Heterogeneous Effects of Tariff and Nontariff Policy Barriers in Quantitative General Equilibrium

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A cost of transporting a good that ***uses up some fraction of the good itself****, rather than other resources. By analogy with floating an iceberg, costless except for the part of the iceberg that melts.* ***Far from realistic, but a tractable way*** *of modeling transport costs since it impacts no other market. Due to Samuelson (1954).* (Alan Deardorff)

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- Quantitative trade models are silent on the functional form of trade costs, $C_{ij} \rightarrow$ **iceberg transport cost** :

- For trade policy evaluation, C_{ij} is parameterized based on three leading assumptions :
  - Trade costs can be **log-linearly** decomposed into its components.
  - Trade policy in this context is mainly **tariffs**.
  - Trade policy can be treated as **exogeneous**.

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$\Rightarrow$ Are we missing something in our modeling of trade costs ?

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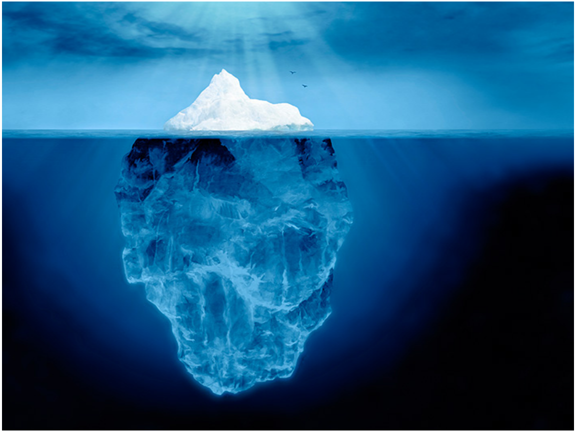

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- Trade policy as **signal**, e.g., for **trade policy uncertainty**.
  (See Handley and Limão, 2015)
- For tariff and nontariff trade-policy barriers : **(strategic) interdependence**.
  (See e.g., Kee and Nicita, 2016)

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  - estimate the potentially **non-linear effect** of trade policy on trade costs.
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- Does it matter ?

  $\Rightarrow$ We uncover **strong non-linear effects** of trade policy on trade costs and, hence, trade flows.

  $\Rightarrow$ These non-linearities are **quantitatively important** in general equilibrium.

Outline

A stylized trade model

- Let us consider a generic quantitative general equilibrium model of trade.
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$\Rightarrow$ in the generic version we refer to the exogenous component of exporter-specific fixed effects as **exporter fundamentals**, F_i^s.

Equilibrium

- In the simplest version of the model, we assume one factor of production, a specific-factors model and balanced trade.
- Tariff revenues are refunded lump-sum to consumers.
- Then, the model is closed by solving for sector-specific wages.

  Equilibrium in levels
- Solution can be expressed in 'hat-notation' (Dekle et al., 2007)

  $\Rightarrow$ Equilibrium can be calculated without relying on calibration of fundamentals.

  Equilibrium in hat notation

A closer look at bilateral trade costs

- Trade policy is denoted by m^s_{ij}.
- We consider **two** trade policy variables :
  - $\tau^s_{ij} = log(1 + t^s_{ij})$ with t^s_{ij} being **tariffs**.
  - $\eta^s_{ij} = log(1 + n^s_{ij})$ with n^s_{ij} being **non-tariff barriers**.

  $\Rightarrow$ m^s_{ij} is a bivariate vector, $m^s_{ij} = (\tau^s_{ij}, \eta^s_{ij})$
- Log bilateral trade costs, d^s_{ij}, are a **flexible function of trade policy**, m^s_{ij}, and a linear function of (exogenous) trade barriers u^s_{ij} :

$$d^s_{ij} = h(m^s_{ij}) + \gamma' u^s_{ij}.$$

- Policy variables are **determined by fundamental drivers** of trade flows :

$$m^s_{ij} = g_s(\mathbf{f}, \mathbf{u}, \boldsymbol{\alpha}),$$

where $\mathbf{f} = (f^s_i)\ \forall\ i, s$, $\mathbf{u} = (u^s_{ij})\ \forall\ i, j, s$ and $\boldsymbol{\alpha} = (\alpha_s)\ \forall\ s$.

Note : We denote the log of any generic variable in upper case, A, by its lower-case counterpart, a.

Data & Measurement

1. **Bilateral imports** and **producer prices** (f.o.b. unit values) and from Worldbank (WITS).
2. **Trade elasticities** from Kee, Nicita, and Olarreaga (2008).
   - Using 1&2, we can back out fundamentals and trade costs from gravity :

$$x_{ij}^s = a_i^s + b_j^s + c_{ij}^s,$$

with $\hat{f}_i^s = \hat{a}_i^s - \alpha_s w_i^s$ and $\hat{d}_{ij}^s = 1/\alpha_s \left(x_{ij}^s - \hat{a}_i^s - \hat{b}_j^s \right)$. See fundamentals

3. **Tariff** data from UNCTAD (TRAINS).
4. Ad-valorem equivalents for **non-tariff policy barriers** from Kee and Nicita (2016).
5. Data on **exogenous trade costs** (distance, adjacency, common language, colonial history, etc.) from CEPII.

$\Rightarrow$ Altogether **92,830 observations**, **115 countries**, and **128 4-digit sectors** for 2011.

Econometric strategy

- Endogeneity arises due to simultaneous determination of bilateral trade flows and policy variables :

$$x_{ij}^s = a_i^s + b_j^s + \alpha_s(\underbrace{h(m_{ij}^s) + \gamma' u_{ij}^s}_{d_{ij}^s}) + \epsilon_{ij}^s$$

with $E(\epsilon_{ij}^s | m_{ij}^s) \neq 0$.

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  with $E(\epsilon_{ij}^s | m_{ij}^s) \neq 0$.

- However, in the context of the model, we know the **exhaustive set of candidate variables** that affect trade policy and trade costs jointly :

$$q_{ij}^s = (f_i^s, f_j^s, u_{ij}^s, \bar{f}_{-i,-j}^s, \bar{u}_{-i,-j}^s, i^s)$$

$\Rightarrow$ Under this assumption, we can address the endogeneity of trade policy by adjusting for the **generalized propensity score** (Hirano and Imbens, 2004).

Empirical implementation

- The generalized propensity score (GPS), is the **conditional density** of trade policy treatment m given **pre-treatment covariates** q :
  - $\rightarrow$ Estimate trade policy determination by multivariate adaptive regression splines using a large set of candidate variables. Model selection Reduced form graphs
  - $\rightarrow$ Estimate density of residuals to obtain GPS. Densities Evaluation of GPS

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- **Modeling bilateral trade flows** as a **flexible function of trade policy** and the **GPS** accounts for selection into treatment.

$$E[x_{ij}^s | r(m_{ij}^s, q_{ij}^s)] = a_i^s + b_j^s + \alpha_s \left(k\left(m_{ij}^s, r(m_{ij}^s, q_{ij}^s)\right) + \gamma' u_{ij}^s\right) + \omega_{ij}^s,$$

where $E(\omega_{ij}^s | m_{ij}^s, q_{ij}^s, a_i^s, b_j^s) = 0$.

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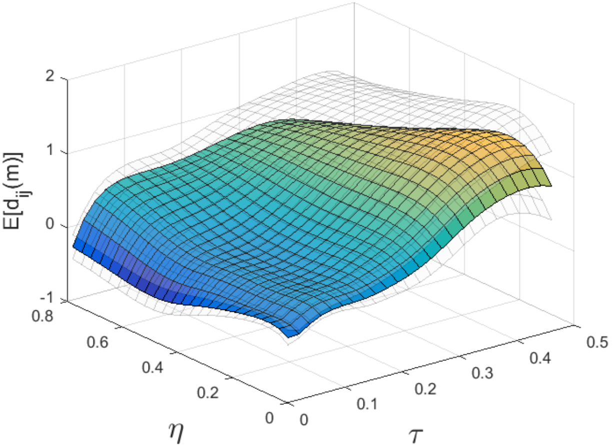
  where $E(\omega_{ij}^s | m_{ij}^s, q_{ij}^s, a_i^s, b_j^s) = 0$.
- Average trade cost function is obtained by **averaging** over all observations **for any trade policy level** m we are interested in.

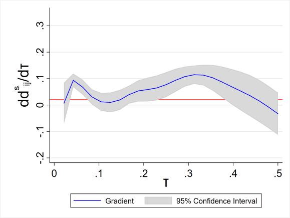
Average dose-response function



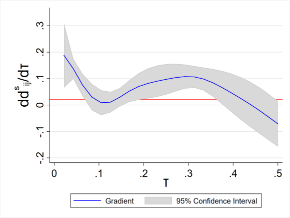
This figure displays log trade costs as a function of trade policy variables, τ (tariffs) and η (non-tariff barriers), as well as the 95% confidence bounds obtained from bootstrapping.

Gradients w.r.t τ and w.r.t. η for different levels of trade policy

Marginal effect of tariff policy on trade costs



Low η.



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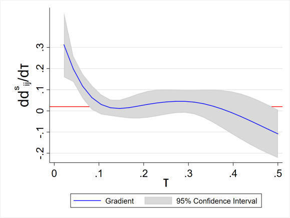

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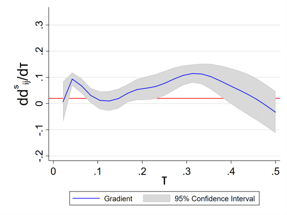

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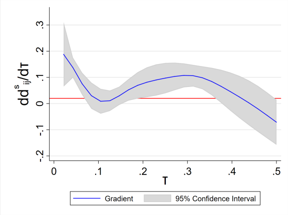

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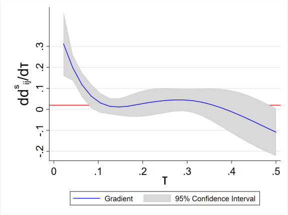
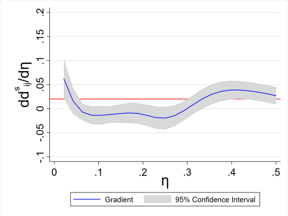
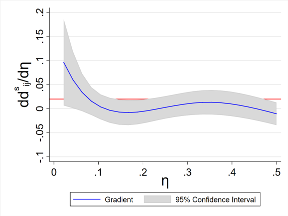


High η.

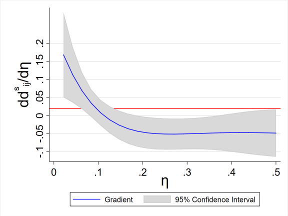
Marginal effect of non-tariff trade policy on trade costs



Low τ.



Medium τ.



High τ.

Quantification in general equilibrium

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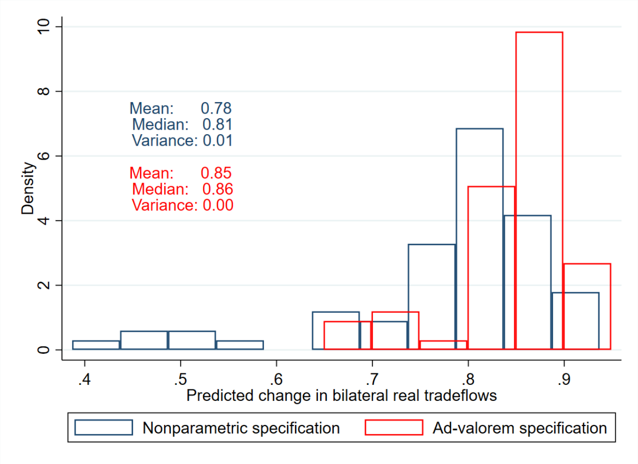
$\Rightarrow$ Compare nonparametric outcome to the customary ad-valorem specification.

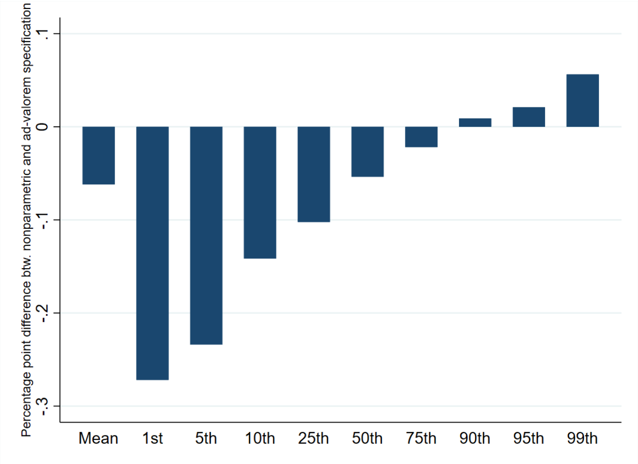
Equilibrium in hat notation
Details on construction of counterfactual

Quantification in general equilibrium : Overall distribution



General equilibrium change in bilateral real trade flows in the non-parametric versus the ad-valorem specification of trade costs. The experiment considered is a 10-percentage-point increase in tariffs on Chinese imports by the US.

Quantification in general equilibrium : Distribution of deviations



Distribution of percentage-point differences of the general equilibrium prediction of bilateral real trade flows between the non-parametric specification and the ad-valorem specification. The experiment considered is a 10-percentage-point increase in tariffs on Chinese imports by the US.

Conclusions

- **Linearity** of the effects of tariff and non-tariff policy barriers on trade costs is **clearly rejected**.
- In a quantitative multi-country, multi-sector general equilibrium model of trade, the effect of a unilateral increase in US tariffs on Chinese imports of 10 percentage points is evaluated :
  - $\Rightarrow$ Average reduction in real bilateral trade flows is **7 percentage points larger** under the nonparametric approach compared to the customary ad-valorem approach.
  - $\Rightarrow$ Maximum difference in predicted outcome can be as large as 27 percentage points.
- These findings are important in view of the growing literature on sufficient statistics for the welfare (or real-consumption) effects of trade openness relative to autarky.

Related literature

- **Generic general equilibrium trade models** : Eaton and Kortum (2002), Anderson and van Wincoop (2003), Arkolakis et al. (2012), Caliendo and Parro (2015).
- **Policy evaluation in general equilibrium trade models** : Breinlich et al. (2016), Felbermayr et al. (2016), Fajgelbaum et al. (2019).
- **Role of non-tariff barriers** : Bown (2011), Baldwin and Evenett (2012), Bown and Crowley (2013), Kinzius et al. (2019).
- **Causal effects estimations with generalized propensity scores** : Hirano and Imbens (2004), Imai and Van Dyk (2004), Flores et al. (2012), Kluve et al. (2012).

Back

Equilibrium

Equilibrium of sector-level wages is determined by

$$\underbrace{W_i^s L_i^s}_{Y_i^s} = \sum_{j=1}^{J} \frac{1}{1+t_{ij}^s} \underbrace{\frac{F_i^s (W_i^s)^{\alpha_s} C_{ij}^s}{\sum_k F_k^s (W_k^s)^{\alpha_s} C_{kj}^s}}_{\pi_{ij}^s} \underbrace{\beta_j^s \sum_{s=1}^{S} \frac{L_j^s W_j^s}{1 - \sum_s \sum_k \frac{t_{kj}^s}{1+t_{kj}^s} \pi_{kj}^s \beta_j^s}}_{E_j^s},$$

where

- Y_i^s is the value of production in sector s in country i.
- $\pi_{ij}^s = \frac{X_{ij}^s}{\sum\limits_k X_{kj}^s}$ is the trade share of goods from country i in j in sector s.
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$\Rightarrow$ Allows for solution in 'hat-notation' (Dekle et al., 2007). See here

Comparative statics

Using hat-notation, where $\dot{x} = \frac{x'}{x}$, trade-cost changes imply general-equilibrium changes of the form (see Dekle, Eaton, and Kortum, 2007) :

$$\dot{Y}_i^s = \frac{1}{Y_i^s} \sum_j \frac{1}{1 + t_{ij}^{s\prime}} \pi_{ij}^s \dot{\pi}_{ij}^s E_j^{s\prime}, \tag{1}$$

where

$$\dot{\pi}_{ij}^s = \frac{\left(\dot{Y}_i^s \dot{D}_{ij}^s\right)^{\alpha_s}}{\sum\limits_k \pi_{kj}^s \left(\dot{Y}_k^s \dot{D}_{kj}^s\right)^{\alpha_s}} \tag{2}$$

and

$$\dot{E}_j^s = \beta_j^s \frac{\sum_s \dot{Y}_j^s Y_j^s}{1 - \sum_s \sum_k \frac{t_{kj}^{s\prime}}{1+t_{kj}^{s\prime}} \pi_{kj}^s \beta_j^s \dot{\pi}_{kj}^s}. \tag{3}$$

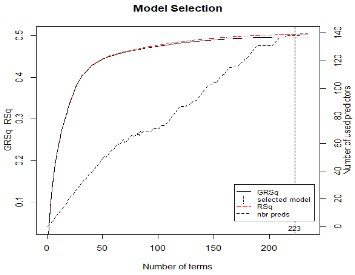
Equilibrium GE analysis

Fundamentals and fixed effects across countries

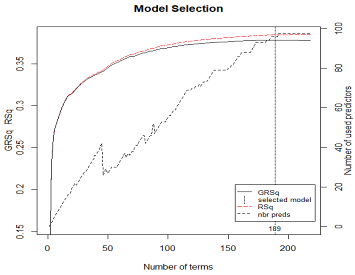
	Sector			
	Structural metal	Motor vehicles	Structural metal	Motor vehicles
Country	$\hat{f}_i^s$		$\hat{a}_i^s$	
China	-22.86	6.30	5.38	5.22
Germany	-20.74	11.21	3.99	7.60
Japan	-23.21	10.90	0.39	7.66
United States	-21.14	9.95	3.66	6.44
Mexico	-27.19	6.89	-0.26	3.92
India	-27.13	6.36	1.73	4.24
Brazil	-25.61	5.15	-0.31	2.49

Back

Model selection of $g_\tau(\cdot)$ and $g_\eta(\cdot)$



Determinants of log ad-valorem tariff barriers τ_{ij}^s : The optimization process selected 223 of 236 terms, and 138 of 313 predictors. The selected model yields a Generalized Cross Validation (GCV) of 0.003, a Residual Sum of Squares (RSS) of 301.080, a Generalized R^2 (GRSq) of 0.497 and a R^2 (RSq) of 0.503.



Determinants of log ad-valorem non-tariff barriers η_{ij}^s : The optimization process selected 189 of 218 terms, and 96 of 313 predictors. The selected model yields a Generalized Cross Validation (GCV) of 0.016, a Residual Sum of Squares (RSS) of 1437.698, a Generalized R^2 (GRSq) of 0.378 and a R^2 (RSq) of 0.385.

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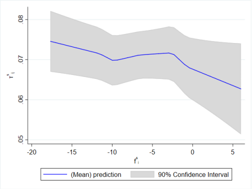
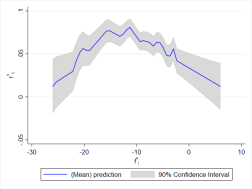
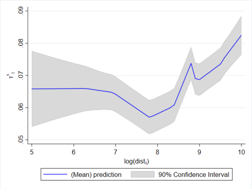
Relationship of policy barriers and selected covariates



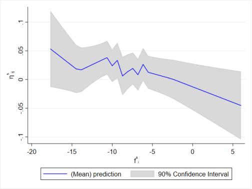
τ_{ij}^{s} across $\hat{f}_{i}^{s}$.



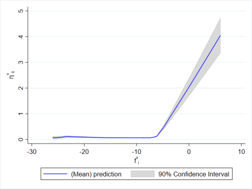
τ_{ij}^{s} across $\hat{f}_{j}^{s}$.



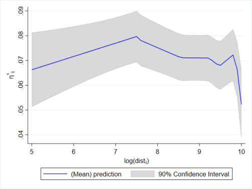
τ_{ij}^{s} across log(Distance$_{ij}$).



η_{ij}^{s} across $\hat{f}_{i}^{s}$.



η_{ij}^{s} across $\hat{f}_{j}^{s}$.



η_{ij}^{s} across log(Distance$_{ij}$).

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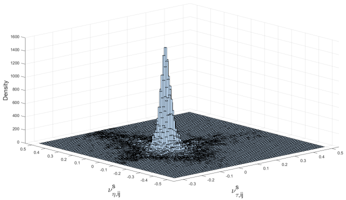
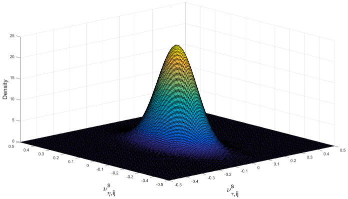
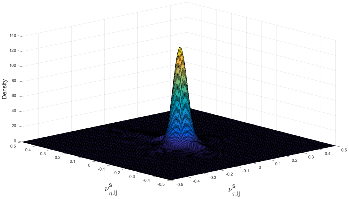
Bivariate histogram of ν_{ij}^s and its estimated distributions



Histogram of residuals.



Normal density estimation.



Non-parametric density estimation.

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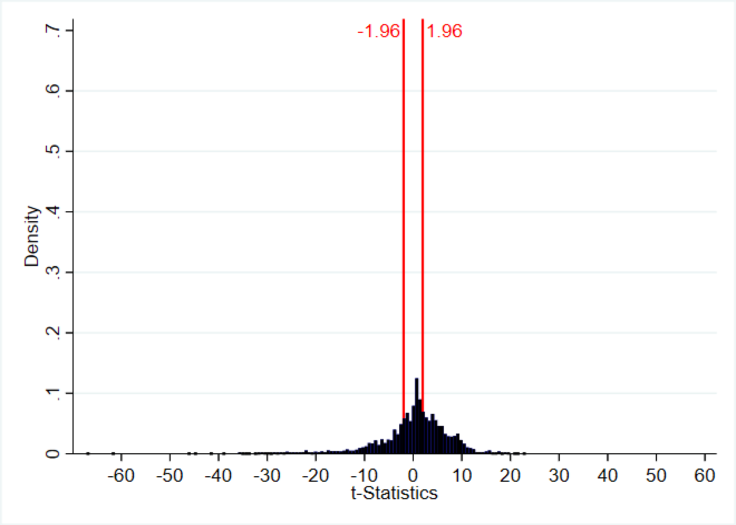
How to validate the generalized propensity score

- The GPS has a balancing property :

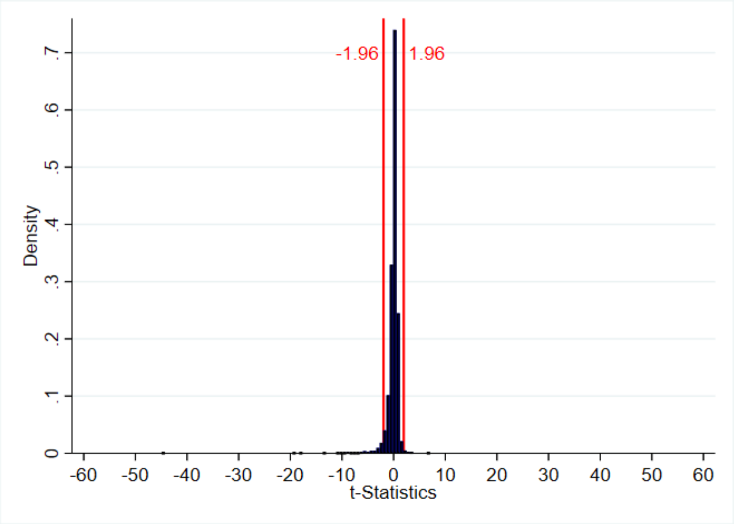
$$q_{ij}^{s} \perp \mathbf{1}\{m_{ij}^{s} = m\} | \hat{r}(m, q_{ij}^{s}).$$

- To assess it, we build nine groups of observations using the 33rd and 66th percentile of the policy variables as a cutoff (i.e., three groups for τ and three for η so that there are nine cells or *groups* ; see Hirano and Imbens, 2004).
- For each covariate q_{ij}^{s}, the mean across groups should be balanced after controlling for the GPS.
- Unconditionally, only 31% of the covariates are balanced while conditionally on the GPS 96% are balanced.
- Among the unbalanced covariates are many binary ones that take unity only in a single cell, e.g., sector indicators.

Distribution of t-statistics of equality-of-means test for all covariates without controlling for GPS



Distribution of t-statistics of equality-of-means test for all covariates controlling for GPS



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Description of GE analysis

- We need to define 2 parameters given the tariff rate, t_{ij}^{s} : the counterfactual level of tariffs, $t_{ij}^{s\prime}$, and the change in overall ad-valorem trade costs associated with this change of the tariff, $\dot{D}_{ij}^{s}$.
- 2 alternative sets of trade-cost responses, $\dot{D}_{ij}^{s}$: $\dot{D}_{ij}^{s,flex.gradient}$ and $\dot{D}_{ij}^{s,ad.valorem}$:
  1. $\dot{D}_{ij}^{s,ad.valorem} = \exp(log(1 + t_{ij}^{s\prime})/\exp(log(1 + t_{ij}^{s}))$.
  2. To obtain the flexible gradient, $\dot{D}_{ij}^{s,flex.gradient}$, we match each observed and counterfactual tariff and non-tariff level to the closest point on the grid : $\dot{D}_{ij}^{s,flex.gradient} = D_{ij}^{s\prime}/D_{ij}^{s}$.
- For the outcome, we consider *real* trade flows making the results independent of the numéraire choice.

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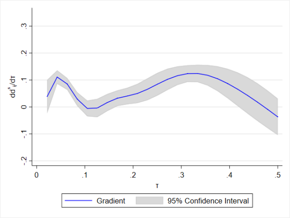
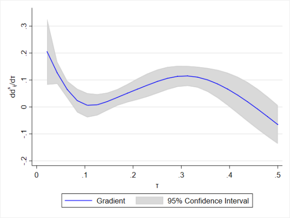
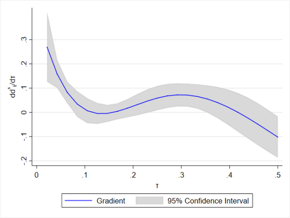
Assessing shape of gradient : Technical NTBs



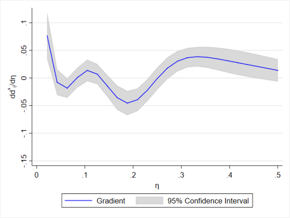
Low η.



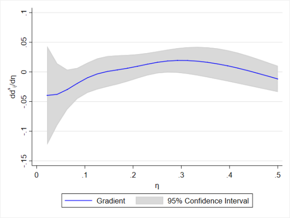
Medium η.



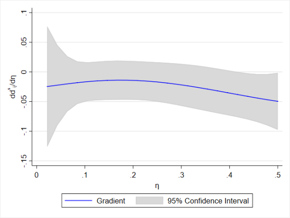
High η.



Low τ.

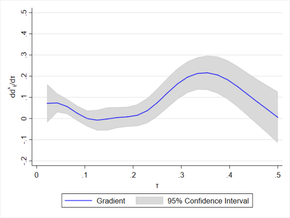


Medium τ.

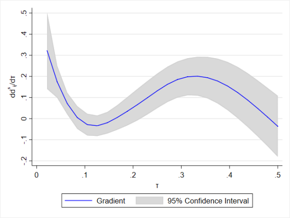


High τ.

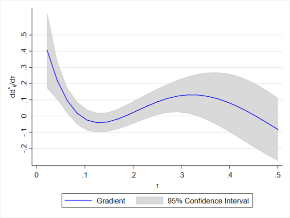
Assessing shape of gradient : Non-Technical NTBs



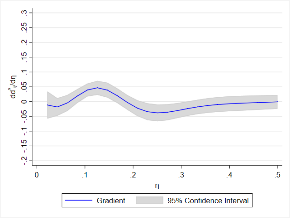
Low η.



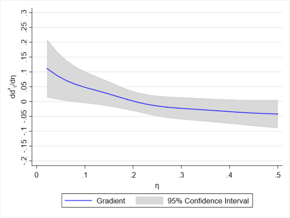
Medium η.



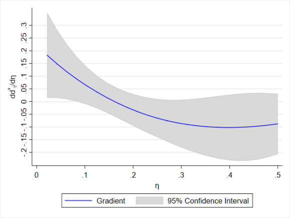
High η.



Low τ.

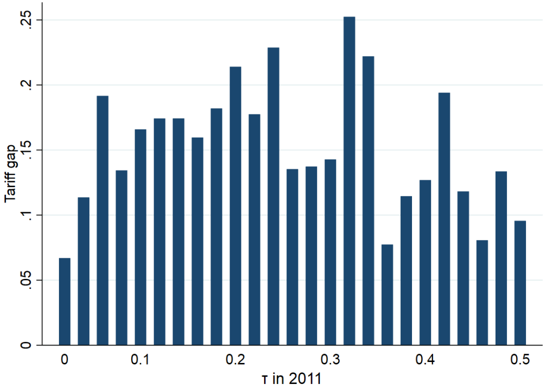


Medium τ.



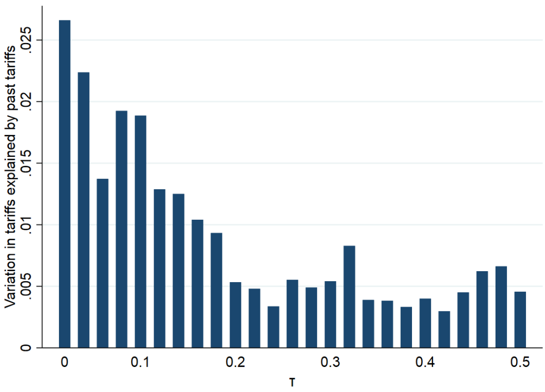
High τ.

Assessing shape of gradient : Uncertainty about tariff policy



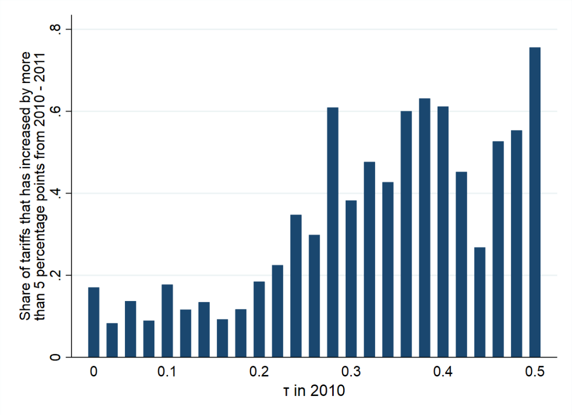
Tariff gap – the difference between bound and applied bilateral average tariffs – within bins of τ in 2011.

Assessing shape of gradient : Uncertainty about tariff policy



Explanatory power (R^2) of an AR(1) regression of τ_{ij}^s on its lagged values within bins of τ for the years 2001-2011.

Assessing shape of gradient : Uncertainty about tariff policy



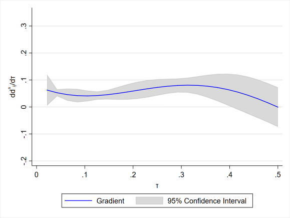
Unconditional probability of a significant rise in tariffs (more than 5 percentage points) from 2010 to 2011 depending on the tariff level in 2010.

Assessing shape of gradient : Further potential explanatory factors

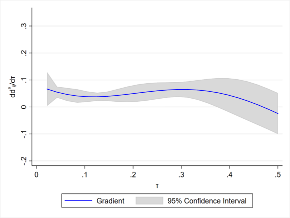
	Gradient w.r.t. τ	
Transparency$_j$	0.0041^{***}	
	(76.42)	
Preference margin$^s_{ij}$		0.0454^{***}
		(7.48)
Fixed effects	Exporter-sector	Exporter-sector
		Importer-sector
Observations	75,767	60,641
R^2	0.24	0.67

Note : We take the sample of the main analysis and merge every observation with the gradient that is closest to its true value of η and τ. We match indices for transparency (2006) from Transparency International as an inverse measure of corruption at the country-level and calculate the size of the preference margin in 2011 at the exporter-importer-sector level as the difference between the effectively applied tariff and the MFN applied tariff. The regression is weighted by the inverse of the

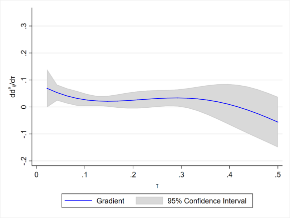
Role of endogeneity : Gradients without GPS



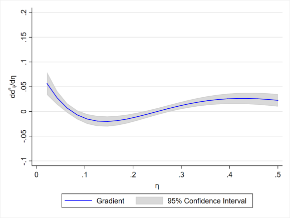
Low η.



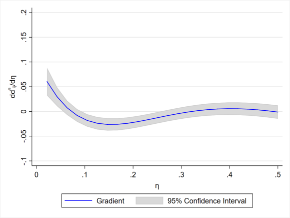
Medium η.



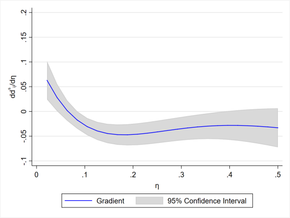
High η.



Low τ.



Medium τ.



High τ.