Gravity beyond CES: Implications for Substitution Patterns and Welfare

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Introduction

- Gravity models are a popular tool for trade economists.
  - Theoretically founded, easy to estimate and have good predictive power.

- However, this tractability rules out important aspects of international trade.

$$\log s_{od} = \log C_o + (1-\sigma)\log \tau_{od} - \log \left[\sum_{o'} C_{o'} \tau_{od}^{1-\sigma} \right]$$

  - Multilateral term is common across origins: no role for vertical differentiation for instance.
  - Change in competition impact all origins similarly: Independence of Irrelevant Alternatives (IIA) property.

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  - Multilateral term is common across origins: no role for vertical differentiation for instance.
  - Change in competition impact all origins similarly: Independence of Irrelevant Alternatives (IIA) property.

- We develop an empirical strategy to capture more realistic patterns of differentiation.
  - Maintain the tractability of gravity regressions (2SLS estimation)
  - Capture the importance of differentiation and generate more realistic substitution patterns.

This paper

- Show evidence of deviations from the IIA assumption.
  - The China shock had a stronger impact on competitors that are similar to China.
- We apply an empirical strategy that linearizes a demand system with mixed preferences
  - Mixed preferences generate flexible substitution patterns across countries.
  - Augment the linear gravity model with additional terms to capture the role of differentiation in the destination market.
- We estimate this gravity model to quantify the importance of vertical and geographical differentiation in the data.
- We explore the implications of these substitution patterns:
  - predictions of the gravity model in response to a trade shock.
  - welfare impacts along the income distribution.

Preview of the results

- We find an important role for vertical and geographical differentiation.
  - The position of a country in the price distribution has an impact on its performance in export markets.
  - For instance, a country whose log price distance from the average moves from 0.5 to 1, increases its export value by 5 percent.

- Simulating the ban of Chinese exports to the US market,
  - we find vastly different effects on countries based on their position in the price distribution.
  - Heterogeneity in consumer preferences generates non-monotonic welfare effects along the income distribution.

Related literature

- Mixed preferences in international trade
  - Adao, Costinot and Donaldson (2017), Heins (2021), Head and Mayer (2021), Piveteau and Smagghue (2021).
- Random-coefficients demand system
  - Berry, Levinsohn and Pakes (1995), Salanie and Wolak (2019).
- Heterogenous gains from trade
  - Fajgelbaum and Khandelwal (2016), Borusyak and Jaravel (2021).

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1. Introduction

2. Evidence of deviations from IIA

3. Model with mixed preferences

4. Gravity estimation

5. Implications

6. Conclusion

Deviations from IIA

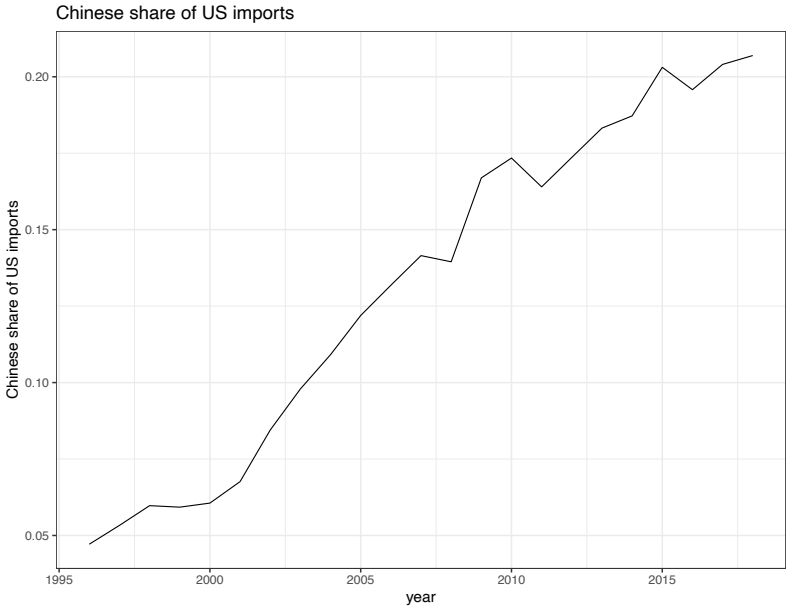
- CES preferences and its IIA assumption imply that all exporters are similarly impacted by a change in competition.
- We test this assumption by looking at a large supply shock: the China shock in the US.
- Are products similar to Chinese products more affected by the rise of China?
- Specification:

$$\log X_{okt} = \beta \left(Position_{ok} \times MSC_{kt} \right) + \gamma_{kt} + \delta_{ok} + \varepsilon_{okt}$$

  - X_{okt} is the US imports of hs6 product k from origin o at time t.
  - MSC_{kt} the US import market share of Chinese products for product k at time t.
  - $Position_{ok}$ the "position" of country o relative to China in product k.

Data

- BACI provides yearly bilateral trade flows at the hs6 level ($\approx$ 5000 products).
- We focus on the exports to the US from 1996 to 2018.
- Position in the price space based on the relative price between origin o and China.
  - $\log \tilde{p}_{okt_0} \equiv \log p_{okt_0} - \log p_{Ckt_0}$.
  - Price defined as unit values (exported value divided by exported quantities).
- Two measures:
  - Quadratic distance: $(\log \tilde{p}_{okt_0})^2$
  - $$Position_{ok} = \begin{cases} -2 & \text{if } \log \tilde{p}_{okt_0} < -2 \\ -1 & \text{if } \log \tilde{p}_{okt_0} \in [-2, -0.5] \\ 0 & \text{if } \log \tilde{p}_{okt_0} \in [-0.5, 0.5] \\ 1 & \text{if } \log \tilde{p}_{okt_0} \in [0.5, 2] \\ 2 & \text{if } \log \tilde{p}_{okt_0} > 2 \end{cases}$$


Chinese share of US imports
Chinese share of US imports
0.20
0.15
0.10
0.05
1995
2000
2005
2010
2015
year

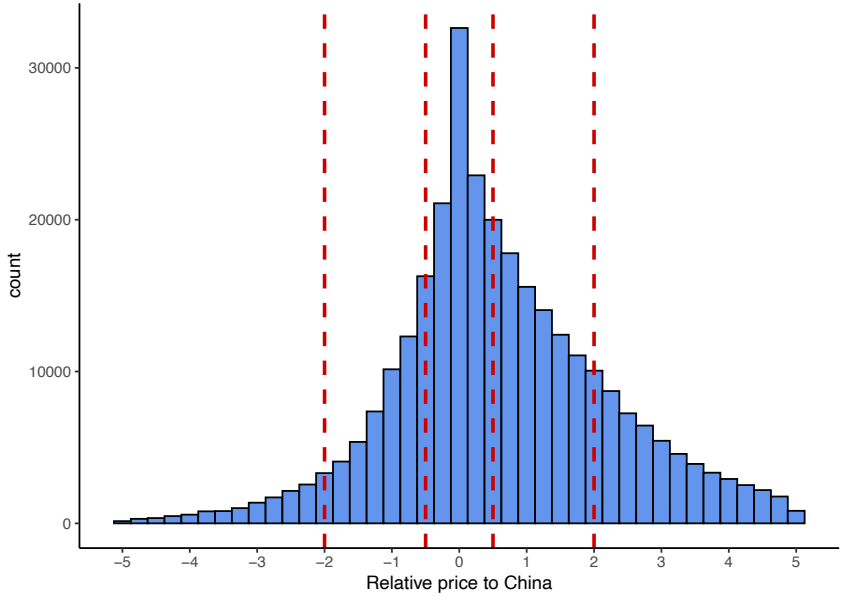

30000
20000
10000
0
count
−5
−4
−3
−2
−1
0
1
2
3
4
5
Relative price to China

Table: Exporters far from China suffer less from the China shock

	log $export_{okt}$			
	(1)	(2)	(3)	(4)
$MSC_{kt} \times (\log \tilde{p}_{okt_0})^2$	0.15***	0.15***		
	(0.01)	(0.01)		
$MSC_{kt} \times (Position_{ok} = -2)$			0.19**	0.20**
			(0.10)	(0.10)
$MSC_{kt} \times (Position_{ok} = -1)$			0.18***	0.20***
			(0.06)	(0.06)
$MSC_{kt} \times (Position_{ok} = 1)$			0.21***	0.19***
			(0.04)	(0.05)
$MSC_{kt} \times (Position_{ok} = 2)$			0.65***	0.62***
			(0.05)	(0.05)
Num.Obs.	2 853 160	2 631 408	2 853 160	2 631 408
Exporting country	All	Top 100	All	Top 100

Notes: Standard errors clustered at the origin country level. All specifications include origin x product and product x time fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p \leqslant 0.01$

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Mixed preferences

- A common solution to relax the IIA assumption is to introduce mixed preferences.
  - Consumers have CES preferences, but differ on how they value product characteristics.
- As a result, consumers buy from different countries based on the characteristics of their product.
- Countries that share characteristics (similar quality, similar prices) sell to the same type of consumers and are closer substitutes.
- In the example of the China shock:
  - Price-elastic consumers buy relatively more from low-cost countries like China.
  - When Chinese products enter the market, those low-cost countries suffer the most because their consumers are likely to switch toward Chinese products.

Preferences

- In a given product market, a consumer i derives utility from varieties o from a set of origin countries.

$$U_i = \left(\sum_o \exp(\beta_i X_o + \xi_o) \, q_{io}^{\frac{\alpha_i}{\alpha_i - 1}} \right)^{\frac{\alpha_i - 1}{\alpha_i}}$$

  - X_o: observable characteristics.
  - ξ_o: unobserved utility shifter (quality).
  - q_{io}: quantity purchased by i from country o.
  - β_i and α_i are consumer-specific preference parameters

- Demand shares from consumer i:

$$s_{io} = \frac{\exp(\beta_i X_o + (1 - \alpha_i) \log p_o + \xi_o)}{\sum_o \exp(\beta_i X_o + (1 - \alpha_i) \log p_o + \xi_o)}.$$

Aggregate import shares

- In each destination market d, we have a continuum of consumer i with a budget e_i, proportional to their income y_i, for this product.

- The aggregate import share in d from a country o is

$$s_{od} = \frac{\int_{i \in d} \pi_{io}\, e_i}{\int_{i \in d} e_i}\, di = \int_{i \in d} \frac{\exp(\beta_i X_{od} + (1 - \alpha_i) \log p_{od} + \xi_{od})}{\sum_o \exp(\beta_i X_{od} + (1 - \alpha_i) \log p_{od} + \xi_{od})}\, \omega_i\, di$$

- We need to make assumptions on the distributions of the consumer-specific terms.
  - $\alpha_i = \alpha + \pi \ln y_i + \sigma_\alpha \varepsilon_i^{(1)}$
  - $\beta_i = \beta + \sigma_\beta \varepsilon_i^{(2)}$
  - $E(\varepsilon_i) \equiv \int_{i \in d} \varepsilon_i \omega_i di = 0$ and $V(\varepsilon_i) \equiv \int_{i \in d} (\varepsilon_i - E(\varepsilon_i))^2 \omega_i di = 1$
  - $E(\ln y_i) = \mu_{y_d}$ and $V(\ln y_i) = V_{y_d}$

Approximation

- Salanie and Wolak (2019) shows how to approximate random-coefficients demand systems with a linear estimator.
  - Intuition: Taylor expansion of the structural error.

- With $\theta \equiv \{\pi, \sigma_\alpha, \sigma_\beta\}$, the vector of structural errors ξ is defined to match the observed import shares $\hat{s}_{od}$:

$$s_{od}(\xi, \theta) = \hat{s}_{od} \quad \text{so that we can write} \quad \xi \equiv \xi(\theta).$$

- Second-order expansion around $\theta = 0$:

$$\xi(\theta) = \xi(0) + \left.\frac{\partial \xi(\theta)}{\partial \theta}\right|_{\theta=0} \theta + \left.\frac{\partial^2 \xi(\theta)}{\partial \theta^2}\right|_{\theta=0} \frac{\theta^2}{2} + O(\sigma^3)$$

Estimation regression

- The second-order expansion leads to a linear regression:

$$\xi(\theta) = \xi(0) + \left.\frac{\partial \xi(\theta)}{\partial \theta}\right|_{\theta=0} \theta + \left.\frac{\partial^2 \xi(\theta)}{\partial \theta^2}\right|_{\theta=0} \frac{\theta^2}{2} + O(\sigma^3)$$

$$\log\left(\frac{\hat{s}_{od}}{\hat{s}_{oo}}\right) = \beta \tilde{X}_{od} - \alpha \widetilde{\log} p_{od} - \pi \mu_{y_d} \widetilde{\log} p_{od} + \sigma_\alpha^2 K_{od}^{\log p} + \sigma_\beta^2 K_{od}^{X} + \pi^2 V_{y_d} K_{od}^{\log p} + \xi_{od}$$

with

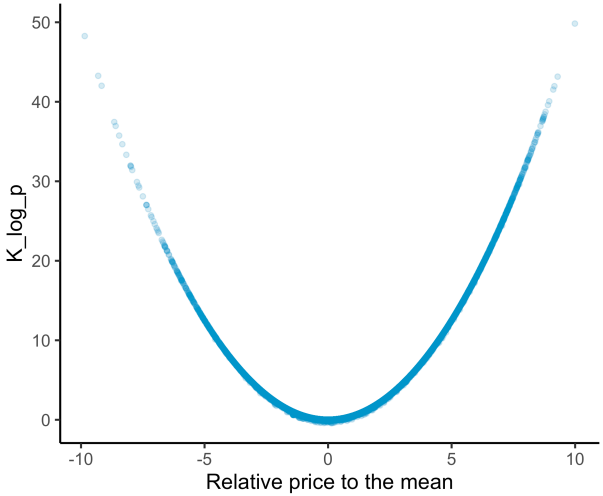
  - $\tilde{X}_{od}$ and $\widetilde{\log} p_{od}$ are characteristics normalized by the domestic good: $\tilde{X}_{od} = X_{od} - X_{oo}$.
  - K variables are called artificial regressors.

- $K_{od}^{\log p} = \widetilde{\log} p_{od} \left(\frac{\widetilde{\log} p_{od}}{2} - \sum_{o'} \hat{s}_{o'd} \widetilde{\log} p_{o'd} \right)$

Artificial regressors – Intuition

Artificial regressors identify the variance in consumer preferences.

- Measure the distance between a variety and the rest of the market.
- A variety far from others will sell more ceteris paribus.



Summary

- Economists used mixed preferences to capture realistic patterns of substitution across firms.
- However, their use is fairly limited because these models are difficult to estimate.
- The small-σ expansion of the model allows us to obtain a linear regression that can easily estimate the non-linear parameters of the model.
- Only requires to compute additional variables and add them in a standard 2SLS regression.

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Data requirements

- The data requirements are similar to those of a gravity model or a demand system.
  - However, necessary to define an outside good to normalize the characteristics.
- Data sources:
  - BACI for trade flows,
  - MacMap for bilateral tariffs,
  - CEPII for gravity variables,
  - World Input Output Database (WIOD) for domestic market shares,
  - World Development Indicator for income distributions.
- Coverage:
  - varieties defined at the country x HS6 level,
  - years 2001, 2004 and 2007 (years of MacMap),
  - 42 destinations from WIOD .

Specification

- Baseline specification for origin o, destination d, product k at time t:

$$\begin{aligned}\log export_{odkt} = &\beta X_{odt} + \alpha \log p_{odkt} + \alpha_y \log p_{odkt} \times \mu_{y_d} \\ &+ \delta_1 K^{\log p}_{odkt} + \delta_2 K^{\log p}_{odkt} \times V_{y_d} + \delta_3 K^{region}_{od} \\ &+ \gamma_{dkt} + \gamma_{okt} + \varepsilon_{odkt}\end{aligned}$$

- Prices are endogenous.
  - Tariffs as instrument.

- K variables also endogenous by construction.
  - $K^{\log p}_{odkt} = \tilde{\log} p_{odkt} \left(\frac{\tilde{\log} p_{odkt}}{2} - \sum_{o'} \hat{s}_{o'dkt} \tilde{\log} p_{o'dkt} \right)$
  - Regress prices and import shares on the set of instruments to construct exogenous predictions of these variables.
  - Construct an "exogenous" version of K to use as instrument.

Results with artificial regressors

	(1) OLS	(2) RF	(3) 2SLS
$\log p$	-0.07^{***}		-1.86^{***}
	(0.00)		(0.06)
$\log(1 + \text{tariff})$		-1.71^{***}	
		(0.05)	

Notes: Number of observations: 8 774 989. Standard errors clustered at the origin -product and destination-product levels. All specifications include origin x product, destination x product time fixed effects and bilateral gravity variables. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Results with artificial regressors

	(1) OLS	(2) RF	(3) 2SLS	(4) OLS	(5) 2SLS
$\log p$	−0.07***		−1.86***		−1.99***
	(0.00)		(0.06)		(0.07)
$\log(1 + \text{tariff})$		−1.71***		−1.46***	
		(0.05)		(0.05)	
$K^{\log p}$				−0.04***	0.18***
				(0.00)	(0.01)
K^{region}				−7.67***	1.14***
				(0.03)	(0.06)

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Results with artificial regressors

	(1) OLS	(2) RF	(3) 2SLS	(4) OLS	(5) 2SLS	(6) 2SLS
$\log p$	−0.07***		−1.86***		−1.99***	−2.67***
	(0.00)		(0.06)		(0.07)	(0.13)
$\log(1 + \text{tariff})$		−1.71***		−1.46***		
		(0.05)		(0.05)		
$K^{\log p}$				−0.04***	0.18***	0.52***
				(0.00)	(0.01)	(0.04)
K^{region}				−7.67***	1.14***	1.42***
				(0.03)	(0.06)	(0.07)
$\log p \times \mu_{y_d}$						0.81***
						(0.08)
$K^{\log p} \times V_{y_d}$						0.64***
						(0.08)

Notes: Number of observations: 8 774 989. Standard errors clustered at the origin -product and destination-product levels. All specifications include origin x product, destination x product time fixed effects and bilateral gravity variables. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Gravity-like regressions

	(1) OLS	(2) OLS	(3) 2SLS
log(1 + tariff)	−1.71***	−1.43***	−1.66***
	(0.05)	(0.05)	(0.05)
$K^{\log gdpc}$		0.02***	0.04***
		(0.00)	(0.00)
K^{region}		−7.71***	1.76***
		(0.03)	(0.05)

Notes: Number of observations: 8 774 989. Standard errors clustered at the origin -product and destination-product levels. All specifications include origin x product, destination x product time fixed effects and bilateral gravity variables. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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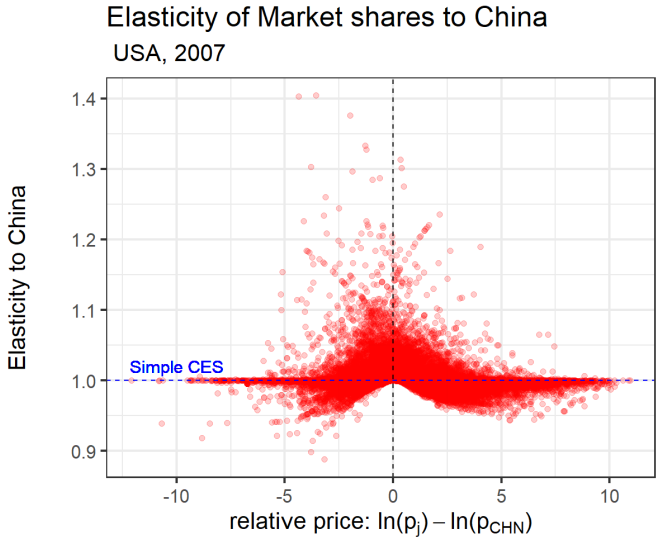
Implications

- We introduced heterogeneity in consumer preferences to obtain a model with more realistic substitution patterns.
  - Role for vertical differentiation, spatial competition.
- First implication on trade flows:
  - the model can capture the heterogenous impacts on trade flows of trade liberalization, competition shocks, etc...
- Second implication for welfare:
  - Because consumers differ in their preferences, they are differently impacted by a change in trade flows.

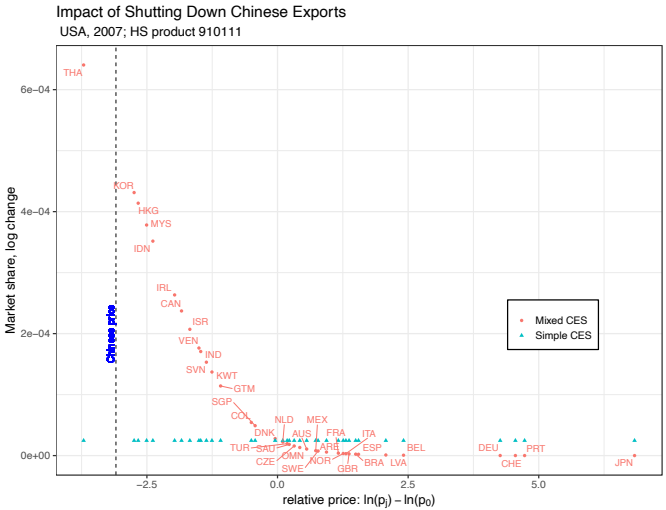
Implications on trade flows

- Countries are now differently impacted by a change in competition.
- The cross elasticity with respect to China depends on the distance from Chinese prices.



Implications on trade flows

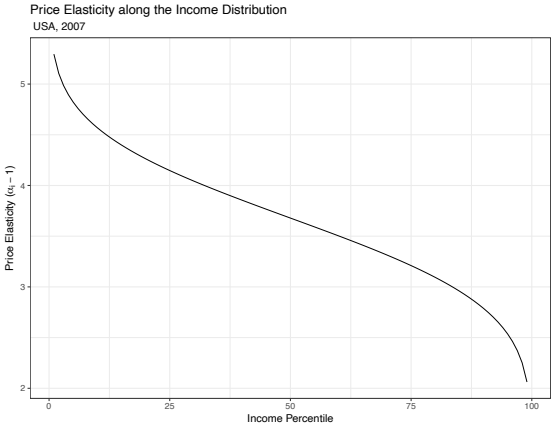
- Countries are now differently impacted by a change in competition.
- The cross elasticity with respect to China depends on the distance from Chinese prices.
- A ban on Chinese exports have very heterogenous effects across countries.

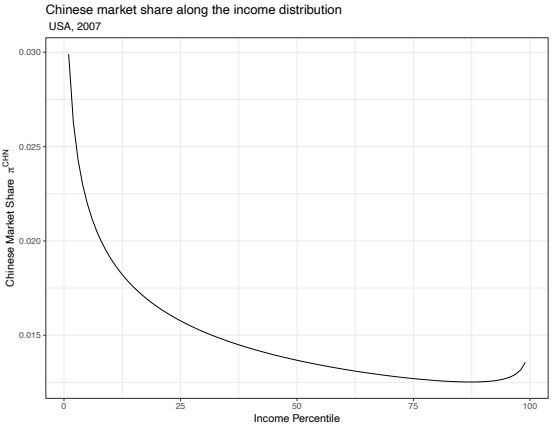


Welfare implications

- The model estimates different elasticities of substitution along the income distribution.
  - Rich consumers have a lower elasticity of substitution (less sensitive to prices).
- Two implications for consumption behavior and welfare:
  - Rich consumers have a stronger taste for variety, which implies larger gains from trade.
  - They consume more expensive varieties, from relatively rich countries.

Welfare implications





The Heterogeneous Welfare Impact of China

- Under Cobb-Douglas preferences across products, the price index of consumer i is

$$P_i = \prod_k P_{ki}^{\rho_k}$$

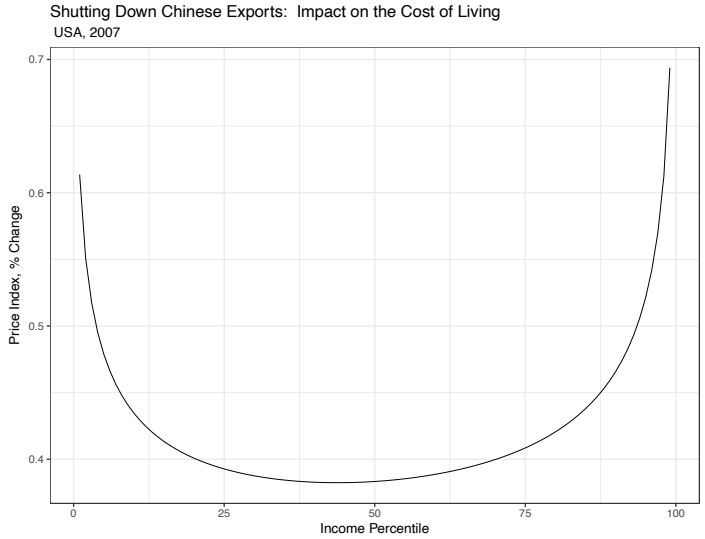
  - $P_{ki} = \left(\sum_o \exp(\beta_i X_{ok} + \xi_{ok}) p_{ok}^{(1-\alpha_i)}\right)^{\frac{1}{1-\alpha_i}}$
  - ρ_k: budget share of product k

- Impact of shutting down Chinese exports on consumer i's cost of living:

$$\hat{P}_i \equiv \frac{P_i'}{P_i} - 1 = \prod_k \left(\frac{P_{ki}'}{P_{ki}}\right)^{\rho_k} - 1 = \prod_k \left[(1 - s_{k,i}^{CHN})^{\frac{1}{1-\alpha_i}}\right]^{\rho_k} - 1$$

- Welfare impact is consumer-specific because of different α_i and different import shares from China.

The Heterogeneous Welfare Impact of China



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Conclusions

- We show how to augment gravity regressions with terms that capture more realistic patterns of substitution across countries.
- Allows to measure the role of vertical differentiation, local competition on trade flows.
- This has direct implications on the predictions of these models in terms of trade elasticities between countries.
- Capturing these substitution patterns also have interesting consequences on the heterogeneity of the gains from trade.