When Trade Costs are not Ad-valorem: What does the Gravity Model Really Measure?

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The motivation

There is a very large empirical literature evaluating the impact of trade policies on the volume of trade and trying to measure trade costs.

Most of the theoretical models used in these studies assume a multiplicative price structure: *iceberg trade costs*, treat different trade barriers as *ad-valorem* duties.

Trade models that rely on this assumption can be a very rough and biased representation of the reality.

Hummels and Skiba (*J of Pol Econ* 2004) extend the Alchian-Allen "shipping the good apples out" hypothesis and show that actual data rejects the iceberg assumption on transport costs.

The agricultural sector is characterized by an extensive use of *non ad-valorem* trade policy measures:

- import tariffs on agricultural products are often defined *per unit* of exchanged products rather than (or in addition to) a percentage of their value

- EU: specific tariffs for 36.5% of the number of imported agricultural products; ad-valorem tariffs for 79%.

- many NTMs not correlated to the price of goods

The use of multiplicative-trade-costs models for evaluating all types of trade barriers comes from:

- the need to quantify (very) complex policy barriers: a multiplicative price structure makes models more tractable

This paper:

Q: Are trade models built on the ad-valorem trade costs assumption fit for evaluating the impact of non ad-valorem trade costs ?

No

Based on the example of agricultural products we focus on:

- the Anderson and van Wincoop (2003, 2004) model: Armington-type elasticities
- one product: the market clearing assumption is verified only in terms of traded quantities (but not values):

$$\sum_i \frac{Y_i}{p_i} = \sum_j \frac{E_j}{p_{ij}} \quad \text{instead of} \quad Y_i = E_i \ \text{ and } \ \sum_i Y_i = \sum_j E_j$$

- specific (per-unit) import tariffs:

$$p_{ij} = p_i + \tau_{ij} \qquad \text{instead of} \quad p_{ij} = p_i t_{ij}$$

A multiplicative price structure produces a gravity-type equation:

$$X_{ij} = \left(\frac{t_{ij}}{P_j \Pi_i}\right)^{1-\sigma} Y_i E_j \tag{1}$$

$$P_j = \left(\sum_i {t_{ij}}^{1-\sigma} Y_i \Pi_i^{\sigma-1}\right)^{1/(1-\sigma)} \tag{2}$$

$$\Pi_i = \left(\sum_j {t_{ij}}^{-\sigma} E_j P_j^{\sigma-1}\right)^{1/(1-\sigma)} \tag{3}$$

An additive price structure requires information about prices:

$$X_{ij} = \left(\frac{p_i + \tau_{ij}}{\tilde{P}_j \tilde{\Pi}_i}\right)^{1-\sigma} (Y_i/p_i) E_j \tag{4}$$

$$\tilde{P}_j = \left(\sum_i (p_i + \tau_{ij})^{1-\sigma} (Y_i/p_i) \tilde{\Pi}_i^{-\sigma}\right)^{1/(1-\sigma)} \tag{5}$$

$$\tilde{\Pi}_i = \left(\sum_j (p_i + \tau_{ij})^{-\sigma} E_j \tilde{P}_j^{\sigma-1}\right)^{1/(1-\sigma)} \tag{6}$$

$\underline{p_{ij} = p_i d_{ij}^{\delta} t_{ij}}$:

$$X_{ij} = \left(\frac{t_{ij} d_{ij}^{\delta}}{P_j \Pi_i}\right)^{1-\sigma} Y_i E_j \qquad (1')$$

$$P_j = \left(\sum_i (t_{ij} d_{ij}^{\delta})^{1-\sigma} Y_i \Pi_i^{\sigma-1}\right)^{1/(1-\sigma)} \qquad (2')$$

$$\Pi_i = \left(\sum_j (t_{ij} d_{ij}^{\delta})^{-\sigma} E_j P_j^{\sigma-1}\right)^{1/(1-\sigma)} \qquad (3')$$

$\underline{p_{ij} = p_i d_{ij}^{\delta} + \tau_{ij}}$:

$$X_{ij} = \left(\frac{p_i d_{ij}^{\delta} + \tau_{ij}}{\tilde{P}_j \tilde{\Pi}_i}\right)^{1-\sigma} (Y_i/p_i) E_j \qquad (4')$$

$$\tilde{P}_j = \left(\sum_i \left(p_i d_{ij}^{\delta} + \tau_{ij}\right)^{1-\sigma} (Y_i/p_i) \tilde{\Pi}_i^{-\sigma}\right)^{1/(1-\sigma)} \qquad (5')$$

$$\tilde{\Pi}_i = \left(\sum_j (p_i d_{ij}^{\delta} + \tau_{ij})^{-\sigma} E_j \tilde{P}_j^{\sigma-1}\right)^{1/(1-\sigma)} \qquad (6')$$

Estimating an ad-valorem-tariffs model on specific tariffs data

The estimate of σ and δ is central for computing the impact of different trade barriers.

Can one correctly estimate σ and δ with a model given by equations (1)-(3) when actual data satisfies equations (4)-(6)?

$$\left(\frac{t_{ij}}{P_j \Pi_i}\right)^{1-\sigma} = \left(\frac{p_i + \tau_{ij}}{\tilde{P}_j \tilde{\Pi}_i}\right)^{1-\sigma} p_i^{-1}$$

or

$$\left(\frac{t_{ij} d_{ij}^{\delta}}{P_j \Pi_i}\right)^{1-\sigma} = \left(\frac{p_i d_{ij}^{\delta} + \tau_{ij}}{\tilde{P}_j \tilde{\Pi}_i}\right)^{1-\sigma} p_i^{-1}$$

$\Rightarrow$ use simulation techniques

Simulated data:

The trade structure is obtained from the "observed" (simulated) E_j, y_i, τ_{ij}, and d_{ij}, for fixed levels of σ and δ.

$$\left.\begin{array}{llll} E_j \sim \mathcal{N}(100, 10) & & & \\ y_j \sim \mathcal{N}(100, 10) & & & \\ \tau_{ij} \sim \mathcal{N}(0.3, 0.1), & \tau_{ij} \geq 0, & \tau_{ii} = 0 & \\ d_{ij} \sim \mathcal{N}(5, 1), & d_{ij} = d_{ji}, & \min(d_{ij}) = 1 & \\ \sigma = 5 \text{ (Hummels, 2001: cereals)} & & & \\ \quad\text{(Chen \& Novy, 2009: grain mill products)} & & & \\ \delta = \{1;\ \frac{1}{2}\} & & & \end{array}\right| \xrightarrow{(4)-(6)} X_{ij} + \varepsilon_{ij}$$

We estimate the system (1)-(3) with $X_{ij} + \varepsilon_{ij}$ as the explained variable
- non linear estimation of parameters σ and δ along with P_j and Π_i
- log-linear gravity with country fixed effects

For robustness check we repeat the procedure for different samples (different values of exogenous variables) and different trade costs structures: 1000 samples considered.

Treating specific tariffs as ad-valorem produces biased results for σ:

small ε_{ij}	gravity FE			non-linear system		
Price structure	$\hat{\sigma}$	95% CI		$\hat{\sigma}$	95% CI	
$p_{ij} = p_i + \tau_{ij}$	1.87	[1.85,	1.89]	5.95	[5.94,	5.96]
$p_{ij} = p_i d_{ij} + \tau_{ij}$	1.73	[1.70,	1.76]	6.06	[6.00,	6.11]
$p_{ij} = p_i d_{ij} + \tau_{ij},\ d_{ii} = 1$	1.17	[1.13,	1.21]	2.37	[2.32,	2.42]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij}$	1.81	[1.79,	1.93]	6.02	[5.98,	6.05]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij},\ d_{ii} = 1$	1.44	[1.42,	1.45]	3.68	[3.63,	3.73]

large ε_{ij}	gravity FE			non-linear system		
Price structure	$\hat{\sigma}$	95% CI		$\hat{\sigma}$	95% CI	
$p_{ij} = p_i + \tau_{ij}$	1.88	[1.85,	1.91]	5.95	[5.91,	6.00]
$p_{ij} = p_i d_{ij} + \tau_{ij}$	1.52	[1.36,	1.69]	6.12	[5.83,	6.40]
$p_{ij} = p_i d_{ij} + \tau_{ij},\ d_{ii} = 1$	1.13	[0.97,	1.29]	2.43	[2.14,	2.73]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij}$	1.87	[1.78,	1.96]	6.02	[5.86,	6.17]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij},\ d_{ii} = 1$	1.45	[1.34,	1.56]	3.66	[3.35,	3.97]

and δ:

small ε_{ij}	gravity FE			non-linear system		
Price structure	$\widehat{\delta}$	95% CI		$\widehat{\delta}$	95% CI	
$p_{ij} = p_i + \tau_{ij}$	-			-		
$p_{ij} = p_i d_{ij} + \tau_{ij}$	4.29	[4.17,	4.41]	0.66	[0.65,	0.68]
$p_{ij} = p_i d_{ij} + \tau_{ij},\ d_{ii} = 1$	23.01	[22.39,	23.63]	2.82	[1.55,	4.10]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij}$	1.83	[1.77,	1.90]	0.34	[0.34,	0.35]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij},\ d_{ii} = 1$	3.93	[3.85,	4.02]	0.73	[0.71,	0.75]

large ε_{ij}	gravity FE			non-linear system		
Price structure	$\widehat{\delta}$	95% CI		$\widehat{\delta}$	95% CI	
$p_{ij} = p_i + \tau_{ij}$	-			-		
$p_{ij} = p_i d_{ij} + \tau_{ij}$	4.22	[3.36,	5.08]	0.64	[0.56,	0.72]
$p_{ij} = p_i d_{ij} + \tau_{ij},\ d_{ii} = 1$	21.97	[18.75,	25.19]	2.81	[2.16,	3.45]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij}$	1.83	[1.56,	2.11]	0.34	[0.31,	0.37]
$p_{ij} = p_i d_{ij}^{1/2} + \tau_{ij},\ d_{ii} = 1$	3.94	[3.28,	4.60]	0.74	[0.64,	0.84]

Non-biased results can be obtained for large measurement errors ε_{ij} (20-30% of trade flows wrongly predicted).

Similar results obtained if the policy cost arises before international shipment (as for many NTBs): $p_{ij} = (p_i + \tau_{ij})d_{ij}^{\delta}$.

SPS, TBT, licensing, etc. $\Rightarrow$ additional costs for exporters

τ_{ij} – cost of compliance, inspection, certification, license, etc.

τ_{ij} – not correlated with the price of traded goods

To obtain unbiased estimates, one needs to compute *true* ad-valorem equivalents of the policy cost τ_{ij}:

- with $p_{ij} = p_i d_{ij}^{\delta} + \tau_{ij}$ (*specific tariffs*): $\hat{t}_{ij} = \tau_{ij}/(p_i d_{ij}^{\delta}) + 1$
- with $p_{ij} = (p_i + \tau_{ij})d_{ij}^{\delta}$ (*NTBs*): $\hat{t}_{ij} = \tau_{ij}/p_i + 1$

$\Rightarrow$ requires information about the price structure.

If prices are known, one can estimate directly the demand function.

Insights for the quantification of NTBs

Controlling for NTB that can be associated with a *per-unit* tariff (SPS, TBT, licensing) using:

- dummy variables
- qualitative variables
- number of barriers (policy measures)

$\rightarrow$ unbiased estimates with uniform prices $p_i = \bar{p}$ $(\forall i)$:

$$\left(\frac{\tau_{ij}}{\bar{p}} + 1\right)^{1-\sigma} \text{ does not vary with the price.}$$

$\rightarrow$ upward biased estimates for low-price goods and down biased estimates for high-price goods:

$$\left(\frac{\tau_{ij}}{\bar{p}+\Delta_i} + 1\right)^{1-\hat{\sigma}} = \left(\frac{\tau_{ij}}{\bar{p}} + 1\right)^{1-\sigma}$$

if $\Delta_i > 0 \;\Rightarrow\; \hat{\sigma} < \sigma$

if $\Delta_i < 0 \;\Rightarrow\; \hat{\sigma} > \sigma$

Solution ? use price-weighted variables
use the trade-coverage ratio