Quantifying the Extensive Margins of Trade and Production

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April 20, 2023

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- International trade has experienced major disruptions in recent years
  - US-China trade war, COVID-19 pandemic, Russian invasion of Ukraine

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- "Industry" examples: batteries, motorcycles, wire of stainless steel
- RQ: When key partner countries drop out of the system, ...
  - ...how can they be replaced?
  - ...what are the implications for welfare?

Procedure

- Build GE framework capturing (bilateral) industry-level zeros
  - Standard trade models: export to & import from every country in all industries
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- Key ingredients:
  - Non-homothetic final-goods-assembly function
  - Upper-bounded productivity distribution

Preview of Results

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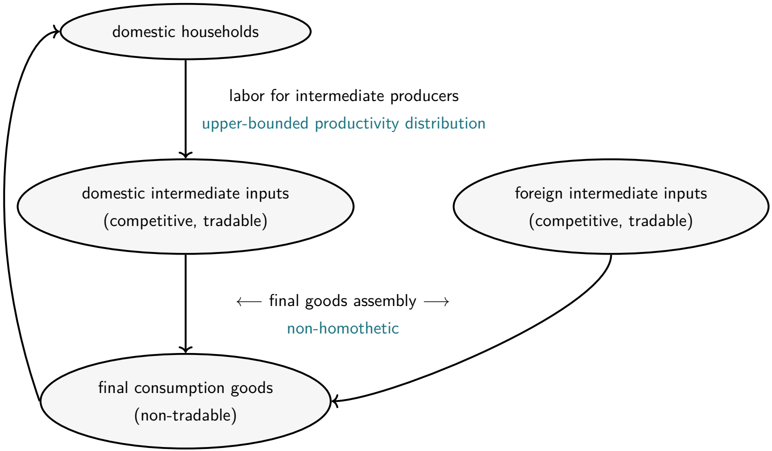
- Novel calibration strategy to match data
  - No need for industry-level production data
- Industry-level bilateral zeros change by about half the shock size
  - E.g., 10% rise in trade costs increases no. of zeros by 5%
- Welfare impact of trade-cost shocks typically amplified with zeros
  - Primarily true for low- to medium-income countries

Related Literature

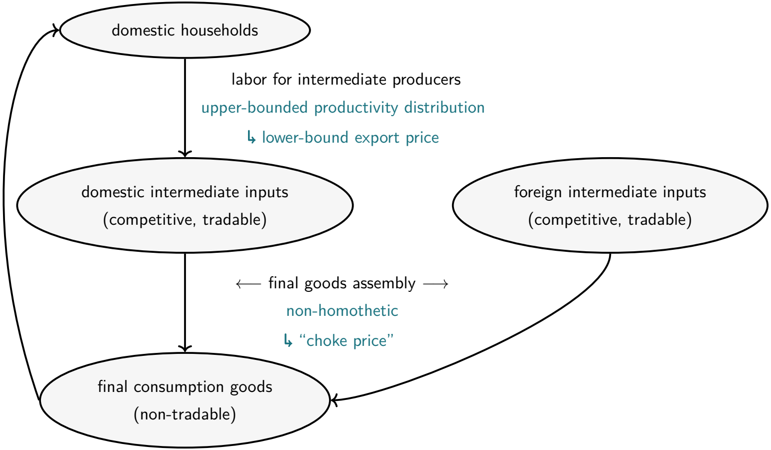
- Quantitative analyses of trade policy (cf. Caliendo and Parro (2022) for review)
- Non-homothetic preferences and trade (e.g., Fieler (2011); Caron et al. (2014); Fajgelbaum and Khandelwal (2016); Foellmi et al. (2018))
- Export and production diversification (e.g., Imbs and Wacziarg (2003); Hidalgo et al. (2007); Cadot et al. (2011))
- Extensive margin at country-level: Helpman et al. (2008); Chor (2010); Eaton et al. (2013); Eaton and Fieler (2019)
  - Need (i) industry-level production data and/or (ii) expensive simulation of model

$\Rightarrow$ This paper: Quantification with closed-form using only readily available data

Model Structure (i/ii)



Model Structure (ii/ii)



Households (i/ii)

- Countries indexed by $i, j = \{1, \dots, N\}$, final goods (industry-level) indexed by $k = \{1, \dots, K\}$
- L_j households, utility from final goods consumption

$$\max_{\{q_j^k\}} U_j = \frac{\sigma}{\sigma - 1} \sum_{k=1}^{K} \left(\xi_j^k\right)^{\frac{1}{\sigma}} \left(q_j^k\right)^{\frac{\sigma-1}{\sigma}}$$

$$\text{s.t. } E_j \geq \sum_{k=1}^{K} P_j^k q_j^k$$

Households (ii/ii)

- Non-tradable final good k assembled using k-specific intermediate varieties

$$q_j^k = \int_0^1 q_j^k(\omega^k)\mathrm{d}\omega^k,$$

where $q_j^k(\omega^k) \in \{0, 1\}$

- Note: intermediate inputs substitutable along *extensive* margin

  $\Rightarrow$ Generates "choke price," $\bar{\mathbf{p}}_{\mathbf{j}}^{\mathbf{k}}$

Production of Tradable Intermediate Inputs (i/iii)

- Perfect competition, labor is only input
- Unit cost of variety ω^k produced in country i and shipped to j:

$$c_{ij}^k(\omega^k) \equiv \frac{w_i \tau_{ij}^k}{\varphi_i(\omega^k)}$$

  - w_i wage rate, τ_{ij}^k iceberg trade costs, $\varphi_i(\omega^k)$ labor productivity
- Price country i offers to j: $p_{ij}^k(\omega^k) = c_{ij}^k(\omega^k)$

Production of Tradable Intermediate Inputs (ii/iii)

- Assume $\varphi_i(\omega^k)$ independently drawn from truncated Fréchet distribution

$$F_i^k(\varphi; \bar{\varphi}_i^k) = \frac{\exp\left(-T_i^k \varphi^{-\theta}\right)}{\exp\left(-T_i^k (\bar{\varphi}_i^k)^{-\theta}\right)}, \quad \text{for } \varphi \in (0, \bar{\varphi}_i^k]$$

  - T_i^k scale parameter, θ shape parameter,
    $\bar{\varphi}_i^k$ productivity upper bound (="technological frontier")

Production of Tradable Intermediate Inputs (iii/iii)

- Let $\underline{p}_{ij}^k \equiv w_i \tau_{ij}^k / \bar{\varphi}_i^k$
- For a given destination j, sort exporters such that

$$\underline{p}_{1j}^k \leq \underline{p}_{2j}^k \leq \cdots \leq \underline{p}_{Nj}^k$$

$\Rightarrow$ Intuition zeros: $\underline{p}_{ij}^k \geq \bar{p}_j^k$

▸ Price Distribution

Trade Flows

- Country j expenditure on intermediates from i in industry k ▸ Details

$$X_{ij}^k = \sum_{n=i}^{N} \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\Phi_j^{k,1:n}} \widetilde{\Gamma}\left(\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}, \min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right) \tilde{\gamma}_j^{k,1:n}$$

  - $\bar{p}_j^k$ is the choke price
  - $\widetilde{\Gamma}(p, p) = 0$
  - Note: trade flows in levels

Trade Flows

- Country j expenditure on intermediates from i in industry k ▸ Details

$$X_{ij}^{k} = \sum_{n=i}^{N} \underbrace{\frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\Phi_j^{k,1:n}}}_{\text{"intensive margin" (EK)}} \widetilde{\Gamma}\left(\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}, \min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right) \tilde{\gamma}_j^{k,1:n}$$

  - $\Phi_j^{k,1:n} := \sum_{i=1}^{n} T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}$
  - Trade flows determined by relative technology & trade costs

Trade Flows

- Country j expenditure on intermediates from i in industry k ▸ Details

$$X_{ij}^{k} = \sum_{n=i}^{N} \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\Phi_j^{k,1:n}} \underbrace{\widetilde{\Gamma}\left(\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}, \min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right)}_{\text{“extensive margin”}} \tilde{\gamma}_j^{k,1:n}$$

- Exporter i cannot compete when $p < \underline{p}_{ij}^k$
- Recall: $\underline{p}_{ij}^k$ increasing in index i

Benchmark: Standard Gravity

- If we let $\bar{\varphi}_i^k \to \infty \; \forall i$, we obtain EK trade shares

$$\frac{X_{ij}^k}{X_j^k} = \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\sum_{i'=1}^N T_{i'}^k \left(w_{i'} \tau_{i'j}^k\right)^{-\theta}},$$

where $X_j^k = \sum_{i=1}^N X_{ij}^k$

- Note: holds irrespective of $\bar{p}_j^k$

Elasticity Piecewise Gravity

Equilibrium Conditions

- Implicit expression for $\bar{p}_j^k$ ▸ Details

$$\frac{w_j L_j}{G_j^k\left(\bar{p}_j^k\right)} = \left(\xi_j^k\right)^{-1}\left(\bar{p}_j^k\right)^{\sigma}\left[\sum_{k'=1}^{K}\xi_j^{k'}\left(\bar{p}_j^{k'}\right)^{-\sigma}\frac{X_j^{k'}}{G_j^{k'}\left(\bar{p}_j^{k'}\right)}\right]$$

- Balanced trade pins down w_j

$$\sum_{i\neq j}^{N}\sum_{k=1}^{K}X_{ij}^k - X_{ji}^k = 0$$

Calibration (i/ii)

- Solve and calibrate model using equilibrium conditions
  - Set $T_i^k, \bar{\varphi}_i^k, \tau_{ij}^k$ to minimize deviations betw. empirical and model trade flows, letting $\tau_{ij}^k = \tau_{ij}\tau_j^k$
  - Benchmark model: $\bar{\varphi} \to \infty$
- Data (80 countries, 1,240 industries):
  - Bilateral 4-digit HS-industry-level trade flows (Atlas of Economic Complexity)
  - Aggregate production (ITPD-E)
  - Population (WDI)

Calibration (ii/ii)

- Set:
  - $\sigma = 2$, $\theta = 4.1$
  - ξ_j^k = product k's trade share
  - $w_j = X_j / L_j$, with $\sum_{j=1}^{N} w_j = 1$
- Moments (min. rel. deviations betw. data and model):
  - $\bar{\varphi}_i^k$: no. of served destinations in i-k cell
  - T_i^k: total exports in i-k cell
  - τ_j^k: total imports in j-k cell
  - τ_{ij}: total trade in i-j cell

  $\Rightarrow$ Solve for $\bar{p}_j^k$ after every iteration

  $\Rightarrow$ ≈300k parameters, 7.8M observations

Model fit Plausibility

Counterfactual Exercises

- What happens when global trade barriers, τ, change?

$\Rightarrow$ Bilateral zeros change by approx. half the shock size Table

$\Rightarrow$ Welfare changes after trade-cost shocks typically amplified by extensive margin Welfare: $\tau \times 0.9$ Welfare: $\tau \times 1.1$

  - Primarily true for low- to medium-income countries

Conclusion

- To create industry-level zeros in Ricardian model, allow for...
  - ...finite productivity levels of most productive firms
  - ...intermediate inputs to be substitutable along extensive margin

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- Accounting for extensive margin seems important for welfare analyses
  - Especially for small- to medium-sized economies

Conclusion

- To create industry-level zeros in Ricardian model, allow for...
  - ...finite productivity levels of most productive firms
  - ...intermediate inputs to be substitutable along extensive margin
- Accounting for extensive margin seems important for welfare analyses
  - Especially for small- to medium-sized economies
- Many industry-level trade relations seem relatively weak

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Appendix: Distribution of Prices

- Price distribution in country j:

$$G_j^k(p) = \begin{cases} 1 - \gamma_j^{k,1:n} \exp\left(-p^\theta \Phi_j^{k,1:n}\right) & \text{for } p \in \left[\underline{p}_{nj}^k, \underline{p}_{(n+1)j}^k\right) \\ 0 & \text{otherwise,} \end{cases}$$

where

$$\gamma_j^{k,1:n} := \exp\left(\sum_{i=1}^{n} T_i^k (\bar{\varphi}_i^k)^{-\theta}\right)$$

$$\Phi_j^{k,1:n} := \sum_{i=1}^{n} T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}$$

Main text

Appendix: Detailed Derivations (i/iii)

- Mass of varieties sourced from i

$$
\begin{aligned}
m_{ij}^k &\equiv \mathbb{1}\left\{\bar{p}_j^k \geq \underline{p}_{ij}^k\right\} \times \int_{\underline{p}_{ij}^k}^{\bar{p}_j^k} \prod_{i' \neq i} \left[1 - G_{i'j}^k(p)\right] g_{ij}^k(p)\mathrm{d}p \\
&= T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta} \\
&\quad \times \sum_{n=i}^{N} \frac{\gamma_j^{k,1:n}}{\Phi_j^{k,1:n}} \left[\exp\left(-\left[\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}\right]^{\theta} \Phi_j^{k,1:n}\right) - \exp\left(-\left[\min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right]^{\theta} \Phi_j^{k,1:n}\right)\right] \\
m_j^k &\equiv G_j^k(\bar{p}_j^k)
\end{aligned}
$$

Main text

Appendix: Detailed Derivations (ii/iii)

- Expected price conditional on i being lowest-cost provider

$$\frac{1}{m_{ij}^k + \mathbb{1}\{m_{ij}^k = 0\}} \sum_{n=i}^{N} \gamma_j^{k,1:n} \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\Phi_j^{k,1:n}} \int_{\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}}^{\min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}} p \Phi_j^{k,1:n} \exp(-p^\theta \Phi_j^{k,1:n}) \theta p^{\theta-1} \mathrm{d}p$$

$$= \frac{1}{m_{ij}^k + \mathbb{1}\{m_{ij}^k = 0\}} \sum_{n=i}^{N} \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\Phi_j^{k,1:n}} \gamma_j^{k,1:n} \left(\Phi_j^{k,1:n}\right)^{-1/\theta} \widetilde{\Gamma} \left(\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}, \min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right)$$

$\Rightarrow$ Expression above multiplied by m_{ij}^k yields X_{ij}^k

▸ Main text

Appendix: Detailed Derivations (iii/iii)

- $\widetilde{\Gamma}(\underline{x}, \bar{x})$ is defined as

$$\widetilde{\Gamma}\left(\underline{x}, \bar{x}\right) \equiv \int_{\underline{x}^{\theta}\Phi}^{\bar{x}^{\theta}\Phi} x^{1/\theta} \exp(-x)\mathrm{d}x$$

- $\tilde{\gamma}_j^{k,1:n} \equiv \gamma_j^{k,1:n}\left(\Phi_j^{k,1:n}\right)^{-1/\theta}$

▸ Main text

Appendix: Trade Elasticity

- Standard gravity (with $\bar{\varphi} \to \infty$) is log-additively separable

$$\log\left(X_{ij}^k\right) = \underbrace{\log\left(T_i^k w_i^{-\theta}\right)}_{i\text{-specific}} + \underbrace{\log\left(X_j^k / \Phi_j^{k,1:N}\right)}_{j\text{-specific}} - \theta \log\left(\tau_{ij}^k\right)$$

$\Rightarrow$ constant "trade elasticity"

▸ Main text

Appendix: Gravity Add-On

- Total expenditures on intermediate varieties in industry k

$$X_j^k = \sum_{n=1}^{N} \underbrace{\widetilde{\Gamma}\left(\min\{\underline{p}_{nj}^k, \bar{p}_j^k\}, \min\{\underline{p}_{(n+1)j}^k, \bar{p}_j^k\}\right) \tilde{\gamma}_j^{k,1:n}}_{:=X_j^{k,(n)}}$$

$\Rightarrow$ bilateral trade flows given by

$$X_{ij}^k = \sum_{n=i}^{N} \frac{T_i^k \left(w_i \tau_{ij}^k\right)^{-\theta}}{\sum_{i'=1}^{n} T_{i'}^k \left(w_{i'} \tau_{i'j}^k\right)^{-\theta}} X_j^{k,(n)}$$

Main text

Appendix: Equilibrium (i/ii)

- UMP: Lagrange function

$$\mathcal{L}\left(\{\bar{\omega}_j^k\}_k, \lambda_j\right) = \frac{\sigma}{\sigma-1}\sum_{k=1}^{K}(\xi_j^k)^{\frac{1}{\sigma}}\left(\int_0^{\bar{\omega}_j^k} \mathrm{d}\omega^k\right)^{\frac{\sigma-1}{\sigma}} + \lambda_j\left[E_j - \sum_{k=1}^{K}\int_0^{\bar{\omega}_j^k} p_j^k(\omega^k)\mathrm{d}\omega^k\right]$$

$\Rightarrow$ yields expenditure shares

$$P_j^k q_j^k = E_j \frac{\xi_j^k \left(\bar{p}_j^k\right)^{-\sigma} P_j^k}{\sum_{k'=1}^{K}\xi_j^{k'}\left(\bar{p}_j^{k'}\right)^{-\sigma} P_j^{k'}},$$

where

$$P_j^k := \frac{1}{q_j^k}\int_0^{\bar{\omega}_j^k} p_j^k(\omega^k)\mathrm{d}\omega^k.$$

▸ Main text

Appendix: Equilibrium (ii/ii)

- In equilibrium, we have $Q_j^k = G_j^k(\bar{p}_j^k)L_j$ and $E_j = w_j$.
- Using $P_j^k = X_j^k / Q_j^k$ yields

$$\frac{w_j L_j}{G_j^k\left(\bar{p}_j^k\right)} = \left(\xi_j^k\right)^{-1}\left(\bar{p}_j^k\right)^{\sigma}\left[\sum_{k'=1}^{K}\xi_j^{k'}\left(\bar{p}_j^{k'}\right)^{-\sigma}\frac{X_j^{k'}}{G_j^{k'}\left(\bar{p}_j^{k'}\right)}\right]$$

$\Rightarrow$ pins down $\bar{p}_j^k$ for given w_j and parameters.

Main text

Appendix: Model Fit

The Extensive Margin of Trade – Data vs. Model

Panel A: Data	Min.	Q1	Median	Q3	Max.
Sh. Served Destinations[(i)]	0.01	0.1	0.3	0.67	1
Sh. Source Countries[(ii)]	0.01	0.2	0.35	0.53	1
No. of Observations	7,836,800				
Panel B: Model	Min.	Q1	Median	Q3	Max.
Sh. Served Destinations[(i)]	0.01	0.09	0.27	0.65	1
Sh. Source Countries[(ii)]	0.01	0.19	0.37	0.58	1
No. of Observations	7,836,800				

Notes. This table depicts the distribution of industry-level export and import extensive margins. Panel A reports the distribution in the data, Panel B the distribution in the model.
[(i)] Conditional on exporting in a given industry.
[(ii)] Conditional on importing in a given industry.

▸ Main text

Appendix: Parameter Correlations (i/ii)

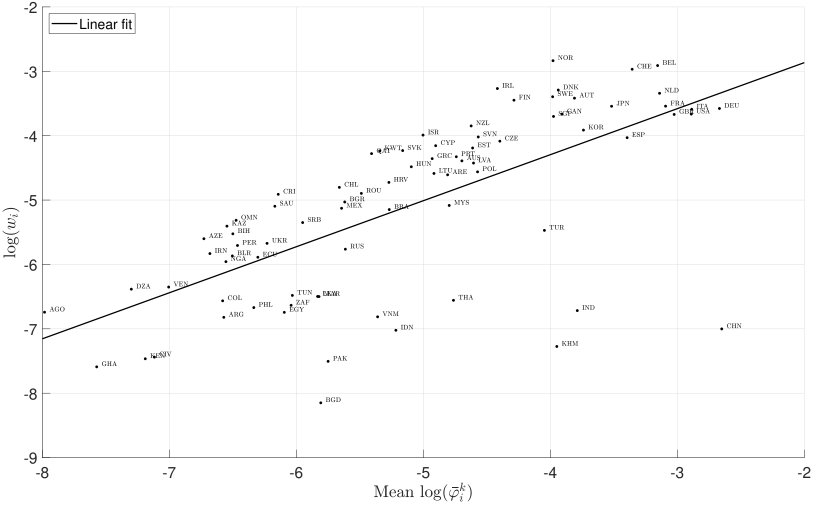
Regression of $-\theta \log(\tau_{ij})$ on Gravity Variables

	Coefficients (SE)	
	(1)	(2)
Log of Distance	-0.642 (0.061)	-0.475 (0.065)
Contiguity	1.468 (0.220)	1.676 (0.217)
Colonial Ties	1.306 (0.302)	0.938 (0.236)
Common Language	0.370 (0.192)	0.633 (0.168)
RTA	0.859 (0.119)	0.356 (0.118)
Imp. & Exp. FE		✓
No. of observations	6,162	6,162

Notes. This table reports regressions of the log of the average τ_{ij}^k on a set of bilateral variables. Robust SEs in parentheses.

▸ Main text

Appendix: Parameter Correlations (ii/ii)



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Appendix: Counterfactuals: Changes in Zeros

Bilateral Zeros after Changes in Global Trade Costs

%-Change in τ	%-Change in Bil. Zeros Rel. to Baseline	%-Change in Trade (through Zeros)
-5%	-3%	0.09%
-10%	-5.9%	0.35%
-15%	-8.9%	0.8%
$+5\%$	2.9%	-0.09%
$+10\%$	5.4%	-0.26%
$+15\%$	7.7%	-0.48%

Notes. This table reports how bilateral industry-level trade zeros change upon a shock to trade barriers.

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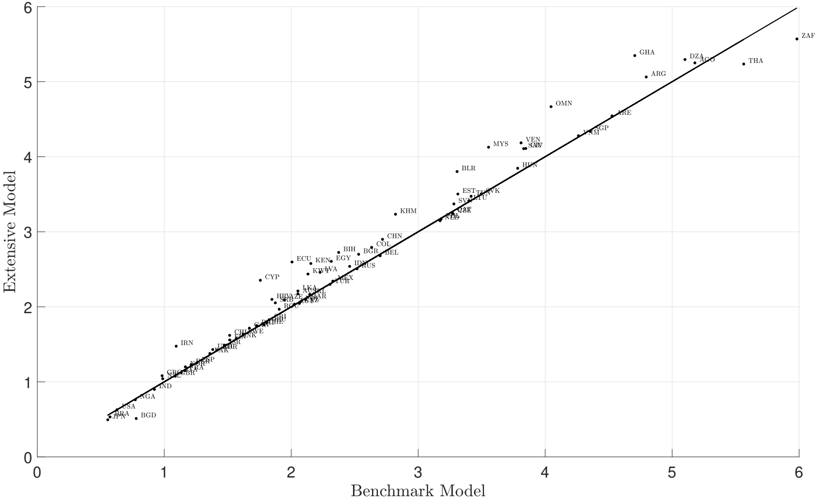
Appendix: Welfare Changes: $\tau \times 0.9$ (i/iii)



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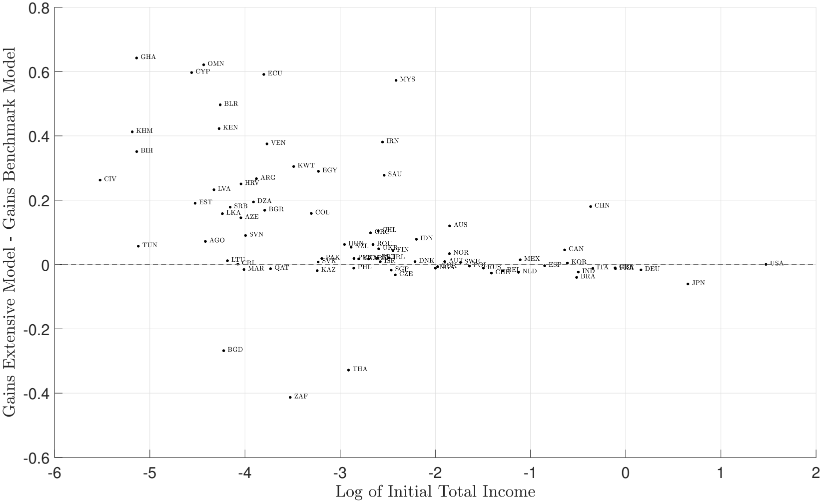
Appendix: Welfare Changes: $\tau \times 0.9$ (ii/iii)



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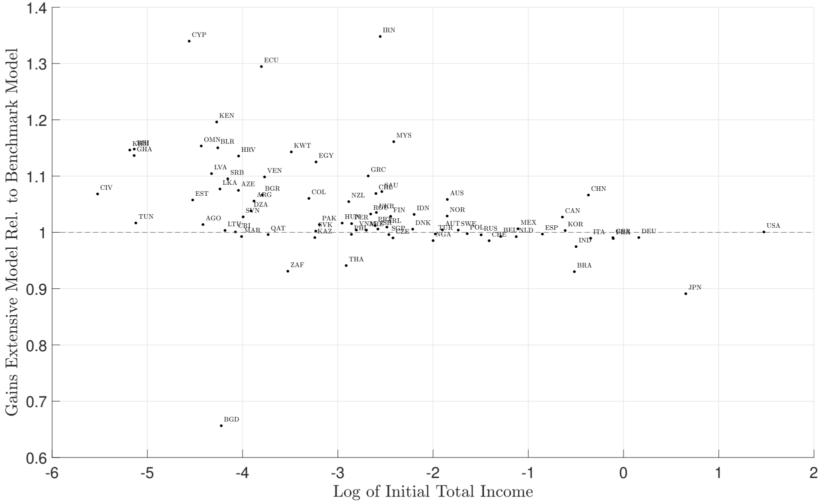
Appendix: Welfare Changes: $\tau \times 0.9$ (iii/iii)



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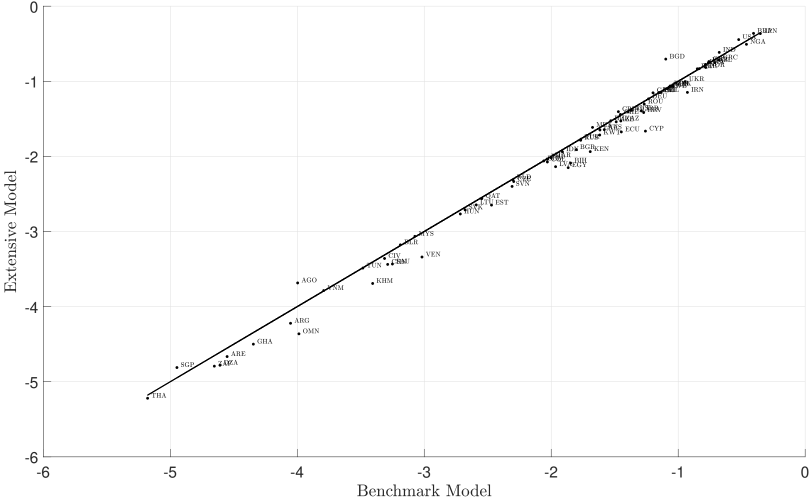
Appendix: Welfare Changes: $\tau \times 1.1$ (i/iii)



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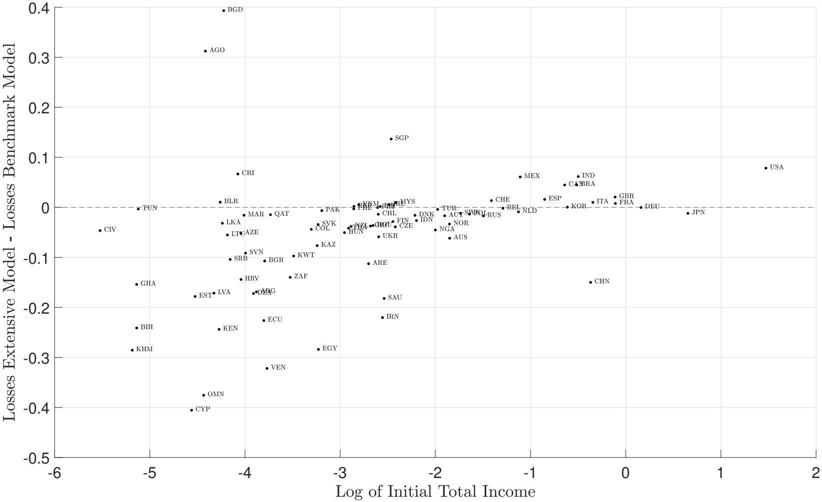
Appendix: Welfare Changes: $\tau \times 1.1$ (ii/iii)



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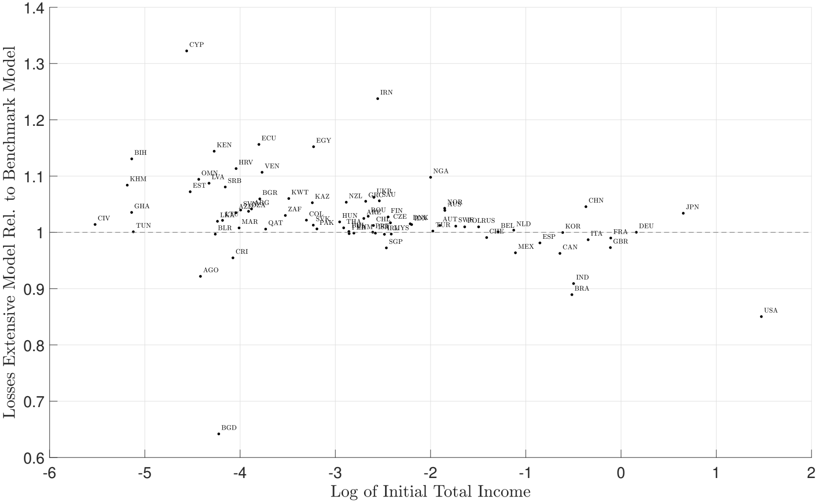
Appendix: Welfare Changes: $\tau \times 1.1$ (iii/iii)



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