering duty free:

$$\frac{\Delta\phi}{\phi} = \frac{\phi(DutyFree = 0) - \phi(DutyFree = 1)}{\phi(DutyFree = 0)} + \eta_y \frac{y(DutyFree = 0) - y(DutyFree = 1)}{y(DutyFree = 1)}$$

Impact of Tariff Rate on the Expected Number of Detections I = ϕS

S = number of shipments per year

Commodities facing a positive tariff:

$$\frac{t}{I}\frac{dI}{dt} = \frac{t}{\phi}\frac{d\phi}{dt} + \frac{t}{S}\frac{dS}{dt}$$

Commodities entering duty free:

$$\frac{\Delta I}{I} = \frac{\Delta \phi}{\phi} + \eta_S \frac{S(DutyFree = 0) - S(DutyFree = 1)}{S(DutyFree = 1)}.$$

Estimated Parameters of the Shipment Volume Model

Dependent Variable = Log Shipment Volume

Log Unit Value	-1.314*** (0.00220)	-0.700*** (0.00383)	-1.309*** (0.00218)	-0.700*** (0.00383)
Log Unit Duty	-0.0525*** (0.000969)	-0.0101*** (0.00115)	-0.0677*** (0.000480)	-0.0152*** (0.000441)
Unit Value Missing (=1)	-2.915*** (0.0133)	-1.934*** (0.0139)	-2.756*** (0.00995)	-1.883*** (0.00904)
Duty Free	-0.168*** (0.00932)	-0.0603*** (0.0125)		
Commodity and Region Fixed Effects	No	Yes	No	Yes
R^2	0.333	0.560	0.333	0.560
N	926,571	926,592	926,571	926,592

Standard errors in parentheses.
*** denotes significantly different from zero at a 1% level.
** denotes significantly different from zero at a 5% level.

Estimated Parameters of the Number of Shipments Model

Dependent Variable = Log Number of Shipments per Year

Log Unit Value	-0.107 (0.0712)	-0.0501 (0.0954)	-0.127 (0.0688)	-0.0476 (0.0952)
Log Unit Duty	-0.196*** (0.0318)	-0.135*** (0.0312)	-0.169*** (0.0201)	-0.149*** (0.0157)
Duty Free	0.288 (0.261)	-0.155 (0.291)		
Commodity, Region, and Year Fixed Effects	No	Yes	No	Yes
R^2	0.091	0.634	0.090	0.634
N	851	851	851	851
*** denotes significantly different from zero at a 1% level. ** denotes significantly different from zero at a 5% level.				