Production network in quantitative spatial models (I)

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Paper

Caliendo, Lorenzo and Fernando Parro,2015 Estimates of the Trade and Welfare Effects of NAFTA, Review of Economic Studies 82, 1-44

Main Contribution

- Extend EK model by incorporating Multi-sectors and I-O linkage.
- A larger welfare effects from tariff reductions when considering intermediate goods or input–output linkages.
- A new method to estimate sectoral trade elasticities;

Introduction

- Sectors and countries are interrelated, and the gains from tariff reductions will spread across sectors through the input-output linkage.
- Why accounting for sectoral heterogeneity and IO linkage
  - Tariff rates vary substantially across sectors.
  - Most goods traded are intermediate goods. (82.1%, 72.3% and 72.8% from NAFTA; 68%, 61.5% and 64.6% from ROW)
  - Tradable and non-tradable sectors are interconnected.
    - average share of tradable sectors in the production of non-tradable sectors is 23%for U.S. and 32% for MEX

Model

- N countries (by i and n) J sectors (by j and k).
- One production factor, labour(L_n) free mobile across sectors.
- Perfectly competitive.
- Household Preferences

$$u(C_n) = \prod_{j=1}^{J} {C_n^j}^{{a_n}^j}$$

where $\sum_{j=1}^{J} {a_n}^j = 1$. we have $P_n = \prod_{j=1}^{J} \left(P_n^j / \alpha_n^j\right)^{\alpha_n^j}$

Intermediate goods

- Production technology

$$q_n^j(w^j) = z_n^j(w^j)[l_n^j(w^j)]^{\gamma_n^j} \prod_{k=1}^{J} [m_n^{k,j}(w^j)]^{\gamma_n^{k,j}}$$

z_n^j: efficiency of producing intermediate good w^j in country n.
$m_n^{k,j}(w^j)$: Composite intermediate goods from sector k used for production of w^j.
$\gamma_n^{k,j}$: share of materials from sector k used in the production of w^j.
γ_n^j: share of value added.

- Unit cost of an input bundle:

$$c_n^j = \gamma_n^j {w_n}^{\gamma_n^j} \prod_{k=1}^{J} {P_n^k}^{\gamma_n^{k,j}}$$

P_n^k: price of a composite intermediate good from sector k.

Composite intermediate goods

- Composite intermediate goods :

$$Q_n^j = [\int r_n^j(w^j)^{1-1/\sigma^j} dw^j]^{\sigma^j/(\sigma^j-1)}$$

- Demand on variety :

$$r_n^j(w^j) = (\frac{p_n^j(w^j)}{P_n^j})^{-\sigma^j} Q_n^j$$

- Price of the composites :

$$P_n^j = [\int p_n^j(w^j)^{1-\sigma^j} dw^j]^{\frac{1}{1-\sigma^j}}$$

International trade costs and prices

- Trade cost : $k^j_{ni} = \tau^j_{ni} d^j_{ni}$, with $K^j_{nh} k^j_{hi} \geq k^j_{ni}$ iceberg trade costs $d^j_{ni} \geq 1$, with $d^j_{nn} = 1$; ad-valorem tariffs $\tilde{\tau}^j_{ni} = 1 + \tau^j_{ni}$
- The price of ^{j} in country n

$$p^j_n(w^j) = min_i \{ \frac{c^j_i k^j_{ni}}{z^j_i(w^j)} \}$$

- For non-tradable sector:

$$p^j_n(w^j) = c^j_n / z^j_n(w^j)$$

International trade costs and prices

- Technology: (EK)
  - z_n^j follows a Fréchet distribution with parameter λ_n^j and shape parameter, θ^j.
  - The composite intermediate good prices:

$$P_n^j = A^j [\sum_{i=1}^{N} \lambda_i^j (c_i^j k_{ni}^j)^{-\theta^j}]^{-1/\theta^j}$$

    where $A^j = \Gamma(1 + (1 - \sigma^j)/\theta^j)^{1/(1-\sigma^j)}$
  - For non-tradable sector

$$P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j$$

Frechet Distribution

for pictures on Frechet distribution

Expenditure shares

- $X_n^j = P_n^j Q_n^j$: total expenditure on sector j goods in country n
- Expenditure in country n of sector j goods from country i.

$$X_{ni}^j = Pr[\frac{c_n^j k_{ni}^j}{z_i^j(w^j)} \leq min_{h \neq i} \frac{c_h^j k_{nh}^j}{z_h^j(w^j)}] X_n^j$$

$$= \frac{\lambda_i^j (c_i^j k_{ni}^j)^{-\theta^j}}{\sum_{i=1}^N \lambda_i^j (c_i^j k_{ni}^j)^{-\theta^j}} [\int_0^\infty \Phi_n^j e^{-\Phi_n^j} p^{\theta^j} \theta^j p^{\theta^j - 1} dp] X_n^j$$

$$= \frac{\lambda_i^j (c_i^j k_{ni}^j)^{-\theta^j}}{\sum_{i=1}^N \lambda_i^j (c_i^j k_{ni}^j)^{-\theta^j}} X_n^j$$

Trade elasticity

- Trade share (country n's expenditure share on goods from i):

$$\pi^j_{ni} = \frac{\lambda^j_i (c^j_i k^j_{ni})^{-\theta^j}}{\sum_{h=1}^{N} \lambda^j_h (c^j_h k^j_{nh})^{-\theta^j}}$$

- Trade elasticity: θ^j (ACR,2014)
  - Intensive margin elasticity: $1 - \sigma$
  - Extensive margin elasticity: $\sigma - 1 + \theta^j$

Total expenditure and trade balance

- Market clearing:

$$X_n^j = \sum_{k=1}^{j} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^k}{1+\tau_{in}^k} + \alpha_n^j I_n$$

where

$$I_n = w_n L_n + R_n + D_n$$

- Tariff revenues: $R_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{ni}^j M_{ni}^j$, $\mathrm{M}_{ni}^j = X_n^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}$
- Trade deficit:

$$\sum_{j=1}^{J} \sum_{i=1}^{N} X_n^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} X_i^j \frac{\pi_{in}^j}{1+\tau_{in}^j}$$

Solving the model

Definition 1. *Given L_n, D_n, λ_n^j, and d_{ni}^j, an equilibrium under tariff structure τ is a wage vector $\mathbf{w} \in \mathbf{R}_{++}^N$ and prices $\{P_n^j\}_{j=1,n=1}^{J,N}$ that satisfy equilibrium conditions (2), (4), (6), (7), and (9) for all j, n.*

Definition 2. *Let $(\mathbf{w}, P)$ be an equilibrium under tariff structure τ and let $(\mathbf{w}', P')$ be an equilibrium under tariff structure τ'. Define $(\hat{\mathbf{w}}, \hat{P})$ as an equilibrium under τ' relative to τ, where a variable with a hat "$\hat{x}$" represents the relative change of the variable, namely $\hat{x} = x'/x$. Using equations (2), (4), (6), (7), and (9) the equilibrium conditions in relative changes satisfy:*

Solving the model

Cost of the input bundles:

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^{J} \hat{P}_n^{k\ \gamma_n^{k,j}}.$$

Price index:

$$\hat{P}_n^j = \left[\sum_{i=1}^{N} \pi_{ni}^j [\hat{\kappa}_{ni}^j \hat{c}_i^j]^{-\theta^j} \right]^{-1/\theta^j}.$$

Bilateral trade shares:

$$\hat{\pi}_{ni}^j = \left[\frac{\hat{c}_i^j \hat{\kappa}_{ni}^j}{\hat{P}_n^j} \right]^{-\theta^j}.$$

Total expenditure in each country n and sector j:

$$X_n^{j\prime} = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} \frac{\pi_{in}^{k\prime}}{1+\tau_{in}^{k\prime}} X_i^{k\prime} + \alpha_n^j I_n^{\prime}.$$

Trade balance:

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j\prime}}{1+\tau_{ni}^{j\prime}} X_n^{j\prime} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^{j\prime}}{1+\tau_{in}^{j\prime}} X_i^{j\prime},$$

where $\hat{\kappa}_{ni}^j = (1+\tau_{ni}^{j\prime})/(1+\tau_{ni}^j)$ *and* $I_n^{\prime} = \widehat{w}_n w_n L_n + \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{ni}^{j\prime} \frac{\pi_{ni}^{j\prime}}{1+\tau_{ni}^{j\prime}} X_n^{j\prime} + D_n$

Data and parameters

- Data or parameters we need:
  - two sets of tariff structures (τ_{ni}^{j}, $\tau_{ni}^{j'}$: UNCTAD-TRAINS
  - data on bilateral trade shares (π_{ni}^{j}): COMTRADE database
  - the share of value added in production (γ_{n}^{j}) :OECD STAN database, OECD IO database
  - the share of intermediate consumption ($\gamma_{n}^{k,j}$): WIOD and OECD IO Database
  - share of each sector in final demand (α_{n}^{j})
  - sectoral dispersion of productivity (θ^{j}) (need to be estimated)

Relative change in real wages

$$\ln\frac{\hat{w}_n}{\hat{P}_n} = -\underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\ln\hat{\pi}_{nn}^j}_{\text{Final goods}} - \underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\frac{1-\gamma_n^j}{\gamma_n^j}\ln\hat{\pi}_{nn}^j}_{\text{Intermediate goods}} - \underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\gamma_n^j}\ln\prod_{k=1}^{J}(\hat{P}_n^k/\hat{P}_n^j)^{\gamma_n^{k,j}}}_{\text{Sectoral linkages}},$$

- No materials: $\gamma_n^j = 1$,

$$\ln\frac{\hat{w}_n}{\hat{P}_n} = -\underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\ln\hat{\pi}_{nn}^j}_{\text{Final goods}}.$$

  consistent with ACR.

- No IO linkage: $\gamma_n^{j,j} = 1 - \gamma_n^j$,

$$\ln\frac{\hat{w}_n}{\hat{P}_n} = -\underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\ln\hat{\pi}_{nn}^j}_{\text{Final goods}} - \underbrace{\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\frac{1-\gamma_n^j}{\gamma_n^j}\ln\hat{\pi}_{nn}^j}_{\text{Intermediate goods}}$$

  Producers of intermediate goods gain from tariff reduction in the cost of their inputs.

Welfare effects from tariff changes

$$d\ln W_n = \frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N}\underbrace{\left(E_{ni}^j d\ln c_n^j - M_{ni}^j d\ln c_i^j\right)}_{\text{Terms of trade}} + \frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N}\underbrace{\tau_{ni}^j M_{ni}^j\left(d\ln M_{ni}^j - d\ln c_i^j\right)}_{\text{Volume of trade}},$$

- Change in TOT by sector and by trade partner:

$$dlntot_{ni} = \sum_{j=1}^{J}(E_{ni}^j dlnc_n^j - M_{ni}^j dlnc_i^j)$$

$$dlntot_n^j = \sum_{j=1}^{N}(E_{ni}^j dlnc_n^j - M_{ni}^j dlnc_i^j)$$

- Change in Trade volume by sector and by trade partner:

$$dlntot_n^j = \sum_{j=1}^{N}(E_{ni}^j dlnc_n^j - M_{ni}^j dlnc_i^j)$$

$$dlnvot_n^j = \sum_{j=1}^{N}\tau_{ni}^j M_{ni}^j(dlnM_{ni}^j - dlnc_i^j)$$

New method to estimate trade elasticity

$$\left.\begin{array}{r}\pi^j_{ni} = \dfrac{\lambda^j_i (c^j_i k^j_{ni})^{-\theta^j}}{\sum_{h=1}^N \lambda^j_h (c^j_h k^j_{nh})^{-\theta^j}} \\ \pi^j_{ni} = X^j_{ni}/X^j_n\end{array}\right\} \frac{X^j_{ni}X^j_{ih}X^j_{hn}}{X^j_{in}X^j_{hi}X^j_{nh}} = \left(\frac{k^j_{ni}k^j_{ih}k^j_{hn}}{k^j_{in}k^j_{hi}k^j_{nh}}\right)^{-\theta^j}$$

- Model the trade cost

$$ln k^j_{ni} = ln\tilde{\tau}^j_{ni} + ln d^j_{ni} = ln\tilde{\tau}^j_{ni} + v^j_{ni} + \mu^j_n + \delta^j_i + \varepsilon^j_{ni}$$

where $v^j_{ni} = v^j_{in}$ captures symmetric bilateral trade costs like distance, language, common border.
μ^j_n:importer sectoral fixed effect.
δ^j_i:exporter sectoral fixed effect.
Assume tariff is the only non-symmetric trade cost.

New method to estimate trade elasticity

- Regressions to estimate trade elasticity

$$ln\left(\frac{X^j_{ni}X^j_{ih}X^j_{hn}}{X^j_{in}X^j_{hi}X^j_{nh}}\right) = -\theta^j ln\left(\frac{\tilde{\tau}^j_{ni}}{\tilde{\tau}^j_{in}}\frac{\tilde{\tau}^j_{ih}}{\tilde{\tau}^j_{hi}}\frac{\tilde{\tau}^j_{hn}}{\tilde{\tau}^j_{nh}}\right) + \tilde{\varepsilon}^j$$

- estimate θ^j sector by sector using this equation for 1993, the year before NAFTA was active.

Trade elasticity estimation in literature

EK paper

- one sector, no IO linkage

$$\pi_{ni} = \frac{\lambda_i (c_i k_{ni})^{-\theta}}{\sum_{h=1}^{N} \lambda_h (c_h k_{nh})^{-\theta}}, with\, c_i = w_i^{\beta} P_i^{(1-\beta)}$$

- After some derivation

$$\frac{\pi_{ni}}{\pi_{nn}} = \kappa_{ni}^{-\theta} (\frac{\lambda_i}{\lambda_n})^{1/\beta} (\frac{w_i}{w_n})^{-\theta} (\frac{\pi_{ii}}{\pi_{nn}})^{(\beta-1)/\beta}$$

- $$ln\bar{\pi}_{ni} = -\theta ln(\kappa_{ni}) - S_n + S_i$$

  where $ln\bar{\pi}_{ni} = ln\pi_{ni} + (1/\beta - 1) ln\pi_{ii} - 1/\beta ln\pi_{nn}$, we have $ln\bar{\pi}_{ni} = ln\pi_{ni} - ln\pi_{nn}$ if $\beta = 0$.
  $S_i = 1/\beta ln\lambda_i - \theta ln w_i$ measuring country i's "competitiveness," technology adjusted for labor cost.

Trade elasticity estimation in literature

EK paper

- measuring trade cost using proxies for geographic barriers

$$ln\kappa_{ni} = d_k + b + l + e_h + m_n + \delta_{ni}$$

  The independent variables include interval for distance, border sharing, language, trading area; m_n:destination effect.

- run regression

$$ln\bar{\pi}_{ni} = -\theta(d_k + b + l + e_h + m_n) - S_n + S_i + \theta\delta_{ni}$$

  get estimation $\hat{S}_n$

Estimating trade elasticity: EK

EK paper

- Using wage data

$$S_i = \alpha_0 + \alpha_R lnR_i - \alpha_H(1/H_i) - \theta lnw_i + \epsilon_i$$

- where R_i is country i's RD stock, H_i is average years of schooling, and ϵ_i is the error. The wage w_i is adjusted for education.
- Endogeneity: wage will increase with its technology level. Using total workforce and population density as IV: Given its technology, a country with more workers has a lower wage.

Estimating trade elasticity: EK

EK paper

- Using price data

$$\frac{\pi_{ni}}{\pi_{nn}} = \left(\frac{P_i \kappa_{ni}}{P_n}\right)^{-\theta}$$

  use retail prices of manufactured products to measure P_i;
  Relative price: $r_{ni}(j) = lnp_n(j) - lnp_i(j)$, and calculate the average across products.
  Take the second largest value of $r_{ni}(j)$ to measure lnd_{ni}
  Measure $ln(p_i d_{ni}/p_n) = \frac{max2_j r_{ni}(j)}{\sum_{j=1}^{N} r_{ni}(j)/N}$

- potential problem: $\hat{\theta}$ is biased because expected value of the maximal difference of logged prices strictly less than the trade cost. (Simonovska and Waugh, 2014)

Estimating trade elasticity in the literature

Giri et al.(2021):SMM, sectoral-level-version of Simonovska and Waugh (2014)

- SMM idea: if the model is correctly specified with θ equal to its true value, then the stochastic properties of the simulated series, including its moments, will be the same as the the actual series that we observe in practice.
- Moment:

$$\hat{\beta} = -\frac{\sum_n \sum_i ln(\pi_{ni}/\pi_{nn})}{\sum_n \sum_i (ln\hat{\kappa}_{ni} + ln\hat{P}_i - ln\hat{P}_n)}$$

where $ln\hat{\kappa}_{ni} = max_l \left[lnp_n(l) - lnp_i(l)\right]$; $\hat{P}_i = 1/N \sum_l lnp_i(l)$.

Estimating trade elasticity: Giri et al(2021)

- Data: micro-level price data, trade flow data
- Procedure: Step 1: calculate the moment in real data:estimating θ^j using trade and price data by the method of moments (MM) estimator as in EK, $\beta^j = \theta^j_{EK}$.
- Step 2: estimate gravity equation

$$\frac{\pi_{ni}}{\pi_{nn}} = -\theta^j ln(\kappa^j_{ni}) - S^j_n + S^j_i, with\, S^j_n = ln\left({c^j_n}^{-\theta^j} \lambda^j_n \right)$$

use distance, border, language, and FTA to represent trade cost. Given θ^j, we have sector-source-destination trade costs, and $\hat{S}^j_n$.

Estimating trade elasticity: Giri et al(2021)

- Step 3: based on trade cost and marginal cost, calculate the set of all possible destination prices for each goods, and select the minimum price for each destination. In total, 50000 possible goods in each sector.
  The inverse of the marginal cost $u_n^j = z_n^j / c_n^j$ distributed following Frechet distribution
  $Pr(u_n^j < x) = exp(-exp(\hat{S}_n^j) x^{-\theta^j})$
- Step 4:based on simulated price, calculate the consumption price, trade share at the sector level.
- Step 5: added disturbances to the predicted trade shares, drawn from a mean zero normal distribution with the standard deviation equal to the sd of the residuals from step 2.

Estimating trade elasticity: Giri et al(2021)

- Step 6: Estimate θ_k^j (the moment in the simulation $\hat{\beta}_k^j$) using the MM estimator (as in EK) according to simulated trade share and price.(two moments: the largest price difference, and second largest price difference to measure trade cost). Repeat K times.
- Step 7: Moment condition: $E(Y(\theta_0^j)) = 0$, θ_0^j is the true value of θ. Therefore, the SMM estimator:

$$\hat{\theta}_{SMM}^j = argmin_{\theta^j} \left[(y(\theta) \mathbf{W} y(\theta)) \right]$$

where $y(\theta) = (\beta - \frac{1}{K} \sum_k \hat{\beta}_k^j(\theta^j, u_n^j))$.
Idea: Though β^j will be biased away from θ^j, the moments $\hat{\beta}^j(\theta^j, u_n^j)$ will be biased by the same amount when evaluated at $\hat{\theta}_0^j$, in expectation.

Estimating trade elasticity: Giri et al(2021)

- Step 8: Compute standard errors using a parametric bootstrap technique. Draw price again and again and repeat the above procedure 100 times, estimate θ^j_{SMM} and construct standard errors accordingly.

The effects of NAFTA across different models

Trade and welfare effects from NAFTA across different models

		Welfare			Imports growth from NAFTA members			
			Multi-sector			Multi-sector		
Benchmark	Country	One sector	No materials	No I–O	One sector	No materials	No I–O	Benchmark
1.31%	Mexico	0.41%	0.50%	0.66%	60.99%	88.08%	98.96%	118.28%
−0.06%	Canada	−0.08%	−0.03%	−0.04%	5.98%	9.95%	10.14%	11.11%
0.08%	U.S.	0.05%	0.03%	0.04%	17.34%	26.91%	30.70%	40.52%

- for all models the welfare effects are smaller compared to the benchmark model.
- One sector: the importance of sector heterogeneity.
- No materials: intermediate goods amplifies the effects.
- No IO: IO linkage amplifies the effects

Steps to solve the model

- Using iteration to solve $\hat{w}$
  - Step 1: Guess a vector of wages $\hat{w} = ones(N)$.
  - Step 2: solve for price change in each sector and each country (iteration). (10,11)
  - Step 3: using (12) to solve $\pi_{ni}^{j'}(\hat{w})$
  - Step 4: Solve for total expenditure in each sector and country $X_n^{j'}(\hat{w})$ by rewriting (13) $X(\hat{w}) = \Omega^{-1}(\hat{w})\Delta(\hat{w})$
  - Step 5: Substitute all obtained variables in (14), check whether equation holds.
  - Step 6: If not, adjust our guess of $\hat{w}$ and proceed to step 1 again until equilibrium condition (14) is obtained.

If we do not use hat algebra

- Calibrating the model: productivity A_n^j,trade cost κ_{ni}^j
- Model validation
- trade cost: Head-Ries(2001)
  Assuming symmetric trade cost, and domestic trade cost=1:

$$\kappa_{ni}^j = \left(\frac{\pi_{ni}^j \pi_{in}^j}{\pi_{nn}^j \pi_{ii}^j} \right)^{-1/2\theta^j}$$

Trade cost

Adjusted Head-Ries(2001), symmetric trade cost with exporter-fixed effect

- trade cost $\kappa_{ni}^{j} = \bar{\kappa}_{ni}^{j}\kappa_{2,i}^{j}$, implying $\kappa_{ni}^{j} = (\frac{\pi_{nn}^{j}\pi_{ii}^{j}}{\pi_{ni}^{j}\pi_{in}^{j}})^{1/2\theta_j}\sqrt{\frac{\kappa_{2,i}^{j}}{\kappa_{2,n}^{j}}}$
- According to trade share determination function

$$ln\left(\frac{\pi_{ni}^{j}}{\pi_{nn}^{j}}\right) = -\theta^{j}ln(\kappa_{ni}^{j}) - \S_{n}^{j} + \S_{i}^{j}$$

  Assuming symmetric part of trade cost is well proxied by geographic distance,

$$ln\left(\frac{\pi_{ni}^{j}}{\pi_{nn}^{j}}\right) = \bar{\theta}^{j}ln(d_{ni}) + \zeta_{n}^{j} + \iota_{i}^{j} + \xi_{ni}^{j}$$

  where d_{ni} is geographic distance;ζ_{n}^{j} and ι_{i}^{j} are sector-specific importer- and exporter-effects.
- exporter effect: $\hat{\iota}_{i}^{j} = \S_{i}^{j} - \theta^{j}ln(\psi_{i}^{j})$; importer effect: $\hat{\zeta}_{n}^{j} = -\S_{n}^{j}$; exporter-specific trade costs $ln(\kappa_{2,i}^{j}) = -\frac{(\hat{\iota}_{i}^{j}+\hat{\zeta}_{n}^{j})}{\theta^{j}}$.

Productivity Estimation

Productivity: run equilibrium to target moment 'sales'

- Outer loop:guess $T_n^j \rightarrow$ *start loop on wage*.
- Inner loop: guess wage $w_n \rightarrow$ *Price*$(\mathrm{P}_n^j) \rightarrow$ *Trade share*$(\pi_{ni}^j) \rightarrow$ Expenditure $(X_n^j) \rightarrow$ *Trade deficit* $\rightarrow$ *adjust wage* $\rightarrow$ *end loop on wage*.
- compare sales with real data $\rightarrow$ *adjust* $\mathrm{T}_n^j \rightarrow$ end the outer loop.

Some tips on coding

- check equilibrium (trade balance or labor market clearance)
- be careful with 0
- constraints on parameters
- solve efficiency: order, minimizing loop variable
- generalizing code

Sectoral trade elasticity

- Related literature: Bagwell et al.(2018), Caliendo and Parro(2015), Giri et al.(2020), Shapiro (2016)
- Median trade elasticity: Shapiro (2019)
- Scaled versions of the original elasticity: Ossa (2014)

Other related

- Parro (2013, AMJ) (skill premium)
- Swiecki (2017, JIE) (Labor friction)
- Albrecht and Tombe (CJE, 2016; Canada internal trade cost)
- Giri et al.(2020)