Horizontal Regulatory Barriers in International Trade: Evidence from Electric Plugs

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Motivation

- The focus of on-going trade negotiations has shifted towards domestic standards on products
  - Continuous effort from the World Trade Organization (WTO) to reduce regulatory barriers
  - Covered in 82% trade agreements (Piermartini and Budetta, 2009)
- Product standards can be vertical or horizontal
  - Vertical: can be ordered by stringency and are usually related to product quality
  - **Horizontal**: alternative means to achieve same level of utility
- Challenges in the analysis of product standards (Goldberg and Pavcnik, 2016)
  - Measurement
  - Endogeneity
  - Anticipation and uncertainty

Types of Electric Plugs Worldwide

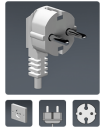
Type A

Type B

Type C

Type D

Type E



Type F

Type G

Type H

Type I

Type J

Type K

Type L

Type M

Type N

Source: International Electrotechnical Commission

This Paper

- **Research Question:** How do trade frictions associated incompatible electric plugs affect the international trade of electronic devices?

- Distinctive features of electric plugs
  - A well-documented example of horizontal regulatory barrier to trade $\Rightarrow$ hardly affect consumer preference
  - Standardized at country-level decades ago and rarely changed since then $\Rightarrow$ arguably immune to endogeneity, anticipation, and uncertainty concerns
  - Relatively homogeneous with simple production procedure $\Rightarrow$ control for firm-side confounding factors

This Paper

- Estimate trade frictions associated with incompatible electric plugs across countries using
  - Publicly available product-level data from United Nation's Comtrade Database
  - Disaggregate transaction-level data from China Customs Database
- Difference-in-difference estimation that exploits the variations in
  - Compatibility of regulations on electric plugs across country-pairs
  - Household and office appliances that use electric plugs versus other products
- Develop a Melitz (2003)-style model with endogenous quality to rationalize empirical findings

Main Findings

- **Intensive margin** (Comtrade and China Customs Database)
  - Countries/Chinese firms export fewer **treated products (household and office electronic devices that use plugs)** to destinations with incompatible electric plugs
- **Extensive margin** (China Customs Database)
  - Less Chinese firms export treated products to destinations with incompatible electric plugs
- **Product quality** (China Customs Database)
  - Chinese firms export treated products to destinations with incompatible electric plugs with **inferior quality**

Literature and Contributions

- **Horizontal standards:** provide empirical support to existing theoretical studies on horizontal standards
  - Costinot (2008); Toulemonde (2013); Mei (2019); Geng (2019); Parenti and Vannoorenberghe (2019); Macedoni and Weinberger (2020); Grossman et al. (2020)

- **Empirical analysis on non-tariff barriers:** first empirical study on horizontal regulatory barriers using both aggregate and disaggregate data
  - Essaji (2008); Chen and Mattoo (2008); Kee et al. (2009); Portugal-Perez et al. (2010); Fontagné et al. (2015); Fontagné and Orefice (2018); Fernandes et al. (2019); Schmidt and Steingress (2019); Yue (2019)

- **Product quality in international trade:** document the effect of horizontal regulations on vertical dimension of product differentiation
  - Verhoogen (2008); Baldwin and Harrigan (2011); Johnson (2012); Kugler and Verhoogen (2012); Hallak and Sivadasan (2013); Fan et al. (2015); Manova and Yu (2017); Fieler et al. (2018); Zhang (2018); Fan et al. (2020)

Roadmap

1. Introduction
2. Background and Data
3. Empirical Analysis
4. Model
5. Conclusion

Some Features of Electric Plugs

- Many countries only use three-pin plugs, other countries use both two- and three-pin plugs
- Three-pin plugs are commonly used in large devices with metal casing
- Two-pin plugs sometimes can fit into three-pin sockets, but different three-pin types are incompatible with each other
- Unsuccessful effort for standardization since 1950s: only Brazil and South Africa adopted the international standard (Type N) promoted by the International Electrotechnical Commission

▸ examples ▸ 2-pin ▸ 3-pin

Data: Incompatible plugs

- Define compatibility separately for two- and three-pin plugs
  - $\mathbf{T}^2_{ij}$: dummy indicating whether **two-pin plugs** in country i and country j are incompatible
  - $\mathbf{T}^3_{ij}$: dummy indicating whether **three-pin plugs** in country i and country j are incompatible
  - Advantage: no need to deal with compatibility between two-pin plugs and three-pin sockets

- Some countries use multiple two- and three-pin plugs
  - Example: Maldives uses Type A, C, D, G, J, K, and L
  - Define as incompatible if two countries do not share **any** two- or three-pin plug

Data: Treated versus Control Products

- Treated products
  - $\mathbf{D}_p$: household & office appliance p using alternating current (AC) and hence electric plugs
  - Treated products belong to 7 HS 2-digit categories ▸ table
  - Further distinguish between two- and three-pin appliances as robustness check

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  - Further distinguish between two- and three-pin appliances as robustness check
- Control groups:
  - **All other products**
  - **Appliances**: all other products in the 7 HS 2-digit categories with treated products
  - Alternative control groups refined within the 7 HS 2-digit categories as robustness check

Other Data Source

- Trade data (year 2010)
  - HS 6-digit trade flow data from Comtrade Database
  - HS 8-digit transaction-level data from China Customs Database

- Control for incompatible voltage requirement and frequencies across countries
  - Can be related to product safety and hence should not be treated as horizontal standards
  - Limited variation: 220V & 50 Hz versus 110V & 60 Hz

▸ voltage ▸ frequency

Summary Statistics

	Two-pin Plug	Three-pin Plug
(A) UN Comtrade Database (2010)		
Number of Exporting Countries	150	150
Number of Importing Countries	227	227
Average Number of Products per Exporter	16.71	26.28
Specific to China:		
China's Exports Share in the Seven HS 2-digit Categories	22.41%	
China's Exports Share in Products Using Plugs	52.54%	
(B) China Custom Database (2010)		
Number of Exporting Firms	10899	7375
Number of Importing Countries	206	207
Number of HS 8-digit Products	79	87
Average Number of Products per Exporting Firm	2.008	1.976

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Evidence from HS 6-digit Aggregate Data

- Difference-in-difference estimation in a structural gravity framework

$$\ln X_{ijp} = \beta_1 \mathbf{D}_p \times \mathbf{T}^2_{ij} + \beta_2 \mathbf{D}_p \times \mathbf{T}^3_{ij} + \mathbf{Z}'_{ijp}\gamma + \delta_{ip} + \delta_{jp} + \delta_{ij} + e_{ijp}$$

where

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where

- $\ln X_{ijp}$: logged value of trade flow of product p from country i to country j
- $\mathbf{D}_p$: dummy indicating whether product p uses electric plug
- $\mathbf{T}^2_{ij}/\mathbf{T}^3_{ij}$: dummies indicating incompatible two/three-pin plugs between country i and country j
- $\mathbf{Z}'_{ijp}$: controls that include incompatible voltage requirements and frequencies
- Exporter-product, importer-product, and exporter-importer fixed effect

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Evidence from HS 6-digit Aggregate Data

	Dependent variable: $\ln X_{ijp}$	
Control group	(1) All other products	(2) Appliances
Incompatible 2-pin plug	-0.144***	-0.169***
	(0.033)	(0.035)
Incompatible 3-pin plug	-0.058***	-0.066***
	(0.020)	(0.022)
Observations	5,709,594	633,568
R-squared	0.659	0.687

Notes: regressions use UN Comtrade data in 2010. All regressions control for incompatibility in voltage and frequency standards. **Exporter-HS6, importer-HS6, and exporter-importer fixed effects** are included; robust standard errors are clustered at exporter and HS 6-digit level and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Chinese Firm Data: Intensive versus Extensive Margin

- **Intensive margin**

$$\ln X_{fjp} = \beta_1 \mathbf{D}_p \times \mathbf{T}_j^2 + \beta_2 \mathbf{D}_p \times \mathbf{T}_j^3 + \mathbf{Z}'_{fjp}\gamma + \delta_{fj} + \delta_{fp} + \delta_{jg} + e_{ijp}$$

  - Dependent variable: sales of HS 8-digit product p from firm f to destination country j
  - Firm-importer, firm-HS-8-digit, and importer-HS-6-digit fixed effect

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- **Extensive margin**

$$N_{jp} = \beta_1 \mathbf{D}_p \times \mathbf{T}_j^2 + \beta_2 \mathbf{D}_p \times \mathbf{T}_j^3 + \mathbf{Z}'_{jp}\gamma + \delta_j + \delta_p + e_{jp}$$

  - Dependent variable: number of Chinese firms exporting HS 8-digit product p to country j
  - Importer and HS-8-digit fixed effect

Chinese Firm Data: Intensive versus Extensive Margin

Control group	All other products		Appliances	
Dependent variable:	(1) N_{jp}	(2) $\ln X_{fjp}$	(3) N_{jp}	(4) $\ln X_{fjp}$
Incompatible 2-pin plug	-0.480***	-0.173*	-0.680***	-0.268**
	(0.129)	(0.097)	(0.223)	(0.134)
Incompatible 3-pin plug	-0.617***	-0.325**	-2.148***	-0.476**
	(0.169)	(0.140)	(0.352)	(0.222)
Observations	1,457,652	3,197,317	116,781	275,195
R-squared	0.238	0.782	0.329	0.831

Notes: regressions use China Customs data in 2010. All regressions control for incompatible voltage and frequency. In regression **(1) and (3)** we control for **importer and HS8 fixed effects**; in regressions **(2) and (4)** we control for **firm-HS8, firm-importer, importer-HS6 fixed effects**. Robust standard errors are clustered at HS 8-digit level for (1) and (3), and at firm and HS 8-digit level for (2) and (4), and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Chinese Firm Data: Product Quality

- Horizontal regulations can still affect vertical dimension of product differentiation indirectly
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- Approach 1

$$\ln quantity_{fjp} = \beta_1 \mathbf{D}_p \times \mathbf{T}_j^2 + \beta_2 \mathbf{D}_p \times \mathbf{T}_j^3 + \beta_3 \ln price_{fjp} + \mathbf{Z}'_{fjp}\gamma + \delta_{fj} + \delta_{fp} + \delta_{jg} + e_{ijp}$$

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- Approach 2: Measure quality directly using the approach from Khandelwal et al. (2013)

$$\ln quantity_{fjp} + \sigma \ln price_{fjp} = \delta_p + \delta_j + e_{fjp} \quad \text{with} \quad \sigma = 4$$ ▸ robustness

  - Estimated quality $\ln \hat{q}_{fjp} = \hat{e}_{fjp}/(\sigma - 1)$

Chinese Firm Data: Product Quality

Control Group	All other products			Appliances		
Dependent Var	(1) Quantity	(2) Quality	(3) Adj-Price	(4) Quantity	(5) Quality	(6) Adj-Price
Incompatible	-0.160**	-0.088*	0.056*	-0.232*	-0.150**	0.085*
2-pin plug	(0.081)	(0.051)	(0.032)	(0.126)	(0.071)	(0.044)
Incompatible	-0.312**	-0.111	0.105**	-0.462*	-0.143	0.153**
3-pin plug	(0.152)	(0.074)	(0.046)	(0.247)	(0.123)	(0.074)
ln $price_{fjp}$	-0.711***			-0.644***		
	(0.003)			(0.009)		
Observations	3,173,306	3,173,306	3,173,306	272,108	272,108	272,108
R-squared	0.848	0.799	0.957	0.854	0.841	0.955

Notes: regressions use China Customs data in 2010. All regressions control for incompatibility in voltage and frequency standards. **Firm-HS8, firm-importer, importer-HS6 fixed effects** are included in all these regressions. Robust standard errors are clustered at firm and HS 8-digit level, and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Robustness Checks

- Alternative control groups ▸ details
  - Parts and components that belong to the seven treated HS 2-digit categories
  - Appliances in the seven treated HS 2-digit categories but do not use electric plugs

- Additional controls
  - Interaction with colonial linkage and language similarity ▸ details
  - Interaction with incompatible voltage and frequency ▸ details

- Distinguish between electronic appliances that use two- or three-pin plugs ▸ details

Roadmap

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Model: Setup

- A Melitz (2003)-style model with endogenous quality for each destination
- Higher product quality increases demand at the cost of
  - Higher marginal cost of production
  - **Higher destination-specific fixed market entry cost**
- In equilibrium, higher fixed cost due to incompatible standards
  - Reduces the number of exporting firms
  - Induce exporting firms to choose lower quality

Model: Demand

- Preference of consumers in country j:

$$U_j = \left(\sum_i \int_{\omega \in \Omega_{ij}} [q_{ij}(\omega) x_{ij}(\omega)]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

- Demand for quality units of variety ω in country j

$$q_{ij}(\omega) x_{ij}(\omega) = [\tilde{p}_{ij}(\omega)]^{-\sigma} P_j^{\sigma-1} E_j$$

  - $\tilde{p}_{ij}(\omega) = p_{ij}(\omega)/q_{ij}(\omega)$ is the quality-adjusted price of variety ω
  - $P_j = \sum_i (\int_{\omega \in \Omega_{ij}} [\tilde{p}_{ij}(\omega)]^{1-\sigma} d\omega)^{1/(\sigma-1)}$ is the (quality-adjusted) ideal price index
  - E_j is country j's aggregate expenditure

Model: Production

- Inverse production function: $\frac{xq^{\eta}}{\varphi} = l$
  - **Assumption**: $0 < \eta < 1$
  - Quality-adjusted price $\tilde{p}_{ij}(\varphi) = \frac{\sigma}{\sigma-1}\frac{\tau_{ij} w_i q_{ij}^{\eta-1}}{\varphi}$ is decreasing in quality
  - Higher marginal cost associated with higher operating profit

- Fixed market entry-cost: $f_{ij}(\varphi) = f_0 + s_{ij} q_{ij}^{\phi}$
  - $s_{ij} > s_{ii} = \underline{s}$ captures trade frictions associated with incompatible electric plugs
  - If $f_{ij}(\varphi)$ is independent of q_{ij}, incompatible standards will **raise** product quality

Model: Equilibrium

- Post-entry profit: $\pi_{ij}(\varphi) = \underbrace{\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{\tau_{ij}w_i q_{ij}^{\eta-1}}{\varphi}\right)^{1-\sigma} P_j^{\sigma-1}E_j}_{\text{variable profit}} - \underbrace{(f_0 + s_{ij}q_{ij}^{\phi})}_{\text{fixed cost}}$
  - **Assumption**: $\phi > (1-\eta)(\sigma-1)$ to ensure interior solution of optimal q_{ij}
- A country i firm with productivity φ chooses optimal quality $q_{ij}^*(\varphi)$ that maximizes $\pi_{ij}(\varphi)$
- Serve market j if $\pi_{ij}^*(\varphi) \geq 0$

Model: Propositions

Proposition 1

Conditional on entering market j, a higher s_{ij} induces an exporter from country i to reduce the quality and hence increase the quality-adjusted price of its exports in equilibrium.

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Proposition 2

An increase in s_{ij} reduces the total number of exporters from country i to country j.

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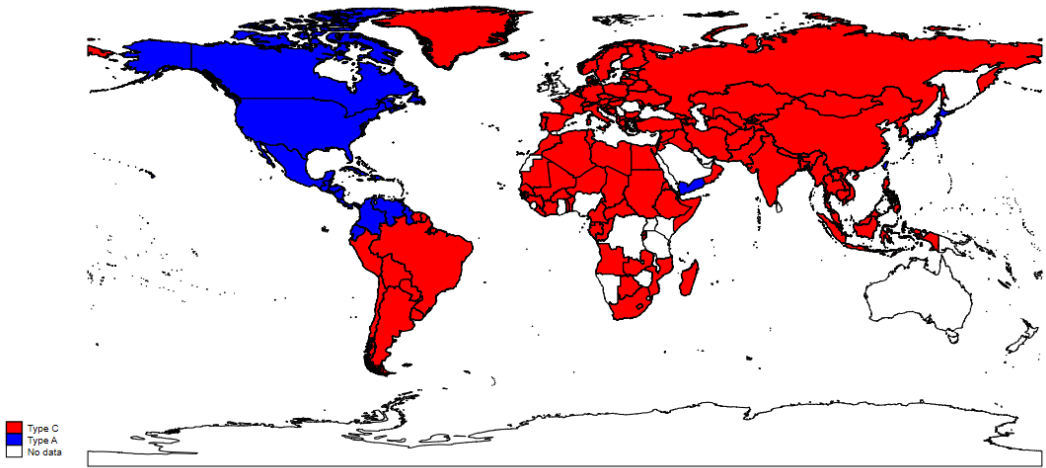
Conclusion

- Quantify trade frictions associated with incompatible electric plugs
- Main findings
  - Incompatible regulations reduce trade through both extensive and intensive margin
  - Horizontal standards can affect firms' decision on vertical product differentiation
- Future Work
  - More appropriate control groups
  - Compute ad valorem equivalent of incompatible plugs
  - Any suggestions?

THANK YOU

Distribution of Two-Pin Plugs

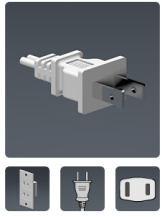


Source: International Electrotechnical Commission

back

Examples

- United States

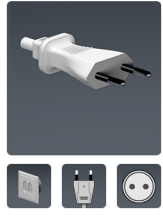


Type A

Type B

- China

Type A

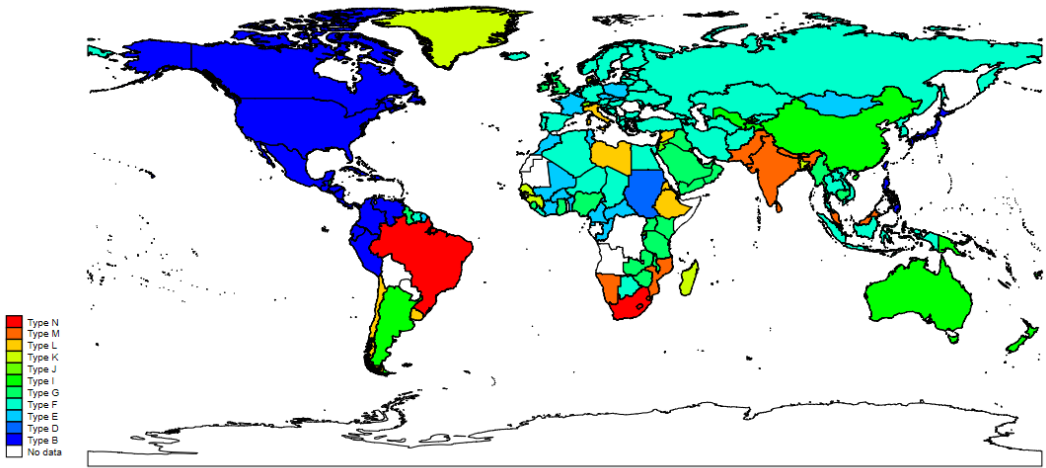


Type C

Type I

back

Distribution of Three-Pin Plugs



Source: International Electrotechnical Commission

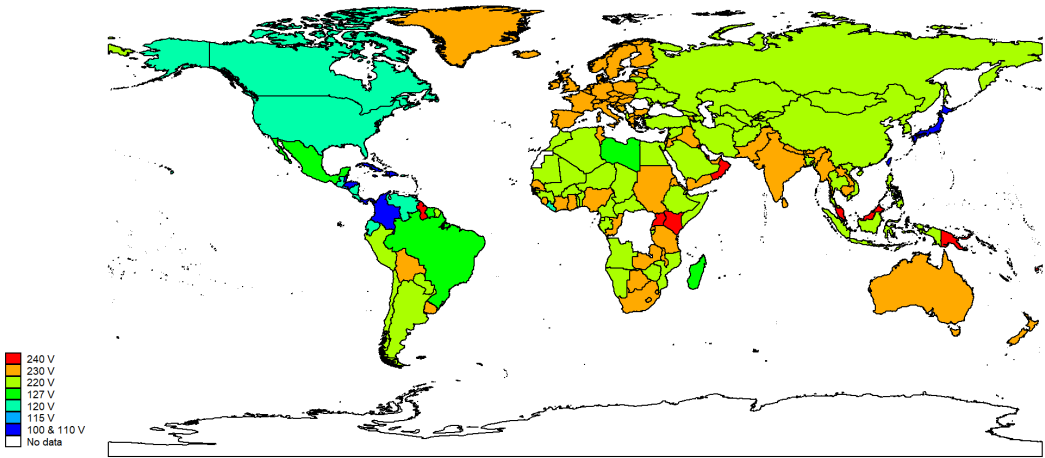
back

Treated Products/Appliances by HS 2-digit Product Category

HS 2-digit	Description
82	Tools, Implements, Cutlery, Spoons And Forks, Of Base Metal; Parts Thereof, Of Base Metal
83	Miscellaneous articles of base metal
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles,
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof
91	Clocks And Watches And Parts Thereof
92	Musical Instruments; Parts And Accessories Of Such Articles

back

Distribution of Voltage Requirements



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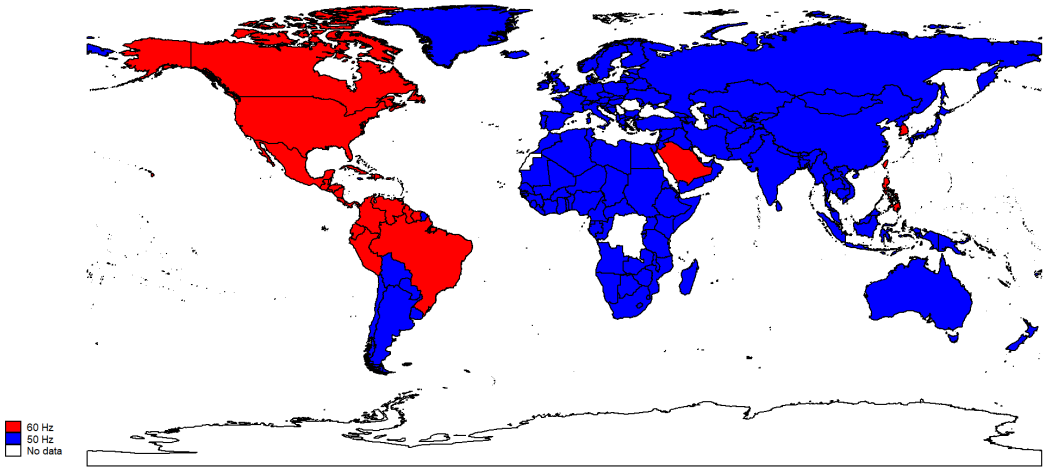
back

Distribution of Frequency



Source: International Electrotechnical Commission

back

Robustness: Different Values of σ

Dependent variable: *quality*	(1) All other products	(2) Appliances
	(A) $\sigma = 2$	
Incompatible 2-pin plug	-0.201*	-0.320**
	(0.107)	(0.148)
Incompatible 3-pin plug	-0.320**	-0.448*
	(0.152)	(0.250)
	(B) $\sigma = 3$	
Incompatible 2-pin plug	-0.116*	-0.192**
	(0.064)	(0.088)
Incompatible 3-pin plug	-0.164*	-0.219
	(0.091)	(0.151)
	(C) $\sigma = 5$	
Incompatible 2-pin plug	-0.074	-0.129**
	(0.046)	(0.063)
Incompatible 3-pin plug	-0.085	-0.105
	(0.067)	(0.111)

back

Robustness Check: Alternative Control Groups

- Parts and components that belong to the seven treated HS 2-digit categories
- Appliances in the seven treated HS 2-digit categories but do not use electric plugs

Dependent variable: $\ln X_{ijp}$	(1) Appliances (parts only)	(2) Appliances (no plugs)
Incompatible 2-pin plug	-0.222***	-0.110**
	(0.038)	(0.043)
Incompatible 3-pin plug	-0.084**	-0.187***
	(0.038)	(0.043)
Observations	470,649	250,260
R-squared	0.682	0.710

Notes: regressions use UN Comtrade data in 2010. All regressions control for incompatibility in voltage and frequency standards. Exporter-HS6, Importer-HS6, and Exporter-Importer fixed effects are included; robust standard errors are clustered at exporter and HS 6-digit level and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

back

Robustness Check: Colonial Linkage and Language Similarity

Interaction	Colonial Linkage		Language Similarity	
Control group:	(1) All other	(2) Appliances	(3) All other	(4) Appliances
Incompatible 2-pin plug	-0.143***	-0.170***	-0.173***	-0.169***
	(0.033)	(0.035)	(0.040)	(0.043)
Incompatible 3-pin plug	-0.056***	-0.070***	-0.037	-0.064**
	(0.021)	(0.023)	(0.025)	(0.027)
Observations	5,709,596	633,568	3,201,406	344,333
R-squared	0.659	0.687	0.705	0.735

Notes: regressions use UN Comtrade data in 2010. All regressions control for incompatibility in voltage and frequency standards. Exporter-HS6, Importer-HS6, and Exporter-Importer fixed effects are included; robust standard errors are clustered at exporter and HS 6-digit level and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

back

Robustness Check: Interaction with Voltage and Frequency

Control group	(1) All other products	(2) Appliances	(3) Appliances	(4) Appliances
Dependent variable: $\ln X_{ijp}$			(parts only)	(no plugs)
Incompatible 2-pin plug	-0.144***	-0.217***	-0.284***	-0.121**
	(0.039)	(0.043)	(0.046)	(0.054)
Incompatible 3-pin plug	-0.063*	-0.118***	-0.115***	-0.193***
	(0.035)	(0.037)	(0.041)	(0.046)
Incompatible voltage	0.033	-0.025	-0.025	-0.030
	(0.023)	(0.024)	(0.026)	(0.030)
Incompatible frequency	-0.151***	-0.153***	-0.144***	-0.191***
	(0.033)	(0.035)	(0.038)	(0.043)
Incompatible voltage &	-0.009	0.075*	0.095**	0.017
Incompatible 2-*or* 3-pin plug	(0.037)	(0.040)	(0.044)	(0.050)
Observations	5,709,594	633,568	470,649	250,260
R-squared	0.659	0.687	0.682	0.710

▸ back

Robustness Check: Distinguish between Two- or Three-pin Appliances

$$\ln X_{ijp} = \beta_1 \mathbf{D}_p^2 \times \mathbf{T}_{ij}^2 + \beta_2 \mathbf{D}_p^3 \times \mathbf{T}_{ij}^3 + \mathbf{Z}'_{ijp}\gamma + \delta_{ip} + \delta_{jp} + \delta_{ij} + e_{ijp}$$

Control group	(1) All other products	(2) Appliances	(3) Appliances	(4) Appliances
Dependent variable: $\ln X_{ijp}$			(parts only)	(No plugs)
Incompatible 2-pin plug	-0.215***	-0.234***	-0.273***	-0.204***
	(0.044)	(0.044)	(0.048)	(0.049)
Incompatible 3-pin plug	-0.074***	-0.077***	-0.100***	-0.079***
	(0.026)	(0.027)	(0.028)	(0.030)
Observations	5,709,594	633,568	470,649	250,260
R-squared	0.659	0.687	0.682	0.710

Notes: regressions use UN Comtrade data in 2010. All regressions control for incompatibility in voltage and frequency standards. Exporter-HS6, Importer-HS6, and Exporter-Importer fixed effects are included; robust standard errors are clustered at exporter and HS 6-digit level and are reported in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

back

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