AEA Continuing Education Program

International Trade

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AEA Continuing Education: International Trade — Lecture 1: The Ricardian Model[1]—

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[1] All material based on earlier courses taught jointly with Arnaud Costinot (MIT).

Taxonomy of Neoclassical Trade Models

- In a neoclassical trade model, comparative advantage, i.e. differences in relative autarky prices (Deardorff, 1980), is the rationale for trade
- Differences in autarky prices may have two origins:
  1. Demand (periphery of the field)
  2. Supply (core of the field)
     1. **Ricardian theory:** Technological differences
     2. **Factor proportion theory**: Factor endowment differences

Taxonomy of Neoclassical Trade Models

- In order to shed light on the role of technological and factor endowment differences:
  - Ricardian theory assumes only one aggregate factor of production
  - Factor proportion theory rules out technological differences across countries
- Neither set of assumptions is realistic, but both may be useful depending on the question one tries to answer:
  - If you want to understand the impact of the rise of China on real incomes in the US, Ricardian theory is the natural place to start
  - If you want to study its effects on the skill premium, more factors will be needed
- Note that:
  - Technological and factor endowment differences are exogenously given
  - No relationship between technology and factor endowments (Skill-biased technological change?)

Standard Ricardian Model
Dornbush, Fischer and Samuelson (1977)

- Consider a world economy with **two countries**: Home and Foreign
- Asterisks denote variables related to the Foreign country
- Ricardian models differ from other neoclassical trade models in that there only is **one aggregate factor** of production
  - There can be many (nontradable) factors, but they can all be aggregated into a single composite input at any relative factor prices (which means that all goods must have the same factor intensities)
- We denote by:
  - L and L^* the endowments of labor (in efficiency units) in the two countries
  - w and w^* the wages (in efficiency units) in the two countries

Standard Ricardian Model

Supply-side assumptions

- There is a **continuum** of goods indexed by $z \in [0, 1]$
- Since there are CRS, we can define the (constant) unit labor requirements in both countries: $a(z)$ and $a^*(z)$
- $a(z)$ and $a^*(z)$ capture all we need to know about technology in the two countries
- W.l.o.g, we order goods such that $A(z) \equiv \frac{a^*(z)}{a(z)}$ is decreasing
    - Hence Home has a comparative advantage in the low-z goods
    - For simplicity, we'll assume strict monotonicity

- Previous supply-side assumptions are all we need to make qualitative predictions about pattern of trade
- Let $p(z)$ denote the price of good z under free trade
- Profit-maximization requires

$$p(z) - wa(z) \leq 0, \text{ with equality if } z \text{ produced at home} \quad (1)$$
$$p(z) - w^* a^*(z) \leq 0, \text{ with equality if } z \text{ produced abroad} \quad (2)$$

- **Proposition** *There exists* $\tilde{z} \in [0,1]$ *such that Home produces all goods* $z < \tilde{z}$ *and Foreign produces all goods* $z > \tilde{z}$

- **Proof:** By contradiction. Suppose that there exists $z' < z$ such that z produced at Home and z' is produced abroad. (1) and (2) imply

$$\begin{aligned} p(z) - wa(z) &= 0 \\ p(z') - wa(z') &\leq 0 \\ p(z') - w^* a^*(z') &= 0 \\ p(z) - w^* a^*(z) &\leq 0 \end{aligned}$$

This implies

$$wa(z)\, w^* a^*(z') = p(z)\, p(z') \leq wa(z')\, w^* a^*(z),$$

which can be rearranged as

$$a^*(z') / a(z') \leq a^*(z) / a(z)$$

This contradicts A strictly decreasing.

Standard Ricardian Model

Free trade equilibrium (I): Efficient international specialization

- Proposition simply states that Home should produce and specialize in the goods in which it has a CA
- Note that:
  - Proposition does not rely on continuum of goods
  - Continuum of goods + continuity of A is important to derive

$$A\left(\tilde{z}\right) = \frac{w}{w^*} \equiv \omega \tag{3}$$

- Equation (3) is the first of DFS's two equilibrium conditions:
  - Conditional on wages, goods should be produced in the country where it is cheaper to do so
- But in order to complete characterization of free trade equilibrium, we need look at the demand side to pin down the relative wage ω

Standard Ricardian Model

Demand-side assumptions

- Consumers have **identical Cobb-Douglas** preferences around the world
- We denote by $b(z) \in (0,1)$ the share of expenditure on good z:

$$b(z) = \frac{p(z)\, c(z)}{wL} = \frac{p(z)\, c^*(z)}{w^* L^*}$$

  where $c(z)$ and $c^*(z)$ are consumptions at Home and Abroad
- By definition, share of expenditures satisfy: $\int_0^1 b(z)\, dz = 1$

Standard Ricardian Model

Free trade equilibrium (II): trade balance

- Let us denote by $\theta(\widetilde{z}) \equiv \int_0^{\widetilde{z}} b(z)\, dz$ the fraction of income spent (*in both countries*) on goods produced at Home
- Trade balance requires

$$\theta(\widetilde{z})\, w^* L^* = [1 - \theta(\widetilde{z})]\, wL$$

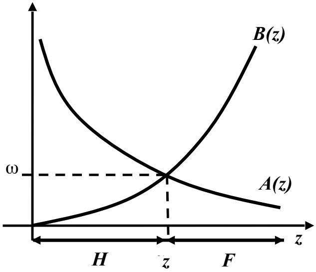
- LHS$\equiv$ Home exports; RHS$\equiv$ Home imports. (TB requires that these are equal, in value terms.)
- Previous equation can be rearranged as

$$\omega = \frac{\theta(\widetilde{z})}{1 - \theta(\widetilde{z})} \left(\frac{L^*}{L}\right) \equiv B(\widetilde{z}) \qquad (4)$$

- Note that $B' > 0$: an increase in $\widetilde{z}$ leads to a trade surplus at Home, which must be compensated by an increase in Home's relative wage ω

Standard Ricardian Model

Putting things together



- Efficient international specialization, Equation (3), and trade balance, (4), jointly determine $(\widetilde{z}, \omega)$

- Since Ricardian model is a neoclassical model, general results about the gains from trade (Samuelson, Kemp, Dixit-Norman, etc) still hold
  - Basic intuition is just that any departure from autarky is a choice, so if a country chooses it then it must be (weakly) welfare-improving
- However, one can directly show the existence of gains from trade in this environment
- **Argument:**
  - Set $w = 1$ under autarky and free trade (numeraire choice)
  - Indirect utility of Home representative household only depends on $p(\cdot)$
  - For goods z produced at Home under free trade: no change compared to autarky
  - For goods z produced Abroad under free trade: $p(z) = w^* a^*(z) < a(z)$
  - Since all prices go down (weakly, and at least some strictly), indirect utility must go up

Adding ("Iceberg") Trade Costs

When selling abroad, costs are $1/g$ times higher ($g < 1$) than when selling at home. More common notation is that $\tau = 1/g$

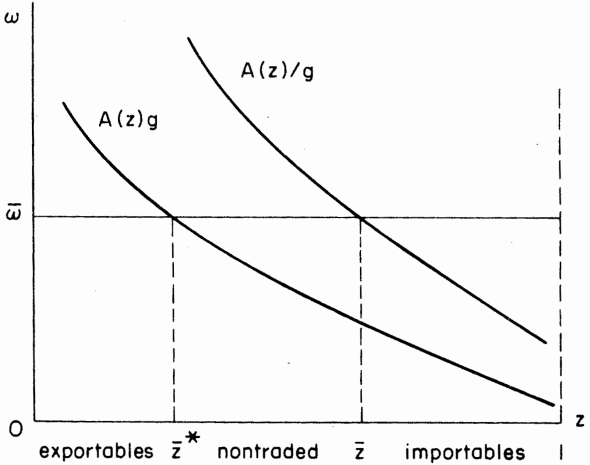


FIGURE 3

Equivalent Representation: Wilson (1980)

- Can think of the demand for country j's labor by any country i, $L_{ji}(\omega)$.

- For example:

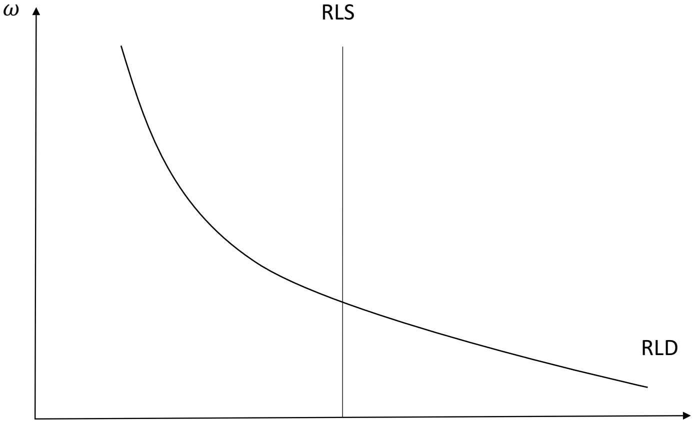
$$\frac{L_{FH}(\omega)}{L_{HH}(\omega)} = \frac{1}{\omega} \times \frac{\int_{A^{-1}(1/\tau_{HF}\omega)}^{1} b(z)dz}{\int_{0}^{A^{-1}(\tau_{FH}/\omega)} b(z)dz}$$

- Equilibrium is where LS = LD: $L_H = L_{HH}(\omega) + L_{HF}(\omega)$

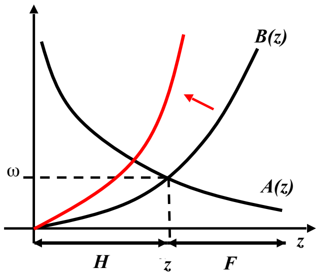
- Welfare is a function of ω only

- So all "macro counterfactuals" (anything aggregate: trade flows, terms of trade, factor prices, welfare) can be solved for with knowledge of $L_{ji}(\omega)$ functions alone.

(Relative) Factor Demand and Supply



What Are the Consequences of (Relative) Country Growth?



- Suppose that L^*/L goes up (rise of China):
  - ω goes up and $\widetilde{z}$ goes down
  - At initial wages, an increase in L^*/L creates a trade deficit Abroad, which must be compensated by an increase in ω

What are the Consequences of (Relative) Country Growth?

- Increase in L^*/L raises indirect utility, i.e. real wage, of representative household at Home and lowers it Abroad:
  - Set $w = 1$ before and after the change in L^*/L
  - For goods z whose production remains at Home: no change in $p(z)$
  - For goods z whose production remains Abroad: $\omega \nearrow \Rightarrow w^* \searrow \Rightarrow p(z) = w^* a^*(z) \searrow$
  - For goods z whose production moves Abroad: $w^* a^*(z) \leq a(z) \Rightarrow p(z) \searrow$
  - So Home gains. Similar logic implies welfare loss Abroad
- **Comments:**
  - In spite of CRS at the industry-level, everything is as if we had DRS at the country-level
  - As Foreign's size increases, it specializes in sectors in which it is relatively less productive (compared to Home), which worsens its terms-of trade, and so, lowers real GDP per capita
  - The flatter the A schedule, the smaller this effect

What are the Consequences of Technological Change?

- There are many ways to model technological change:
  1. Global uniform technological change: for all z, $\widehat{a}(z) = \widehat{a}^*(z) = x > 0$
  2. Foreign uniform technological change: for all z, $\widehat{a}(z) = 0$, but $\widehat{a}^*(z) = x > 0$
  3. International transfer of the most efficient technology: for all z, $a(z) = a^*(z)$ (Offshoring?)
- Using the same logic as in the previous comparative static exercise, one can easily check that:
  1. Global uniform technological change increases welfare everywhere
  2. Foreign uniform technological change increases welfare everywhere (For Foreign, this depends on Cobb-Douglas assumption)
  3. If Home has the most efficient technology, $a(z) < a^*(z)$ initially, then it will lose from international transfer (no gains from trade)

- Suppose that there is $T > 0$ such that:
  - Home's income is equal to $wL + T$,
  - Foreign's income is equal to $w^*L^* - T$
- If preferences are identical in both countries, transfers do not affect the trade balance condition:

$$\left[1 - \theta\left(\widetilde{z}\right)\right]\left(wL + T\right) - \theta\left(\widetilde{z}\right)\left(w^*L^* - T\right) = T$$

$\Leftrightarrow$

$$\theta\left(\widetilde{z}\right) w^*L^* = \left[1 - \theta\left(\widetilde{z}\right)\right] wL$$

- So there are no terms-of-trade effect
- If Home consumption is biased towards Home goods, $\theta\left(z\right) > \theta^*\left(z\right)$ for all z, then transfer further improves Home's terms-of trade
- See Dekle, Eaton, and Kortum (2007) for a recent application

Multi-country extensions

- DFS 1977 provides extremely elegant version of the Ricardian model:
  - Characterization of free trade equilibrium boils down to finding $(\widetilde{z}, \omega)$ using efficient international specialization and trade balance
- Problem is that this approach does not easily extend to economies with more than two countries
  - In the two-country case, each country specializes in the goods in which it has a CA compared to the other country
  - Who is the other country if there are more than 2?
- **Multi-country extensions of the Ricardian model:**
  1. Jones (1961)
  2. Costinot (2009)
  3. Wilson (1980)
  4. Eaton and Kortum (2002)

“Putting Ricardo to Work” (EK, JEP, 2012)

- Ricardian model has long been perceived has useful pedagogic tool, with little empirical content:
    - Great to explain undergrads why there are gains from trade
    - But grad students should study richer models (e.g. Feenstra’s graduate textbook has a total of 3 pages on the Ricardian model!)
- Eaton and Kortum (2002) has lead to “Ricardian revival”
    - Same basic idea as in Wilson (1980): Who cares about the pattern of trade for counterfactual analysis?
    - But more structure: Small number of parameters, so well-suited for quantitative work

Basic Assumptions

- N countries, $i = 1, ..., N$
- Continuum of goods $u \in [0, 1]$
- Preferences are CES with elasticity of substitution σ (this is actually way stronger than needed):

$$U_i = \left(\int_0^1 q_i(u)^{(\sigma-1)/\sigma} du \right)^{\sigma/(\sigma-1)},$$

- One factor of production ("labor")
- There may also be intermediate goods (more on that later)
- $c_i \equiv$ unit cost of the "common input" used in production of all goods
    - Without intermediate goods, c_i is equal to wage w_i in country i

Basic Assumptions (Cont.)

- Constant returns to scale:
  - $Z_i(u)$ denotes productivity of (any) firm producing u in country i
  - $Z_i(u)$ is drawn independently (across goods and countries) from a **Fréchet distribution**:

$$\Pr(Z_i \leq z) = F_i(z) = e^{-T_i z^{-\theta}},$$

    with $\theta > \sigma - 1$ (important restriction, see below)
  - Since goods are symmetric except for productivity, we can forget about index u and keep track of goods through $\boldsymbol{Z} \equiv (Z_1, ..., Z_N)$.
- Trade is subject to iceberg costs $d_{ni} \geq 1$
  - d_{ni} units need to be shipped from i so that 1 unit makes it to n
- All markets are perfectly competitive

- Let $P_{ni}(\boldsymbol{Z}) \equiv c_i d_{ni} / Z_i$ be the unit cost at which country i can serve a good $\boldsymbol{Z}$ to country n and let $G_{ni}(p) \equiv \Pr(P_{ni}(\boldsymbol{Z}) \leq p)$. Then:

$$G_{ni}(p) = \Pr\left(Z_i \geq c_i d_{ni} / p\right) = 1 - F_i(c_i d_{ni} / p)$$

- Let $P_n(\boldsymbol{Z}) \equiv \min\{P_{n1}(\boldsymbol{Z}), ..., P_{nN}(\boldsymbol{Z})\}$ and let $G_n(p) \equiv \Pr(P_n(\boldsymbol{Z}) \leq p)$ be the price distribution in country n. Then:

$$G_n(p) = 1 - \exp[-\Phi_n p^\theta]$$

where

$$\Phi_n \equiv \sum_{i=1}^{N} T_i (c_i d_{ni})^{-\theta}$$

- To show this, note that (suppressing notation $\boldsymbol{Z}$ from here onwards)

$$\begin{aligned}\Pr(P_n \leq p) &= 1 - \Pi_i \Pr(P_{ni} \geq p) \\ &= 1 - \Pi_i \left[1 - G_{ni}(p)\right]\end{aligned}$$

- Using

$$G_{ni}(p) = 1 - F_i(c_i d_{ni}/p)$$

then

$$\begin{aligned}1 - \Pi_i \left[1 - G_{ni}(p)\right] &= 1 - \Pi_i F_i(c_i d_{ni}/p) \\ &= 1 - \Pi_i e^{-T_i (c_i d_{ni})^{-\theta} p^{\theta}} \\ &= 1 - e^{-\Phi_n p^{\theta}}\end{aligned}$$

- Consider a particular good. Country n buys the good from country i if $i = \arg\min\{p_{n1}, ..., p_{nN}\}$. The probability of this event is simply country i's contribution to country n's price parameter Φ_n,

$$\pi_{ni} = \frac{T_i(c_i d_{ni})^{-\theta}}{\Phi_n}$$

- To show this, note that

$$\pi_{ni} = \Pr\left(P_{ni} \leq \min_{s \neq i} P_{ns}\right)$$

- If $P_{ni} = p$, then the probability that country i is the least cost supplier to country n is equal to the probability that $P_{ns} \geq p$ for all $s \neq i$

Four Key Results

B - The Allocation of Purchases (Cont.)

- The previous probability is equal to

$$\Pi_{s\neq i} \Pr(P_{ns} \geq p) = \Pi_{s\neq i} \left[1 - G_{ns}(p)\right] = e^{-\Phi_n^{-i} p^{\theta}}$$

where

$$\Phi_n^{-i} = \sum_{s\neq i} T_i \left(c_i d_{ni}\right)^{-\theta}$$

- Now we integrate over this for all possible p's times the density $dG_{ni}(p)$ to obtain

$$\int_0^{\infty} e^{-\Phi_n^{-i} p^{\theta}} T_i \left(c_i d_{ni}\right)^{-\theta} \theta p^{\theta-1} e^{-T_i \left(c_i d_{ni}\right)^{-\theta} p^{\theta}} dp$$

$$= \left(\frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n}\right) \int_0^{\infty} \theta \Phi_n e^{-\Phi_n p^{\theta}} p^{\theta-1} dp$$

$$= \pi_{ni} \int_0^{\infty} dG_n(p) dp = \pi_{ni}$$

Four Key Results

B - The Allocation of Purchases (Cont.)

- Close connection between EK and McFadden's logit model
- Take heteorogeneous consumers, indexed by u, with utility $U_n(u)$ from consuming good i:

$$U_i(u) = U_i - p_i + \varepsilon_i(u)$$

with $\varepsilon_i(u)$ i.i.d from **Gumbel distribution:**

$$\Pr(\varepsilon_i(u) \leq \varepsilon) = \exp(-\exp(-\theta\varepsilon))$$

- **Logit:** for each *consumer u*, choose *good i* that maximizes $U_i(u) \Rightarrow$

$$\pi_i = \frac{\exp[\theta(U_i - p_i)]}{\sum_j \exp[\theta(U_j - p_j)]}$$

- **EK:** for each *good u*, choose *source country i* that minimizes $\ln p_i(u) = \ln c_i - \ln Z_i(u)$. Then $\ln($**Fréchet**$) =$**Gumbel** $\Rightarrow$

$$\pi_i = \frac{\exp[\theta(-\ln c_i)]}{\sum_j \exp[\theta(-\ln c_j)]} = \frac{c_i^{-\theta}}{\sum_j c_j^{-\theta}}$$

- The price of a good that country n actually buys from any country i also has the distribution $G_n(p)$.
- To show this, note that if country n buys a good from country i it means that i is the least cost supplier. If the price at which country i sells this good in country n is q, then the probability that i is the least cost supplier is

$$\Pi_{s \neq i} \Pr(P_{ni} \geq q) = \Pi_{s \neq i} \left[1 - G_{ns}(q)\right] = e^{-\Phi_n^{-i} q^{\theta}}$$

- The joint probability that country i has a unit cost q of delivering the good to country n **and** is the the least cost supplier of that good in country n is then

$$e^{-\Phi_n^{-i} q^{\theta}} dG_{ni}(q)$$

- Integrating this probability $e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q)$ over all prices $q \leq p$ and using $G_{ni}(q) = 1 - e^{-T_i(c_i d_{ni})^{-\theta} p^\theta}$ then

$$\int_0^p e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q)$$
$$= \int_0^p e^{-\Phi_n^{-i} q^\theta} \theta T_i(c_i d_{ni})^{-\theta} q^{\theta-1} e^{-T_i(c_i d_{ni})^{-\theta} p^\theta} dq$$
$$= \left(\frac{T_i(c_i d_{ni})^{-\theta}}{\Phi_n} \right) \int_0^p e^{-\Phi_n q^\theta} \theta \Phi_n q^{\theta-1} dq$$
$$= \pi_{ni} G_n(p)$$

- Given that $\pi_{ni} \equiv$ probability that for any particular good country i is the least cost supplier in n, then conditional distribution of the price charged by i in n for the goods that i actually sells in n is

$$\frac{1}{\pi_{ni}} \int_0^p e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q) = G_n(p)$$

Four Key Results

C - The Conditional Price Distribution (Cont.)

- In Eaton and Kortum (2002):
  1. All the adjustment is at the extensive margin: countries that are more distant, have higher costs, or lower $T's$, simply sell a smaller range of goods, but the average price charged is the same.
  2. The share of spending by country n on goods from country i is the same as the probability π_{ni} calculated above.
- You will see in later lectures a similar property in models of monopolistic competition with Pareto distributions of firm-level productivity

- The exact price index for a CES utility with elasticity of substitution $\sigma < 1 + \theta$, defined as

$$p_n \equiv \left(\int_0^1 p_n(u)^{1-\sigma} du \right)^{1/(1-\sigma)},$$

is given by

$$p_n = \gamma \Phi_n^{-1/\theta}$$

where

$$\gamma = \left[\Gamma \left(\frac{1-\sigma}{\theta} + 1 \right) \right]^{1/(1-\sigma)},$$

where Γ is the Gamma function, *i.e.* $\Gamma(a) \equiv \int_0^\infty x^{a-1} e^{-x} dx$.

- To show this, note that

$$\begin{aligned} p_n^{1-\sigma} &= \int_0^1 p_n(u)^{1-\sigma} du = \\ \int_0^\infty p^{1-\sigma} dG_n(p) &= \int_0^\infty p^{1-\sigma} \Phi_n \theta p^{\theta-1} e^{-\Phi_n p^\theta} dp. \end{aligned}$$

- Defining $x = \Phi_n p^\theta$, then $dx = \Phi_n \theta p^{\theta-1}$, $p^{1-\sigma} = (x/\Phi_n)^{(1-\sigma)/\theta}$, and

$$\begin{aligned} p_n^{1-\sigma} = \int_0^\infty (x/\Phi_n)^{(1-\sigma)/\theta} e^{-x} dx \\ = \Phi_n^{-(1-\sigma)/\theta} \int_0^\infty x^{(1-\sigma)/\theta} e^{-x} dx \\ = \Phi_n^{-(1-\sigma)/\theta} \Gamma\left(\frac{1-\sigma}{\theta} + 1\right) \end{aligned}$$

- This implies $p_n = \gamma \Phi_n^{-1/\theta}$ with $\frac{1-\sigma}{\theta} + 1 > 0$ or $\sigma - 1 < \theta$ for gamma function to be well defined

Equilibrium

- Let X_{ni} be total spending in country n on goods from country i
- Let $X_n \equiv \sum_i X_{ni}$ be country n's total spending
- We know that $X_{ni}/X_n = \pi_{ni}$, so

$$X_{ni} = \frac{T_i(c_i d_{ni})^{-\theta}}{\sum_j T_j(w_j d_{nj})^{-\theta}} X_n \qquad (*)$$

- Suppose that there are no intermediate goods so that $c_i = w_i$.
- In equilibrium, total income in country i must be equal to total spending on goods from country i so

$$w_i L_i = \sum_n X_{ni}$$

- Trade balance further requires $X_n = w_n L_n$ so that

$$w_i L_i = \sum_n \frac{T_i(w_i d_{ni})^{-\theta}}{\sum_j T_j(w_j d_{nj})^{-\theta}} w_n L_n$$

Equilibrium (Cont.)

- This provides a system of $N-1$ independent equations (Walras' Law) that can be solved for wages $(w_1, ..., w_N)$ up to a choice of numeraire
- Everything is as if countries were exchanging labor
  - Fréchet distributions imply that labor demands are iso-elastic
  - Armington model leads to similar eq. conditions under assumption that each country is exogenously specialized in a differentiated good
  - In the Armington model, the labor demand elasticity simply coincides with elasticity of substitution σ.
    - See Anderson and van Wincoop (2003)
- Iso-elastic case is what trade economists refer to as a "gravity model" with (*)="gravity equation"
  - We'll come back to gravity models many times in this course

How to Estimate the Trade Elasticity?

- As we will see, trade elasticity $\theta =$ key structural parameter for welfare and counterfactual analysis in EK model (and other gravity models)
- From (*) we also get that country i's share in country n's expenditures normalized by its own share is

$$S_{ni} \equiv \frac{X_{ni}/X_n}{X_{ii}/X_i} = \frac{\Phi_i}{\Phi_n} d_{ni}^{-\theta} = \left(\frac{p_i d_{ni}}{p_n} \right)^{-\theta}$$

- This shows the importance of trade costs in determining trade volumes. Note that if there are no trade barriers (i.e, frictionless trade), then $S_{ni} = 1$.
- If we had data on d_{ni}, we could run a regression of $\ln S_{ni}$ on $\ln d_{ni}$ with importer and exporter dummies to recover θ
  - But how do we get d_{ni}?

How to Estimate the Trade Elasticity?

- EK use price data to measure $p_i d_{ni} / p_n$:
- They use retail prices in 19 OECD countries for 50 manufactured products from the UNICP 1990 benchmark study.
- They interpret these data as a sample of the prices $p_i(j)$ of individual goods in the model.
- They note that for goods that n imports from i we should have $p_n(j) / p_i(j) = d_{ni}$, whereas goods that n doesn't import from i can have $p_n(j) / p_i(j) \leq d_{ni}$.
- Since every country in the sample does import manufactured goods from every other, then $\max_j \{ p_n(j) / p_i(j) \}$ should be equal to d_{ni}.
- To deal with measurement error, they actually use the second highest $p_n(j) / p_i(j)$ as a measure of d_{ni}.

How to Estimate the Trade Elasticity?

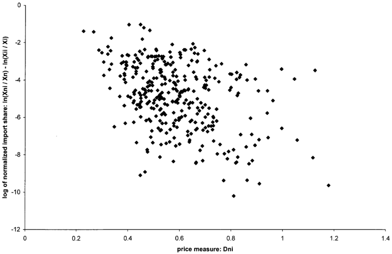


FIGURE 2.—Trade and prices.

- Let $r_{ni}(j) \equiv \ln p_n(j) - \ln p_i(j)$. They calculate $\ln(p_n/p_i)$ as the mean across j of $r_{ni}(j)$. Then they measure $\ln(p_i d_{ni}/p_n)$ by

$$D_{ni} = \frac{\max 2_j\{r_{ni}(j)\}}{\sum_j r_{ni}(j)/50}$$

- Given $S_{ni} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta}$ they estimate θ from $\ln(S_{ni}) = -\theta D_{ni}$. Method of moments: $\theta = 8.28$. OLS with zero intercept: $\theta = 8.03$.

Alternative Strategies for Estimating θ

- Simonovska and Waugh (2014, JIE) argue that EK's procedure suffers from upward bias:
  - Since EK are only considering 50 goods, maximum price gap may still be strictly lower than trade cost
  - If we underestimate trade costs, we overestimate trade elasticity
  - Simulation based method of moments leads to a θ closer to 4.
- An alternative approach is to use tariffs (Caliendo and Parro, 2015, REStud). If $d_{ni} = t_{ni}\tau_{ni}$ where t_{ni} is one plus the ad-valorem tariff (they actually do this for each 2 digit industry) and τ_{ni} is assumed to be symmetric, then

$$\frac{X_{ni}X_{ij}X_{jn}}{X_{nj}X_{ji}X_{in}} = \left(\frac{d_{ni}d_{ij}d_{jn}}{d_{nj}d_{ji}d_{in}}\right)^{-\theta} = \left(\frac{t_{ni}t_{ij}t_{jn}}{t_{nj}t_{ji}t_{in}}\right)^{-\theta}$$

- They can then run an OLS regression and recover θ. Their preferred specification leads to an estimate of 8.22

Alternative Strategies for Estimating θ

- Shapiro (2014) uses time-variation in freight costs (again for each 2 digit industry):

$$\ln X_{ni}^{t} = \alpha_{ni} + \beta_{nt} + \gamma_{it} - \theta \ln(1 + s_{ni}^{t}) + \varepsilon_{ni}^{t}$$

  - $s_{ni}^{t} \equiv$ total shipping costs between i and n in (Q1 and Q4 of) year t
  - $\alpha_{ni} \equiv$ importer-exporter fixed effect; $\beta_{nt} \equiv$ importer-year fixed effect; $\gamma_{it} \equiv$ exporter-year fixed-effect
  - To deal with measurement error in freight costs, he instruments shipping costs from Q1 and Q4 with shipping costs from Q2 and Q3
  - IV estimate of trade elasticity $\equiv$ 7.91.

- Head and Mayer (2015) offer a review of trade elasticity estimates:
  - Typical value is around 5
  - But should we expect aggregate $=$ sector-level elasticities?

Gains from Trade

- Consider again the case where $c_i = w_i$
- From (*), we know that

$$\pi_{nn} = \frac{X_{nn}}{X_n} = \frac{T_n w_n^{-\theta}}{\Phi_n}$$

- We also know that $p_n = \gamma \Phi_n^{-1/\theta}$, so

$$\omega_n \equiv w_n / p_n = \gamma^{-1} T_n^{1/\theta} \pi_{nn}^{-1/\theta}.$$

- Under autarky we have $\omega_n^A = \gamma^{-1} T_n^{1/\theta}$, hence the **gains from trade** are given by

$$GT_n \equiv \omega_n / \omega_n^A = \pi_{nn}^{-1/\theta}$$

- Trade elasticity θ and share of expenditure on domestic goods π_{nn} are sufficient statistics to compute GT. We will see this again in the next lecture.

Gains from Trade (Cont.)

- A typical value for π_{nn} (manufacturing) is 0.7. With $\theta = 5$ this implies $GT_n = 0.7^{-1/5} = 1.074$ or 7.4% gains. Belgium has $\pi_{nn} = 0.2$, so its gains are $GT_n = 0.2^{-1/5} = 1.38$ or 38%.
- One can also use the previous approach to measure the welfare gains associated with any foreign shock, not just moving to autarky:

$$\omega_n'/\omega_n = \left(\pi_{nn}'/\pi_{nn}\right)^{-1/\theta}$$

- For more general counterfactual scenarios, however, one needs to know both π_{nn}' and π_{nn}.

Adding an Input-Output Loop

- Imagine that intermediate goods are used to produce a composite good with a CES production function with elasticity $\sigma > 1$. This composite good can be either consumed or used to produce intermediate goods (input-output loop).
- Each intermediate good is produced from labor and the composite good with a Cobb-Douglas technology with labor share β. We can then write $c_i = w_i^{\beta} p_i^{1-\beta}$.

Adding an Input-Output Loop (Cont.)

- The analysis above implies
$$\pi_{nn} = \gamma^{-\theta} T_n \left(\frac{c_n}{p_n}\right)^{-\theta}$$
and hence
$$c_n = \gamma^{-1} T_n^{-1/\theta} \pi_{nn}^{-1/\theta} p_n$$
- Using $c_n = w_n^{\beta} p_n^{1-\beta}$ this implies
$$w_n^{\beta} p_n^{1-\beta} = \gamma^{-1} T_n^{-1/\theta} \pi_{nn}^{-1/\theta} p_n$$
so
$$w_n / p_n = \gamma^{-1/\beta} T_n^{-1/\theta\beta} \pi_{nn}^{-1/\theta\beta}$$
- The gains from trade are now
$$\omega_n / \omega_n^A = \pi_{nn}^{-1/\theta\beta}$$
- Standard value for β is $1/2$ (Alvarez and Lucas, 2007). For $\pi_{nn} = 0.7$ and $\theta = 5$ this implies $GT_n = 0.7^{-2/5} = 1.15$ or 15% gains.

Adding Non-Tradables

- Assume now that the composite good cannot be consumed directly.
- Instead, it can either be used to produce intermediates (as above) or to produce a consumption good (together with labor).
- The production function for the consumption good is Cobb-Douglas with labor share α.
- This consumption good is assumed to be non-tradable.

Adding Non-Tradables (Cont.)

- The price index computed above is now p_{gn}, but we care about $\omega_n \equiv w_n / p_{fn}$, where
$$p_{fn} = w_n^{\alpha} p_{gn}^{1-\alpha}$$
- This implies that
$$\omega_n = \frac{w_n}{w_n^{\alpha} p_{gn}^{1-\alpha}} = \left(w_n / p_{gn}\right)^{1-\alpha}$$
- Thus, the gains from trade are now
$$\omega_n / \omega_n^A = \pi_{nn}^{-\eta/\theta}$$
where
$$\eta \equiv \frac{1-\alpha}{\beta}$$
- Alvarez and Lucas argue that $\alpha = 0.75$ (share of labor in services). Thus, for $\pi_{nn} = 0.7$, $\theta = 5$ and $\beta = 0.5$, this implies $GT_n = 0.7^{-1/10} = 1.036$ or 3.6% gains

Comparative statics (Dekle, Eaton and Kortum, 2008)

- Go back to the simple EK model above ($\alpha = 0$, $\beta = 1$). We have

$$\begin{aligned} X_{ni} &= \frac{T_i (w_i d_{ni})^{-\theta} X_n}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \\ \sum_n X_{ni} &= w_i L_i \end{aligned}$$

- As we have already established, this leads to a system of non-linear equations to solve for wages,

$$w_i L_i = \sum_n \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_k T_k (w_k d_{nk})^{-\theta}} w_n L_n.$$

Comparative statics (Dekle, Eaton and Kortum, 2008)

- Consider a shock to labor endowments, trade costs, or productivity. One could compute the original equilibrium, the new equilibrium and compute the changes in endogenous variables.
- But there is a simpler way that uses only information for observables in the initial equilibrium, trade shares and GDP; the trade elasticity, θ; and the exogenous shocks. First solve for changes in wages by solving

$$\hat{w}_i \hat{L}_i Y_i = \sum_n \frac{\pi_{ni} \hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}} \hat{w}_n \hat{L}_n Y_n$$

and then get changes in trade shares from

$$\hat{\pi}_{ni} = \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.$$

- From here, one can compute welfare changes by using the formula above, namely $\hat{\omega}_n = \left(\hat{\pi}_{nn}\right)^{-1/\theta}$.

Comparative statics (Dekle, Eaton and Kortum, 2008)

- To show this, note that trade shares are

$$\pi_{ni} = \frac{T_i \left(w_i d_{ni}\right)^{-\theta}}{\sum_k T_k \left(w_k d_{nk}\right)^{-\theta}} \text{ and } \pi'_{ni} = \frac{T'_i \left(w'_i d'_{ni}\right)^{-\theta}}{\sum_k T'_k \left(w'_k d'_{nk}\right)^{-\theta}}.$$

- Letting $\hat{x} \equiv x'/x$, then we have

$$\begin{aligned}
\hat{\pi}_{ni} &= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k T'_k \left(w'_k d'_{nk}\right)^{-\theta} / \sum_j T_j \left(w_j d_{nj}\right)^{-\theta}} \\
&= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta} T_k \left(w_k d_{nk}\right)^{-\theta} / \sum_j T_j \left(w_j d_{nj}\right)^{-\theta}} \\
&= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.
\end{aligned}$$

Comparative statics (Dekle, Eaton and Kortum, 2008)

- On the other hand, for equilibrium we have

$$w_i' L_i' = \sum_n \pi_{ni}' w_n' L_n' = \sum_n \hat{\pi}_{ni} \pi_{ni} w_n' L_n'$$

- Letting $Y_n \equiv w_n L_n$ and using the result above for $\hat{\pi}_{ni}$ we get

$$\hat{w}_i \hat{L}_i Y_i = \sum_n \frac{\pi_{ni} \hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}} \hat{w}_n \hat{L}_n Y_n$$

- This forms a system of N equations in N unknowns, $\hat{w}_i$, from which we can get $\hat{w}_i$ as a function of shocks and initial observables (establishing some numeraire). Here π_{ni} and Y_i are data and we know $\hat{d}_{ni}$, $\hat{T}_i$, $\hat{L}_i$, as well as θ.

Comparative statics (Dekle, Eaton and Kortum, 2008)

- To compute the implications for welfare of a foreign shock, simply impose that $\hat{L}_n = \hat{T}_n = 1$, solve the system above to get $\hat{w}_i$ and get the implied $\hat{\pi}_{nn}$ through

$$\hat{\pi}_{ni} = \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.$$

  and use the formula to get

$$\hat{\omega}_n = \hat{\pi}_{nn}^{-1/\theta}$$

- Of course, if it is not the case that $\hat{L}_n = \hat{T}_n = 1$, then one can still use this approach, since it is easy to show that in autarky one has $w_n / p_n = \gamma^{-1} T_n^{1/\theta}$, hence in general

$$\hat{\omega}_n = \left(\hat{T}_n\right)^{1/\theta} \hat{\pi}_{nn}^{-1/\theta}$$

Extensions of EK

- **Bertrand Competition**: Bernard, Eaton, Jensen, and Kortum (2003)
  - Bertrand competition $\Rightarrow$ variable markups at the firm-level
  - Measured productivity varies across firms $\Rightarrow$ one can use firm-level data to calibrate model
  - Still tractable because everything in Bertrand depends on max and 2nd-max prices, both of which are relatively easy to work with when using EV distribution.
- **Multiple Sectors**: Costinot, Donaldson, and Komunjer (2012)
  - $T_i^k \equiv$ fundamental productivity in country i and sector k
  - One can use EK's machinery to study pattern of trade, not just volumes
- **Non-homothetic preferences:** Fieler (2011)
  - Rich and poor countries have different expenditure shares
  - Combined with differences in θ^k across sectors k, one can explain pattern of North-North, North-South, and South-South trade

An Empirical Challenge when Applying Ricardian Models

- Suppose that different factors of production specialize in different economic activities based on their relative productivity differences
- Following Ricardo's famous example, if English workers are relatively better at producing cloth than wine compared to Portuguese workers:
  - England will produce cloth
  - Portugal will produce wine
  - At least one of these two countries will be completely specialized in one of these two sectors
- Accordingly—as discussed in Lecture #5—the key explanatory variable in Ricardo's theory, relative productivity, cannot be directly observed

How Can One Solve This Identification Problem?

Existing Approach

- Previous identification problem is emphasized by Deardorff (1984) in his review of empirical work on the Ricardian model of trade
- A similar identification problem arises in labor literature in which self-selection based on CA is often referred to as the Roy model
  - Heckman and Honore (1990): if general distributions of worker skills are allowed, the Roy model has no empirical content
- One potential solution:
  - Make (fundamentally untestable) functional form assumptions about distributions
  - Use these assumptions to relate observable to unobservable productivity,
- Examples:
  - In a labor context: Log-normal distribution of worker skills
  - In a trade context: Fréchet distributions across countries and industries (Costinot, Donaldson and Komunjer, 2012)

How Can One Solve This Identification Problem?

- We'll look at Costinot and Donaldson (2012, 2016) who focus on sector in which scientific knowledge of how essential inputs map into outputs is well understood: agriculture
- As a consequence of this knowledge, agronomists predict the productivity of a 'field' (small parcel of land) if it were to grow any one of a set of crops
- In this particular context, we know the productivity of a 'field' in *all* economic activities, not just those in which it is currently employed

Basic Theoretical Environment

- The basic environment is the same as in the purely Ricardian part of Costinot (ECMA, 2009)
- Consider a world economy comprising:
  - $c = 1, ..., C$ countries
  - $g = 1, ..., G$ goods [crops in our empirical analysis]
  - $f = 1, ..., F$ factors of production ['fields', or grid cells, in our empirical analysis]
- Factors are immobile across countries, perfectly mobile across sectors
  - $L_{cf} \geq 0$ denotes the inelastic supply of factor f in country c
- Factors of production are perfect substitutes within each country and sector, but vary in their productivities $A_{cf}^{g} \geq 0$

Cross-Sectional Variation in Output

- Total output of good g in country c is given by

$$Q_c^g = \sum_{f=1}^{F} A_{cf}^g L_{cf}^g$$

- Take producer prices $p_c^g \geq 0$ as given and focus on the allocation that maximizes total revenue at these prices
- Assuming that this allocation is unique, can express output as

$$Q_c^g = \sum_{f \in \mathcal{F}_c^g} A_{cf}^g L_{cf} \tag{5}$$

where $\mathcal{F}_c^g$ is the set of factors allocated to good g in country c:

$$\mathcal{F}_c^g = \{ f = 1, \dots F | \, A_{cf}^g / A_{cf}^{g'} > p_c^{g'} / p_c^g \text{ if } g' \neq g \} \tag{6}$$

Data Requirements

- CD (2012; AER P&P)'s test of Ricardo's ideas requires data on:
  - Actual output levels, which we denote by $\widetilde{Q}_c^g$
  - Data to compute predicted output levels, which we denote by Q_c^g
- By equations (5) and (6), we can compute Q_c^g using data on:
  - Productivity, A_{cf}^g, for all factors of production f
  - Endowments of different factors, L_{cf}
  - Producer prices, p_c^g

Output and Price Data

- Output ($\widetilde{Q}_c^g$) and price (p_c^g) data are from FAOSTAT
- Output is equal to quantity harvested and is reported in tonnes
- Producer prices are equal to prices received by farmers net of taxes and subsidies and are reported in local currency units per tonne
- In order to minimize the number of unreported observations, our final sample includes 55 countries and 17 crops
- Since Ricardian predictions are cross-sectional, all data are from 1989

Productivity Data

- Global Agro-Ecological Zones (GAEZ) project run by FAO
  - Used in Nunn and Qian (2011) as proxy for areas where potato could be grown
- Productivity (A^g_{cf}) data for:
  - 154 varieties grouped into 25 crops c (though only 17 are relevant here)
  - All 'fields' f (5 arc-minute grid cells) on Earth
- Inputs:
  - Soil conditions (8 dimensional vector)
  - Climatic conditions (rainfall, temperature, humidity, sun exposure)
  - Elevation, average land gradient.
- Modeling approach:
  - Entirely 'micro-founded' from primitives of how each crop is grown.
  - 64 parameters per crop, each from field and lab experiments.
  - Different scenarios for other human inputs. We use 'mixed, irrigated'

Example: Relative Wheat-to-Sugar Cane Productivity

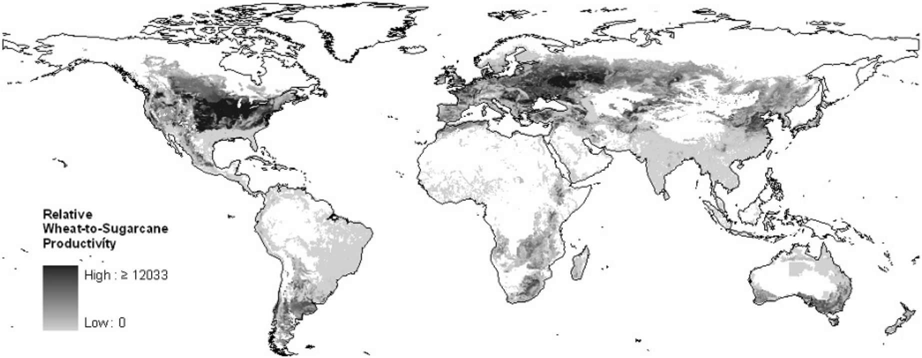


Figure 1: An Example of Relative Productivity Differences. Notes: Ratio of productivity in wheat (in tonnes/ha) relative to productivity in sugarcane (in tonnes/ha). Areas shaded white have either zero productivity in wheat, or zero productivity in both wheat and sugarcane. Areas shaded dark, with the highest value (">12,033"), have zero productivity in sugarcane and strictly positive productivity in wheat. Source: GAEZ project.

Empirical Strategy

- To overcome identification problem highlighted by Deardorff (1984) and Heckman and Honore (1990), CD (2012) follow two-step approach:
  1. We use the GAEZ data to predict the amount of output (Q_c^g) that country c should produce in crop g according to (5) and (6)
  2. We regress observed output ($\widetilde{Q}_c^g$) on predicted output (Q_c^g)
- Like in HOV literature, they consider test of Ricardo's theory of comparative advantage to be a success if:
  - The slope coefficient in this regression is close to unity
  - The coefficient is precisely estimated
  - The regression fit is good
- Compared to HOV literature, CD (2012) estimate regressions in logs:
  - Core of theory lies in how *relative* productivity predict *relative* quantities
  - *Absolute* levels of output are far off because more uses of land than 17 crops

Results

Table 1: Comparison of Actual Output to Predicted Output

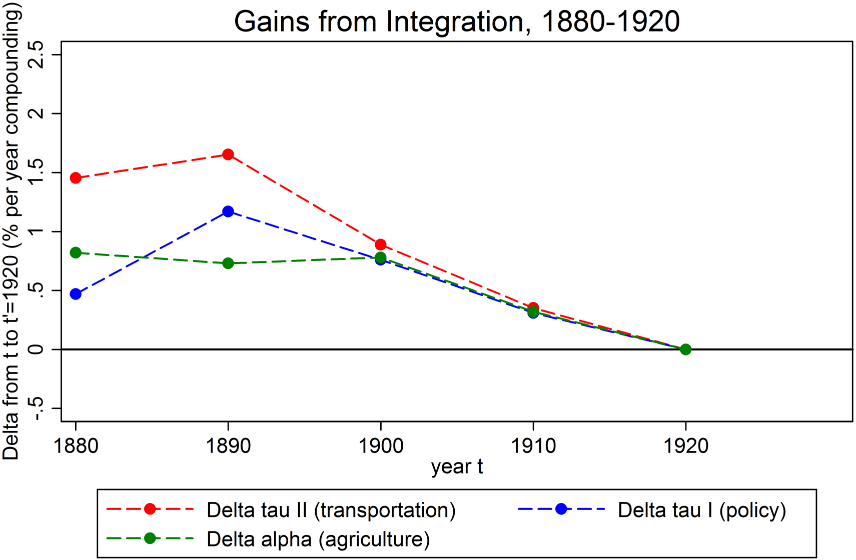
Dependent variable:	log (output)				
	(1)	(2)	(3)	(4)	(5)
log (predicted output)	0.212***	0.244***	0.096**	0.143**	0.273***
	(0.057)	(0.074)	(0.038)	(0.062)	(0.074)
sample	all	all	all	major countries	major crops
fixed effects	none	crop	country	none	none
observations	349	349	349	226	209
R-squared	0.06	0.26	0.54	0.04	0.07

Notes: All regressions include a constant. Standard errors clustered by country are in parentheses. ** indicates statistically significant at 5% level and *** at the 1% level.

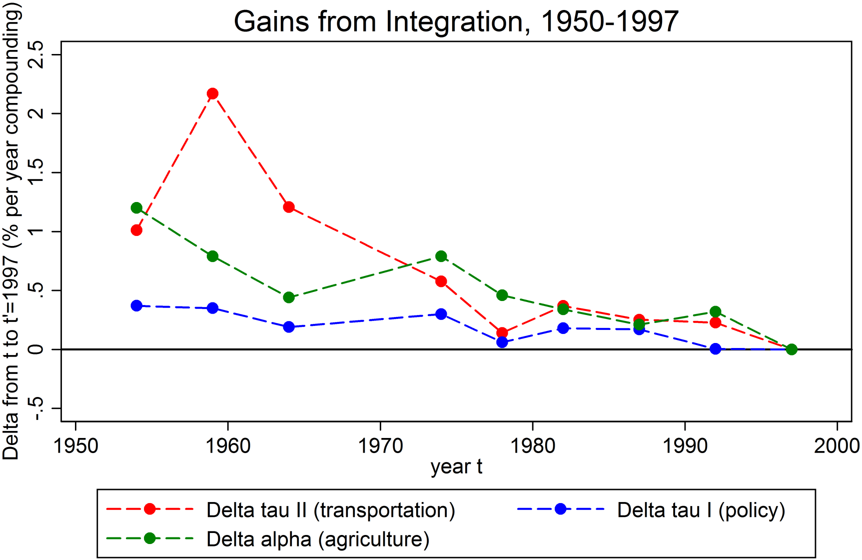
How Large are the Gains from Economic Integration?

- Regions of the world, both across and within countries, appear to have become more economically integrated with one another over time.
- Two natural questions arise:
  1. How large have been the gains from this integration?
  2. How large are the gains from further integration?
- CD (2016) apply same agricultural approach as in CD (2012) to answer question #1 in the context of the enhanced *intra*-national economic integration within the United States from 1880-1997.
  - Deardorff's identification problem for testing the Ricardian model arises again when using Ricardian model to measure gains from trade
  - Develop extension to allow for changing Ricardian PPFs between GAEZ period (c. 2000) and past

Gains from Economic Integration: Estimates



Gains from Economic Integration: Estimates



AEA Continuing Education: International Trade — Lecture 2: The Heckscher-Ohlin Model[1]—

Dave Donaldson (MIT)

[1] All material based on earlier courses taught jointly with Arnaud Costinot (MIT).

Factor Proportion Theory

- The law of comparative advantage establishes the relationship between relative autarky prices and trade flows
  - But where do relative autarky prices come from?
- Factor proportion theory emphasizes **factor endowment differences**
- **Key elements:**
  1. Countries differ in terms of factor abundance [i.e *relative* factor supply]
  2. Goods differ in terms of factor intensity [i.e *relative* factor demand]
- Interaction between 1 and 2 will determine differences in relative autarky prices, and in turn, the pattern of trade

Factor Proportion Theory

- In order to shed light on factor endowments as a source of CA, we will assume that:
  1. Production functions are identical around the world
  2. Households have identical homothetic preferences around the world
- We will first focus on two special models:
  - **Ricardo-Viner** with 2 goods, 1 "mobile" factor (labor) and 2 "immobile" factors (sector-specific capital)
  - **Heckscher-Ohlin** with 2 goods and 2 "mobile" factors (labor and capital)
- The second model is often thought of as a long-run version of the first (Neary 1978)
  - In the case of Heckscher-Ohlin, what it is the time horizon such that one can think of total capital as fixed in each country, though freely mobile across sectors?

Ricardo-Viner Model

Basic environment

- Consider an economy with:
  - Two goods, $g = 1, 2$
  - Three factors with endowments l, k_1, and k_2
- Output of good g is given by

$$y_g = f^g\left(l_g, k_g\right),$$

where:
  - l_g is the (endogenous) amount of labor in sector g
  - f^g is homogeneous of degree 1 in $\left(l_g, k_g\right)$
- **Comments:**
  - l is a "mobile" factor in the sense that it can be employed in all sectors
  - k_1 and k_2 are "immobile" factors in the sense that they can only be employed in one of them
  - Model is isomorphic to DRS model: $y_g = f^g\left(l_g\right)$ with $f^g_{ll} < 0$
  - Payments to specific factors under CRS $\equiv$ profits under DRS

Ricardo-Viner Model

Equilibrium (I): small open economy

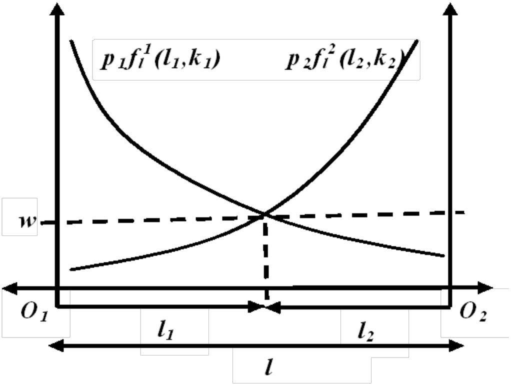
- We denote by:
  - p_1 and p_2 the prices of goods 1 and 2
  - w, r_1, and r_2 the prices of l, k_1, and k_2
- For now, (p_1, p_2) is exogenously given: **"small open economy"**
  - So no need to look at good market clearing
- **Profit maximization:**

$$p_g f_l^g(l_g, k_g) = w \tag{1}$$

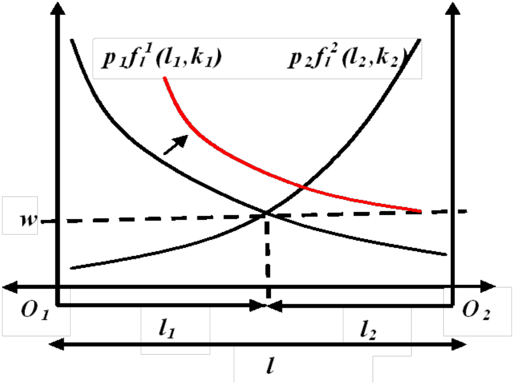
$$p_g f_k^g(l_g, k_g) = r_g \tag{2}$$

- **Labor market clearing:**

$$l = l_1 + l_2 \tag{3}$$



- Equations (1) and (3) jointly determine labor allocation and wage
- Payments to the specific factor from this graph?



- Consider a TOT shock such that p_1 increases:
  - $w \nearrow$, $l_1 \nearrow$, and $l_2 \searrow$
  - Condition (2) $\Rightarrow r_1/p_1 \nearrow$ whereas r_2 (and a fortiori r_2/p_1) $\searrow$

- One can use the same type of arguments to analyze consequences of:
  - Productivity shocks
  - Changes in factor endowments
- In all cases, results are intuitive:
  - "Dutch disease" (Boom in export sectors, Bids up wages, which leads to a contraction in the other sectors)
  - Useful political-economy applications (Grossman and Helpman 1994)
- Easy to extend the analysis to more than 2 sectors:
  - Plot labor demand in one sector vs. rest of the economy
  - Convenient for empirical work (Kovak 2013), as we shall see next lecture

- Predictions on the pattern of trade in a two-country world depend on whether differences in factor endowments come from:
  - Differences in the relative supply of specific factors
  - Differences in the relative supply of mobile factors
- Accordingly, any change in factor prices is possible as we move from autarky to free trade (see Feenstra's grad textbook, Problem 3.1 p. 98)

- Consider an economy with:
  - Two goods, $g = 1, 2$,
  - Two factors with endowments l and k
- Output of good g is given by

$$y_g = f^g(l_g, k_g),$$

where:

  - l_g, k_g are the (endogenous) amounts of labor and capital in sector g
  - f^g is homogeneous of degree 1 in (l_g, k_g)

- $c_g(w, r) \equiv$ unit cost function in sector g

$$c_g(w, r) = \min_{l,k} \{wl + rk | f^g(l, k) \geq 1\},$$

where w and r the price of labor and capital

- $a_{fg}(w, r) \equiv$ unit demand for factor f in the production of good g
- Using the Envelope Theorem, it is easy to check that:

$$a_{lg}(w, r) = \frac{dc_g(w, r)}{dw} \text{ and } a_{kg}(w, r) = \frac{dc_g(w, r)}{dr}$$

- $A(w, r) \equiv [a_{fg}(w, r)]$ denotes the matrix of total factor requirements

- Like in RV model, we first look at the case of a small open economy (so no need to look at good market clearing)
- **Profit-maximization:**

$$p_g \leq wa_{lg}(w,r) + ra_{kg}(w,r) \text{ for all } g = 1,2 \quad (4)$$
$$p_g = wa_{lg}(w,r) + ra_{kg}(w,r) \text{ if } g \text{ is produced in equilibrium} \quad (5)$$

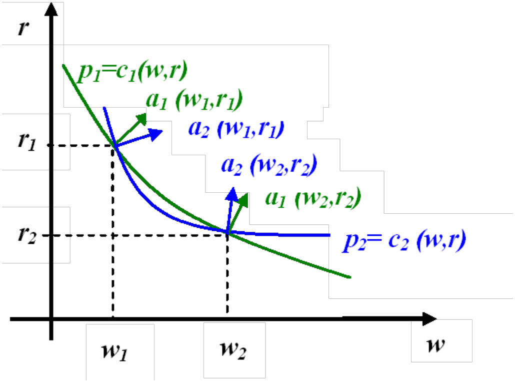
- **Factor market-clearing**:

$$l = y_1 a_{l1}(w,r) + y_2 a_{l2}(w,r) \quad (6)$$
$$k = y_1 a_{k1}(w,r) + y_2 a_{k2}(w,r) \quad (7)$$

- **Question:**
  Can trade in goods be a (perfect) substitute for trade in factors?
- First classical result from the HO literature answers in the affirmative
- To establish this result formally, we'll need the following definition:
- **Definition**. *Factor Intensity Reversal (FIR) does not occur if:* (i) $a_{l1}(w,r)/a_{k1}(w,r) > a_{l2}(w,r)/a_{k2}(w,r)$ *for all* (w,r)*; or* (ii) $a_{l1}(w,r)/a_{k1}(w,r) < a_{l2}(w,r)/a_{k2}(w,r)$ *for all* (w,r).

- **Lemma** *If both goods are produced in equilibrium and FIR does not occur, then factor prices* $\omega \equiv (w, r)$ *are uniquely determined by good prices* $p \equiv (p_1, p_2)$
- **Proof:** If both goods are produced in equilibrium, then $p = A'(\omega)\omega$. By Gale and Nikaido (1965), this equation admits a unique solution if $a_{fg}(\omega) > 0$ for all f,g and $\det[A(\omega)] \neq 0$ for all ω, which is guaranteed by no FIR.
- **Comments:**
  - Good prices rather than factor endowments determine factor prices
  - In a closed economy, good prices and factor endowments are, of course, related, but not for a small open economy
  - All economic intuition can be gained by simply looking at Leontieff case
  - Proof already suggests that "dimensionality" will be an issue for FIR

- Link between no FIR and FPI can be seen graphically:



- If iso-cost curves cross more than once, then FIR must occur

- The previous lemma directly implies (Samuelson 1949) that:
- **FPE Theorem** *If two countries produce both goods under free trade with the same technology and FIR does not occur, then they must have the same factor prices*
- **Comments:**
  - Trade in goods can be a "perfect substitute" for trade in factors
  - Countries with different factor endowments can sustain same factor prices through different allocation of factors across sectors
  - Assumptions for FPE are stronger than for FPI: we need free trade and same technology in the two countries...
  - For next results, we'll maintain assumption that both goods are produced in equilibrium, but won't need free trade and same technology

- **Stolper-Samuelson Theorem** *An increase in the relative price of a good will increase the real return to the factor used intensively in that good, and reduced the real return to the other factor*
- **Proof:** W.l.o.g. suppose that (i) $a_{l1}(\omega)/a_{k1}(\omega) > a_{l2}(\omega)/a_{k2}(\omega)$ and (ii) $\widehat{p}_2 > \widehat{p}_1$. Differentiating the zero-profit condition (5), we get

$$\widehat{p}_g = \theta_{lg}\widehat{w} + (1 - \theta_{lg})\widehat{r}, \tag{8}$$

where $\widehat{x} = d\ln x$ and $\theta_{lg} \equiv wa_{lg}(\omega)/c_g(\omega)$. Equation $(8) + (ii)$ imply

$$\widehat{w} > \widehat{p}_2 > \widehat{p}_1 > \widehat{r} \text{ or } \widehat{r} > \widehat{p}_2 > \widehat{p}_1 > \widehat{w}$$

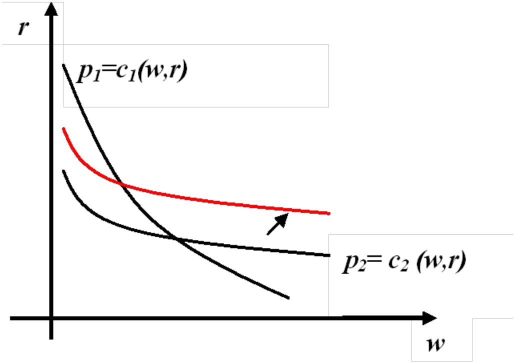
By (i), $\theta_{l2} < \theta_{l1}$. So (ii) further requires $\widehat{r} > \widehat{w}$. Combining the previous inequalities, we get

$$\widehat{r} > \widehat{p}_2 > \widehat{p}_1 > \widehat{w}$$

- **Comments:**
  - Previous "hat" algebra is often referred to "Jones' (1965) algebra"
  - The chain of inequalities $\widehat{r} > \widehat{p}_2 > \widehat{p}_1 > \widehat{w}$ is referred as a "magnification effect"
  - SS predict both winners and losers from change in relative prices
  - Like FPI and FPE, SS entirely comes from zero-profit condition (+ no joint production)
  - Like FPI and FPE, sharpness of the result hinges on "dimensionality"
  - In the empirical literature, people often talk about "Stolper-Samuelson effects" whenever looking at changes in relative factor prices (though changes in relative good prices are rarely observed)

Heckscher-Ohlin Model

Stolper-Samuelson (1941) Theorem: graphical analysis



- Like for FPI and FPE, all economic intuition could be gained by looking at the simpler Leontieff case:
  - In the general case, iso-cost curves are not straight lines, but under no FIR, same logic applies

- Previous results have focused on the implication of *zero profit condition*, Equation (5), for *factor prices*
- We now turn our attention to the implication of *factor market clearing*, Equations (6) and (7), for *factor allocation*
- **Rybczynski Theorem** *An increase in factor endowment will increase the output of the industry using it intensively, and decrease the output of the other industry*

- **Proof:** W.l.o.g. suppose that (i) $a_{l1}(\omega)/\,a_{k1}(\omega) > a_{l2}(\omega)/\,a_{k2}(\omega)$ and (ii) $\widehat{k} > \widehat{l}$. Differentiating factor market clearing conditions (6) and (7), we get

$$\widehat{l} = \lambda_{l1}\widehat{y}_1 + (1 - \lambda_{l1})\,\widehat{y}_2 \tag{9}$$

$$\widehat{k} = \lambda_{k1}\widehat{y}_1 + (1 - \lambda_{k1})\,\widehat{y}_2 \tag{10}$$

where $\lambda_{l1} \equiv a_{l1}(\omega)\,y_1/l$ and $\lambda_{k1} \equiv a_{k1}(\omega)\,y_1/k$. Equation (8) + (ii) imply

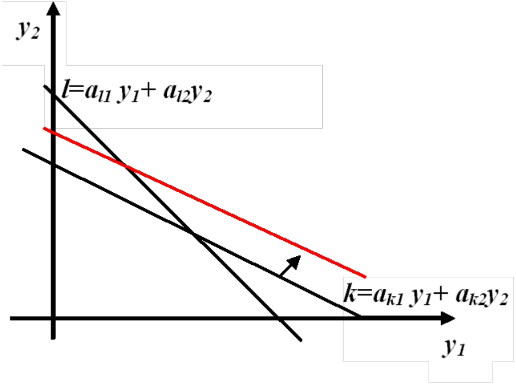
$$\widehat{y}_1 > \widehat{k} > \widehat{l} > \widehat{y}_2 \text{ or } \widehat{y}_2 > \widehat{k} > \widehat{l} > \widehat{y}_1$$

By (i), $\lambda_{k1} < \lambda_{l1}$. So (ii) further requires $\widehat{y}_2 > \widehat{y}_1$. Combining the previous inequalities, we get

$$\widehat{y}_2 > \widehat{k} > \widehat{l} > \widehat{y}_1$$

- Like for FPI and FPE Theorems:
  - (p_1, p_2) is exogenously given $\Rightarrow$ factor prices and factor requirements are not affected by changes factor endowments
  - Empirically, Rybczynski Theorem suggests that impact of immigration may be very different in closed vs. open economy
- Like for SS Theorem, we have a "magnification effect"
- Like for FPI, FPE, and SS Theorems, sharpness of the result hinges on "dimensionality"

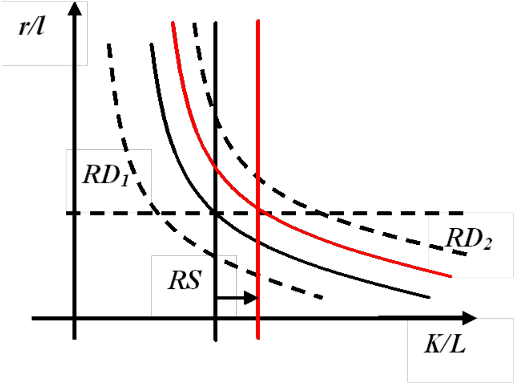
- Since good prices are fixed, it is as if we were in Leontieff case



Two-by-Two Heckscher-Ohlin Model

Rybczynski (1965) Theorem: graphical analysis (II)

- Rybczynski effect can also be illustrated using relative factor supply and relative factor demand:



- *Cross-sectoral reallocations* are at the core of HO predictions:
  - For relative factor prices to remain constant, *aggregate* relative demand must go up, which requires expansion capital intensive sector

- Previous results hold for small open economies
  - relative good prices were taken as exogenously given
- We now turn world economy with two countries, North and South
- We maintain the two-by-two HO assumptions:
  - there are two goods, $g = 1{,}2$, and two factors, k and l
  - identical technology around the world, $y_g = f_g(k_g, l_g)$
  - identical homothetic preferences around the world, $d_g^c = \alpha_g(p)I^c$
- **Question**
  What is the pattern of trade in this environment?

- Start from **Integrated Equilibrium** $\equiv$ competitive equilibrium that would prevail if *both* goods and factors were freely traded
- Consider **Free Trade Equilibrium** $\equiv$ competitive equilibrium that prevails if goods are freely traded, but factors are not
- Ask: Can free trade equilibrium reproduce integrated equilibrium?
- *If factor prices are equalized through trade*, the answer is yes
- In this situation, one can then use homotheticity to go from differences in factor endowments to pattern of trade

- **Integrated equilibrium** corresponds to (p, ω, y) such that:

$$
\begin{aligned}
(ZP) &: \quad p = A'(\omega)\,\omega & (11)\\
(GM) &: \quad y = \alpha(p)\,(\omega' v) & (12)\\
(FM) &: \quad v = A(\omega)\,y & (13)
\end{aligned}
$$

where:

- $p \equiv (p_1, p_2)$, $\omega \equiv (w, r)$, $A(\omega) \equiv [a_{fg}(\omega)]$, $y \equiv (y_1, y_2)$, $v \equiv (l, k)$, $\alpha(p) \equiv [\alpha_1(p), \alpha_2(p)]$
- $A(\omega)$ derives from cost-minimization
- $\alpha(p)$ derives from utility-maximization

- **Free trade equilibrium** corresponds to $(p^t, \omega^n, \omega^s, y^n, y^s)$ such that:

$$(ZP) \quad : \quad p^t \leq A'(\omega^c)\,\omega^c \text{ for } c = n, s \tag{14}$$
$$(GM) \quad : \quad y^n + y^s = \alpha\left(p^t\right)\left(\omega^{n\prime} v^n + \omega^{s\prime} v^s\right) \tag{15}$$
$$(FM) \quad : \quad v^c = A(\omega^c)\, y^c \text{ for } c = n, s \tag{16}$$

  where (14) holds with equality if good is produced in country c

- **Definition** *Free trade equilibrium replicates integrated equilibrium if* $\exists\ (y^n, y^s) \geq 0$ *such that* $(p, \omega, \omega, y^n, y^s)$ *satisfy conditions* (14)-(16)

- **Definition** (v^n, v^s) *are in the FPE set if* $\exists\ (y^n, y^s) \geq 0$ *such that condition* (16) *holds for* $\omega^n = \omega^s = \omega$.
- **Lemma** *If* (v^n, v^s) *is in the FPE set, then free trade equilibrium replicates integrated equilibrium*
- **Proof:** By definition of the FPE set, $\exists\ (y^n, y^s) \geq 0$ such that

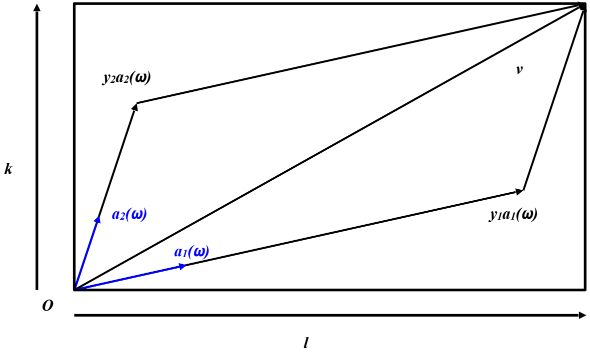
$$v^c = A(\omega)\, y^c$$

So Condition (16) holds. Since $v = v^n + v^s$, this implies

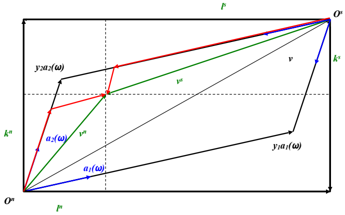
$$v = A(\omega)\,(y^n + y^s)$$

Combining this expression with condition (13), we obtain $y^n + y^s = y$. Since $\omega^{n\prime} v^n + \omega^{s\prime} v^s = \omega' v$, Condition (15) holds as well. Finally, Condition (11) directly implies (14) holds.

- Factor market clearing in the integrated equilibrium:

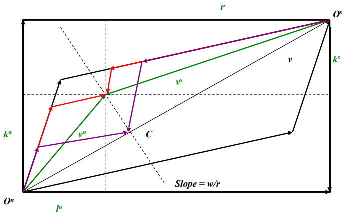


- **FPE set** $\equiv (v^n, v^s)$ inside the parallelogram



- When v^n and v^s are inside the parallelogram, we say that they belong to the same **diversification cone**
- This is a very different way of approaching FPE than FPE Theorem
  - Here, we have shown that there can be FPE iff factor endowments are not too dissimilar, whether or not there are no FIR
  - Instead of taking prices as given—whether or not they are consistent with integrated equilibrium—we take factor endowments as primitives

- Suppose that (v^n, v^s) is in the FPE set
- **HO Theorem** *In the free trade equilibrium, each country will export the good that uses its abundant factor intensively*



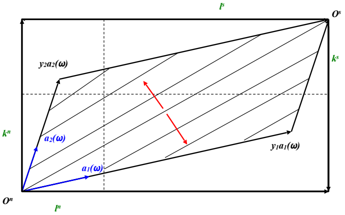
- Outside the FPE set, additional technological and demand considerations matter (e.g. FIR or no FIR)

- HO Theorem can also be derived using Rybczynski effect:
  1. Rybczynski theorem $\Rightarrow y_2^n/y_1^n > y_2^s/y_1^s$ for any p
  2. Homotheticity $\Rightarrow c_2^n/c_1^n = c_2^s/c_1^s$ for any p
  3. This implies $p_2^n/p_1^n < p_2^s/p_1^s$ under autarky
  4. Law of comparative advantage $\Rightarrow$ HO Theorem

- Predictions of HO and SS Theorems are often combined:
  - HO Theorem $\Rightarrow p_2^n / p_1^n < p_2 / p_1 < p_2^s / p_1^s$
  - SS Theorem $\Rightarrow$ *Moving from autarky to free trade, real return of abundant factor increases, whereas real return of scarce factor decreases*
  - If North is skill-abundant relative to South, inequality increases in the North and decreases in the South
- So why may we observe a rise in inequality in the South in practice?
  - Southern countries are not moving from autarky to free trade
  - Technology is not identical around the world
  - Preferences are not homothetic and identical around the world
  - There are more than two goods and two countries in the world

Two-by-Two-by-Two Heckscher-Ohlin Model
Trade volumes

- Let us define trade volumes as the sum of exports plus imports
- Inside FPE set, iso-volume lines are parallel to diagonal (HKa p.23)
  - the further away from the diagonal, the larger the trade volumes
  - factor abundance rather than country size determines trade volume



- If country size affects trade volumes in practice, what should we infer?

"High-Dimensional" Models: Beyond 2×2

- The previous canonical HO results (S-S, FPI, FPE, H-O, Rybczinski) can all be extended to settings with more than two factors and goods.

- However, without further restrictions (beyond simply: CRS technologies, identical and homothetic tastes, no trade costs) only available qualitative results are either of the:
  1. "Friends and enemies" form (Jones and Sheinkman, 1977): e.g. for S-S, effect of increasing one good's price raises at least one, and reduces at least one, factor price
  2. "Correlation" form (Ethier, 1984): e.g. for S-S, a particular weighted correlation between goods price changes and factor price changes must be positive.
- Alternative is to add more structure: e.g. multi-sector, multi-factor version of EK (2002), as in (for example)
  - Chor (JIE 2010)
  - Costinot and Rodriguez-Clare (2014)
  - Burstein and Vogel (2016), Galle, Rodriguez-Clare and Yi (2017)
  - See also Burstein, Hanson, Tian, and Vogel (2018) for immigration

Testing Predictions from the HO Model

- The bulk of such testing has concerned the HO Theorem's prediction about the pattern of trade.
- When > 2 goods and ≥ 2 factors, and $\#$ goods $> \#$ factors, the HO-Vanek theorem can be derived by nothing that (simply multiplying the goods market clearing condition ($T = Y - C$) by the factor use matrix $A(w)$, and applying factor market clearing ($A(w)Y = V$) and homothetic preferences):

$$A^c(w^c)T^c = V^c - A^c(w^c)\alpha^c(p^c)Y^c \tag{17}$$

- Where:
  - These are vector equations (one vector per country c)
  - $\alpha^c(p^c)$ is the expenditure share on each good
  - Y^c is the (scalar) value of GDP in country c
  - V^c is the endowment (of factors) vector in country c
  - The term $A^c(w^c)T^c$ is called the "factor content of (net) exports" (NFCT) by country c

The (Net) Factor Content of Trade

The Heckscher-Ohlin-Vanek Theorem

- If we also have free trade ($p^c = p$), identical technologies ($A^c(.) = A(.)$), identical tastes ($\alpha^c(.) = \alpha(.)$), and factor endowments inside the FPE set so FPE holds ($w^c = w$), then equation (17) simplifies dramatically to the HOV equations:

$$A(w)T^c = V^c - s^c V^w.$$

- Where s^c is country c's share of world GDP, and V^w is the world factor endowment vector
- And note that it doesn't matter for which country we use data on $A^c(w^c)$, as prediction is that those are the same for all countries anyway

Measuring the NFCT: An Aside

- In reality, production uses intermediates:
  - This means (for example) that the capital content of shoe production includes not only the *direct* use of capital in making shoes, but also the *indirect* use of capital in making all upstream inputs to shoes (like rubber).
  - Let $A(w)$ be the input-output matrix for commodity production. And let $B(w)$ be the matrix of direct factor inputs.
  - Then, if we assume that only final goods are traded, (it takes some algebra, due to Leontief, to show that) the only change we have to make to the HOV theorem is to use $\bar{B}(w) \equiv B(w)(I - A(w))^{-1}$ in place of $A(w)$ above.
    - Trefler and Zhu (JIE, 2010) show that the "only final goods are traded" assumption is not innocuous and propose extensions to deal with trade in intermediates.
    - See also recent work by Johnson and Noguera (JIE, 2012) on this and related issues.

Testing the HOV Equations

- How do we test $\bar{B}(w)T^c = V^c - s^c V^w$?
  - This is really a set of vector equations (one element per factor k).
  - So there is one of these predictions per country c and factor k.
- There are of course many things one can do with these predictions, so many different tests have been performed.
  1. Leontief (1953) and Leamer (JPE, 1980)
  2. Bowen, Leamer and Sveikauskas (AER, 1987)
  3. Trefler (JPE, 1993)
  4. Trefler (AER, 1995)
  5. Davis, Weinstein, Bradford and Shimpo (AER, 1997)
  6. Davis and Weinstein (AER, 2001)
- We will focus on DW (2001), as it contains many of the lessons learned from the earlier literature

DW (2001): "The Matrix"

- Work prior to DW (2001) had left impression that raw HOV fits poorly, mostly likely because assuming $\bar{B}^c(w^c) = \bar{B}^{US}(w^{US})$ is wrong.
- DW (2001) were the first to get data on $\bar{B}^c(w^c)$ for all countries c in their sample (not easy!)
    - Just taking a casual glance at these suggests that the $\bar{B}(w)$'s around the OECD are very different. So something needs to be done.
    - One approach would be just to use the data on $\bar{B}^c(w^c)$ for each country—but then the production side of the HOV equations would hold as an identity and that wouldn't be much of a test. (But see Hakura (JIE, 2001) for what can still be learned about measurement error.)
    - DW instead seek to parsimoniously *parameterize* the cross-country differences in $\bar{B}^c(w^c)$ by considering 7 nested hypotheses, which drop standard HO assumptions sequentially, about how endowments affect both *technology* (i.e. $\bar{B}(.)$) and *technique* (i.e. $\bar{B}(w)$).

DW (2001): The 7 Nested Hypotheses and 7 Results

"P"=Production, "T"=Trade

- "P1&T1": Standard HOV, common (US) technology. (The baseline.)
  - That is, P1: $B^{US}(w^{US})Y^c = V^c$ is tested.
  - That is, T1: $B^{US}(w^{US})T^c = V^c - s^c V^w$ is tested.
- "P2&T2": Common technology with measurement error:
  - Suppose the differences in $\bar{B}(w)$ we see around the world are just classical (log) ME.
  - DW look for this by estimating $\ln \bar{B}^c(w^c) = \ln \bar{B}(w)^{\mu} + \varepsilon^c$, where $\bar{B}(w)^{\mu}$ is the common technology around the world, and ε^c is the classical measurement error (i.e. just noise).
  - The actual regression across industries i and factors k is: $\ln \bar{B}^c(w^c)_{ik} = \beta_{ik} + \varepsilon^c_{ik}$, where β_{ik} is a fixed-effect.
  - Then (for P2), $\widehat{\bar{B}(w)}^{\mu} Y^c = V^c$ is tested, using $\widehat{\beta}_{ik}$ to construct $\widehat{\bar{B}(w)}^{\mu}$

DW (2001): Hypothesis 1 (Standard HOV)

This is 'P1', the *production* side of H1

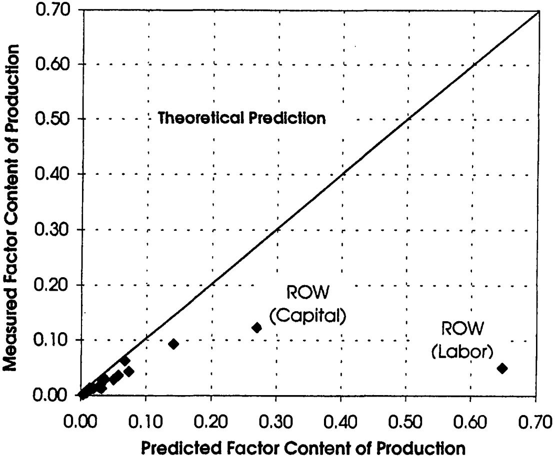


FIGURE 1. PRODUCTION WITH COMMON TECHNOLOGY (US) (P1)

DW (2001): Hypothesis 1 (Standard HOV)

This is 'T1', the *trade* side of H1

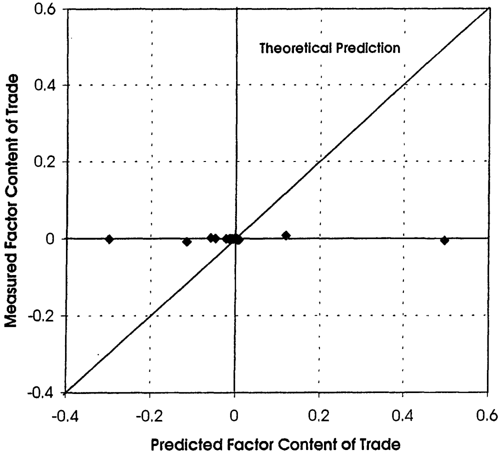


FIGURE 2. TRADE WITH COMMON TECHNOLOGY (US) (T1)

DW (2001): Hypothesis 2 (Measurement error)

This is 'P2', the *production* side of H2. (Plot of 'T2' looks like 'T1'.)

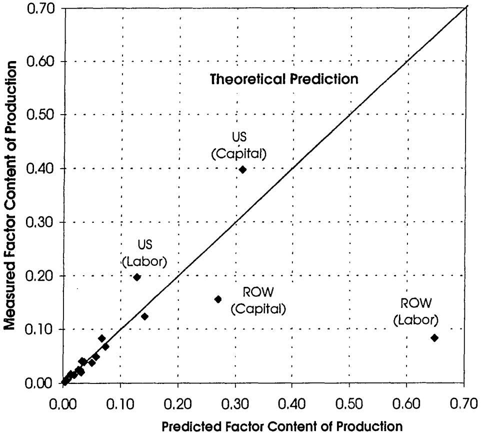


FIGURE 3. PRODUCTION WITH COMMON TECHNOLOGY (AVERAGE) (P2)

DW (2001): The 7 Nested Hypotheses and Results (cont.)

- "P3&T3": Hicks-neutral technology differences:
  - Here, as in Trefler (1995), DW (2001) allow each country to have a λ^c such that: $\bar{B}^c(w^c) = \lambda^c \bar{B}(\lambda^c w^c)$.
  - Note that this still has 'conditional FPE', so the *ratio* of techniques used across factors or goods will be the same across countries.
  - This translates into estimating θ^c in the regression: $\ln \bar{B}^c(w^c)_{ik} = \theta^c + \beta_{ik} + \varepsilon^c_{ik}$

DW (2001): Hypothesis 3 (Hicks-neutral tech diffs)

This is 'P3', the *production* side of H3. (Plot of 'T3' looks like 'T1'.)

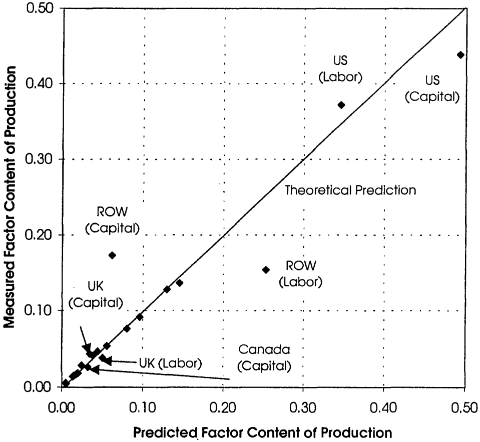


FIGURE 4. PRODUCTION WITH HICKS-NEUTRAL TECHNICAL DIFFERENCES
(P3)

DW (2001): The 7 Nested Hypotheses and Results (cont.)

- "P4&T4": DFS (1980) continuum model aggregation:
  - In a DFS-HO model with infinitessimally small trade costs, countries will use different techniques when they produce traded goods. However, this won't spill over onto non-traded goods.
  - If the industrial classifications in our data are really aggregates of more finely-defined goods (as in a continuum) then at the aggregated industry level it will look like countries' endowments affect their choice of technique.
  - To incorporate this, DW estimate $\ln \bar{B}^c(w^c)_{ik} = \theta^c + \beta_{ik} + \gamma_i^T \ln(\frac{K^c}{L^c}) \times TRAD_i + \varepsilon_{ik}^c$, where $TRAD_i$ is a dummy for tradable sectors.
  - Estimates of this are used to construct $\widehat{\bar{B}(w)}^{DFS}$ analogously to before. But this correction alters both the production and absorption equations (since the factor content of what country c imports depends on the endowments of each separate exporter to c).

DW (2001): Hypothesis 4 (DFS model aggregation)

This is 'P4', the *production* side of H4.

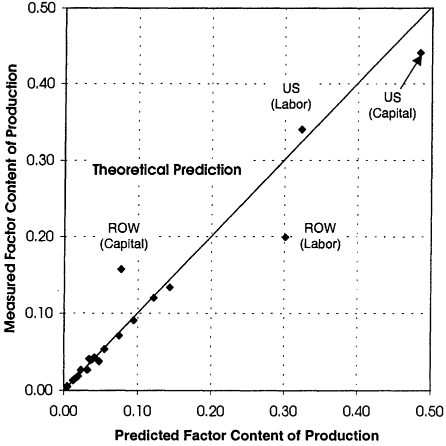


Figure 5. Production with Continuum of Goods Model and FPE (P4)

DW (2001): Hypothesis 4 (DFS model aggregation)

This is ‘T4’, the *trade* side of H4.

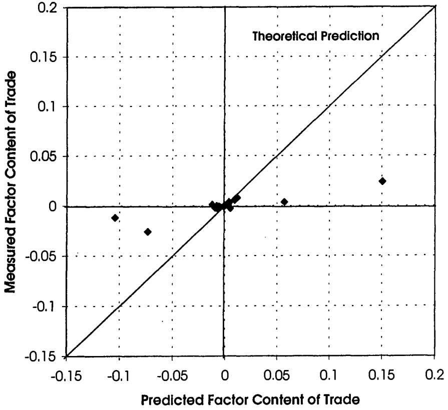


FIGURE 6. TRADE WITH CONTINUUM OF GOODS MODEL AND FPE (T4)

DW (2001): The 7 Nested Hypotheses and Results (cont)

- "P5&T5": DFS (1980) continuum model with non-FPE:
  - Another reason for $\gamma_i^T \neq 0$ in the regression above (other than aggregation) is the failure of FPE due to countries being in different cones of diversification. (See Helpman (JEP, 1999) for description.)
  - In this case, this effect *will* spill over onto non-traded goods (since factor prices affect technique choice in all industries).
  - To incorporate this, DW estimate $\ln \bar{B}^c(w^c)_{ik} = \theta^c + \beta_{ik} + \gamma_i^T \ln(\frac{K^c}{L^c}) \times TRAD_i + \gamma_i^{NT} \ln(\frac{K^c}{L^c}) \times NT_i \varepsilon_{ik}^c$, where NT_i is a dummy for non-tradable sectors.
  - Here, tests of the HOV analogue equations need to be more careful still, to make sure we use only the bits of the technology matrix that relate to tradable sector production.

DW (2001): Hypothesis 5 (DFS model with non-FPE)

This is 'P5', the *production* side of H5.

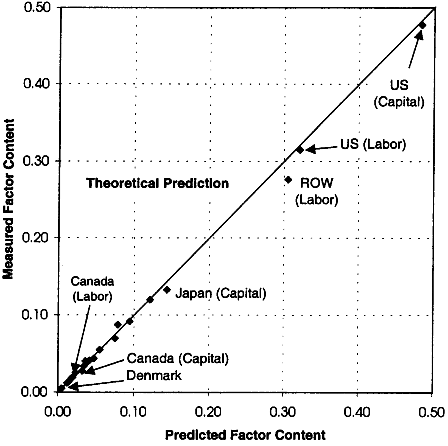


FIGURE 7. PRODUCTION WITHOUT FPE (P5)

DW (2001): Hypothesis 5 (DFS model with non-FPE)

This is 'T5', the *trade* side of H5.

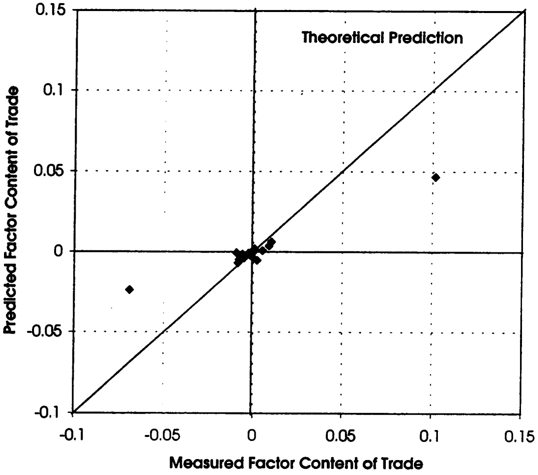


FIGURE 8. TRADE WITH NO-FPE, NONTRADED GOODS (T5)

DW (2001): The 7 Nested Hypotheses and Results (cont)

- "P7&T7": Demand-side differences due to trade costs:
  - Predicted imports in the HO setup are many times larger than actual imports. One explanation is trade costs.
  - To incorporate this, DW estimate gravity equations on imports, allowing them to estimate how trade costs (proxied for by distance) impedes imports.
  - They then use the predicted imports (from this gravity equation) in place of actual data on imports when testing the HOV trade equation (i.e. T7).
  - Note that this is not really an internally-consistent way of introducing trade costs. Trade costs also tilt relative prices (so countries want different ratios of goods), and relative factor prices (so techniques differ in ways that are not simply dependent on endowments).

DW (2001): Hypothesis 7 (Demand-side differences due to trade costs)

This is 'T7', the *trade* side of H7.

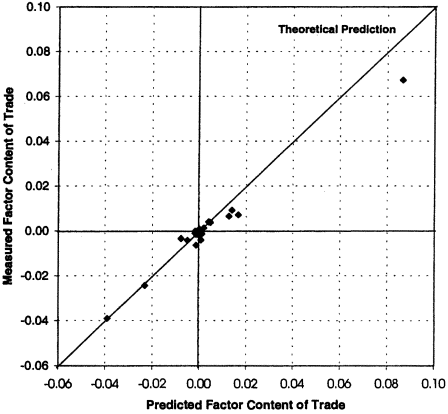


FIGURE 10. TRADE WITH NO-FPE, GRAVITY DEMAND SPECIFICATION, AND ADJUSTED ROW (T7)

DW (2001): Taking Stock

- DW (2001) conduct a formal model test on the production side off the model.
    - For the purposes of fitting production, and as judged by the Schwarz criterion (which trades off fit vs extra parameters used up in a particular way), P5 is "best".
- However, because these hypotheses affect the absorption side too, a good fit on the production side doesn't guarantee a good fit on the trade side.
    - By all measures they consider (sign tests, regressions, "missing trade" statistic) T7 does best on the trade side.
    - And T7 has an R^2 of 0.76, which is pretty impressive when you consider how grand an exercise this is (accounting for production, consumption and trade around the OECD, in a relatively parsimonious model).

Subsequent Work on NFCT Empirics

- Antweiler and Trefler (AER, 2002):
  - Adding external returns to scale (as in parts of Helpman and Krugman (1985 book)) to HOV equations in order to estimate the magnitude of these RTS.
- Schott (QJE, 2003):
  - Even within narrowly-defined (10-digit) industries, the unit value of US imports vary dramatically across exporting countries (and this variation is correlated with exporter endowments).
- Trefler and Zhu (JIE, 2010):
  - The treatment of *traded* intermediates affects how you calculate the HOV equations properly.
  - Also a characterization of the class of demand systems that generates HOV. (That is, is IHP necessary?)
- Davis and Weinstein (2008, book chapter, "Do Factor Endowments Matters for North-North Trade?"):
  - Intra-industry trade and HOV empirics.

AEA Continuing Education: International Trade — Lecture 3: Trade and Inequality[1]—

Dave Donaldson (MIT)

[1] All material based on earlier courses taught jointly with David Atkin (MIT) and Arnaud Costinot (MIT).

Trade and Wages

- What has been the impact of globalization on the earnings of factor-owners (e.g. workers with varying degrees of human capital) around the world?
- Some great surveys:
  - Leamer (2000, JIE) and Krugman (2000, JIE)
  - Feenstra and Hanson (2001, *Handbook*)
  - Goldberg and Pavcnik (2007, JEL)
  - Harrison, McLaren and McMillan (2011, ARE)
  - Helpman (2018, *book*)
- Many challenges involved in answering this question empirically.
- We will focus on recent work that has looked at differential exposure across regions/industries within a country to provide an answer.

Differential Regional Exposure Approach

- Suppose a change in trade policy affects p (i.e. one nation-wide goods price vector). How does this affect relative levels of welfare (i.e., real income, here) in different regions of a country?
  - This is the question that Topalova (AEJ Applied, 2009), Kovak (AER 2013), and Dix-Carneiro and Kovak (AER 2017) aim to answer, with respect to India and Brazil, respectively.
  - Autor, Dorn and Hanson (AER, 2013) is closely related methodologically but looks instead at the impact of Chinese productivity improvements (and/or trade cost reductions) on US regions.
- NB: while the regional relative levels of outcomes don't necessarily connect to national aggregate effects, regional incidence can obviously be of great interest in its own right (especially when connected to questions of political economy, etc).

Topalova (2010)

- Topalova (2010) aims to evaluate India's 1991 trade liberalization with following regression:

$$y_{dt} = \alpha_d + \beta_t + \gamma \text{Tariff}_{dt} + \varepsilon_{dt}$$

- Here, y_{dt} is the district d poverty rate, and Tariff_{dt} is a measure of the tariffs that matter from perspective of district d.
- India is attractive here for many reasons:
    - India went through an important and controversial trade liberalization in 1991 (and later in the 1990s).
    - There are very good, long-running surveys of poverty, for which the micro data is available from 1983 onwards.
    - There are 400-600 districts, depending on the time period (will be useful).

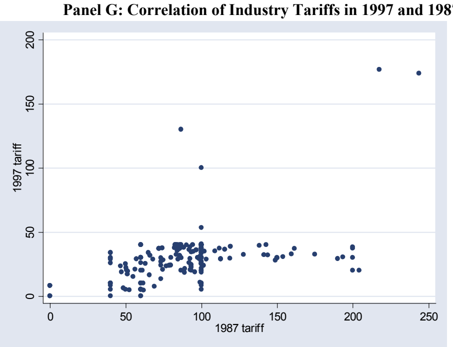
Topalova (2010)

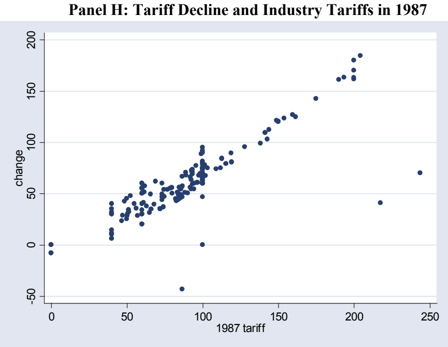
- Topalova (2010) aims to evaluate India's 1991 trade liberalization with following regression:

$$y_{dt} = \alpha_d + \beta_t + \gamma \text{Tariff}_{dt} + \varepsilon_{dt}$$

- Tariff_{dt} is tariff exposure calculated as the district employment-weighted average of national industry-wise tariffs (using 1991 employment weights).
  - This is a so-called "Bartik" (1991) (or "shift-share") approach: interacting national-level time-varying measure (tariff rates by sector and year) with region-specific pre-period weights (employment composition by sector and district) composition.
- Because of OVB concerns, Topalova (2010) uses a (now standard) IV for tariffs:
  - In trade liberalization episodes, higher tariffs have "further to fall".
  - So a plausible instrument for tariff changes is pre-liberalization tariff levels.

Topalova (2010): Identification Strategy for Tariff Changes





Check for Pre-Trends: Topalova and Khandelwal (2010)

Table 2: Declines in Trade Protection and Pre-Reform Industrial Characteristics

Log Real Wage (1)	Share of Non-production Workers (2)	Capital Labor ratio (3)	Log Output (4)	Factory size (5)	Log Employment (6)	Growth in Output 82-87 (7)	Growth in Employment 82-87 (8)	Observations in each regression (9)
Panel A: Output Tariffs								
0.049	0.300	0.000	0.002	0.000	-0.028	0.000	0.001	135
[0.069]	[0.425]	[0.033]	[0.035]	[0.000]	[0.024]	[0.000]	[0.001]	
Panel B: Input Tariffs								
0.096**	0.553	0.011	-0.007	0.000	-0.033	0.000	0.000	129
[0.045]	[0.347]	[0.019]	[0.010]	[0.000]	[0.020]	[0.000]	[0.000]	
Panel C: Effective Rates of Protection								
0.039	0.348	-0.006	0.018	0.000	-0.031	0.000	0.001	129
[0.130]	[0.864]	[0.059]	[0.060]	[0.000]	[0.046]	[0.001]	[0.001]	

Note: The data used in this table are from the 1987 ASI which covers all mining and manufacturing industries. Each cell represents a *separate* regression on either output tariffs (panel A), input tariffs (panel B) or effective rates of protection (panel C) on the variable in the column heading. The number of observations are reported in column 9 (note that the number of observations for regressions in column 6 is one less than that reported column 9). All regressions include indicators for industry use type: Capital Goods, Consumer Durables, Consumer Non-Durables and Intermediate. The regressions are weighted by the square root of the number of factories. Robust standard errors are reported in parantheses. Significance: * 10 percent; ** 5 percent; *** 1 percent.

Topalova (2010): Results

3.9pp *increase* in poverty for avg. 5.5pp tariff drop

Table 4a. Effect of Trade Liberalization on Poverty and Inequality in Indian Districts

	I. RURAL				II. URBAN			
	Tariff	TrTariff	IV-TrTariff	IV-TrTariff, Init TrTariff	Tariff	TrTariff	IV-TrTariff	IV-TrTariff, Init TrTariff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A. Dependent variable: Poverty Rate							
Tariff Measure	-0.287 **	-0.297 ***	-0.834 ***	-0.687 ***	-0.215	-0.065	-0.156	-0.403
	(0.118)	(0.084)	(0.250)	(0.225)	(0.190)	(0.156)	(0.353)	(0.275)
Obs	725	725	725	725	703	703	703	703
	Panel B. Dependent variable: Poverty Gap							
Tariff Measure	-0.129 ***	-0.114 ***	-0.319 ***	-0.206 ***	-0.084	-0.032	-0.076	-0.131
	(0.038)	(0.021)	(0.073)	(0.075)	(0.052)	(0.046)	(0.101)	(0.087)
Obs	725	725	725	725	703	703	703	703
	Panel C. Dependent variable: StdLog Consumption							
Tariff Measure	-0.086	-0.094	-0.265	-0.161	0.092	0.108	0.257	0.213
	(0.154)	(0.082)	(0.228)	(0.183)	(0.094)	(0.115)	(0.295)	(0.250)
Obs	725	725	725	725	703	703	703	703
	Panel D. Dependent variable: Log Deviation of Consumption							
Tariff Measure	-0.016	-0.020	-0.057	-0.020	0.034	0.090	0.215	0.172
	(0.066)	(0.042)	(0.115)	(0.071)	(0.062)	(0.066)	(0.174)	(0.144)
Obs	725	725	725	725	703	703	703	703
	Panel E. Dependent variable: Log Average Per Capita Expenditures							
Logmean	-0.015	0.132	0.370	0.552	-0.063	-0.126	-0.301	0.048
	(0.314)	(0.183)	(0.522)	(0.433)	(0.150)	(0.212)	(0.521)	(0.468)
Obs	725	725	725	725	703	703	703	703

Note: All regressions include year and district dummies. Standard errors (in parentheses) are corrected for clustering at the state year level. Regressions are weighted by the square root of the number of people in a district. Significance at the 10 percent level of confidence is represented by a *, at the 5 percent level by **, and at the 1 percent level by ***.

Kovak (2013)

- Kovak (2013) performs a similar exercise to Topalova (2010), but with some extensions:
    - The estimating equation emerges directly from a specific factors model like we saw last lecture.
    - The estimating equation is similar to Topalova (2010), but with a slight alteration to the way that Tariff_{dt} is calculated (Kovak uses different weights and different treatment of the non-traded sector).
    - Unlike Topalova (2010), Kovak (2013) finds economically and statistically significant migration responses: people appear to move around the country in response to (national) tariff changes, to get closer to favored industry-specific factors like capital/land.

Kovak (2013): Model

- Consider general SF model, but with multiple regions r. For now consider one region.
- Many industries i. Each with specific factor K_i. One factor L that is mobile across sectors (and in principle across regions).
- Factor market clearing then requires (where a_{fi} is amount of factor f required to produce in industry i):

$$\begin{aligned} a_{Ki} Y_i &= K_i & (1) \\ \sum_i a_{Li} Y_i &= L & (2) \end{aligned}$$

- Differentiating this yields $\sum_i \lambda_i (\hat{a}_{Li} - \hat{a}_{Ki}) = \hat{L}$ where $\lambda_i \equiv \frac{L_i}{L}$
- Perfect competition requires $a_{Li} w + a_{Ki} r_i = p_i$. Differentiating that gives $(1-\theta_i)\hat{w} + \theta_i \hat{r}_i = \hat{p}_i$ (for all i), where $\theta_i \equiv \frac{r_i K_i}{p_i Y_i}$.

Kovak (2013): Model

- Letting σ_i be the elasticity of substitution between K_i and L in industry i we have (by definition):

$$\hat{a}_{Ki} - \hat{a}_{Li} = \sigma_i(\hat{w} - \hat{r}_i) \tag{3}$$

- So combining the previous expressions we have

$$\sum_i \lambda_i \sigma_i (\hat{r}_i - \hat{w}) = \hat{L} \tag{4}$$

- This can be re-written as:

$$\hat{w} = \frac{-\hat{L}}{\sum_{i'} \lambda_{i'} \frac{\sigma_{i'}}{\theta_{i'}}} + \sum_i \beta_i \hat{p}_i \tag{5}$$

- With $\beta_i \equiv \frac{\lambda_i \frac{\sigma_i}{\theta_i}}{\sum_{i'} \lambda_{i'} \frac{\sigma_{i'}}{\theta_{i'}}}$

Kovak (2013): Model

- Kovak (2013) then takes this to the data, with the following additions/simplifications:
  - In baseline, no migration, so $\hat{L} = 0$. (But see online appendix for those results.)
  - Sets $\sigma_i = 1$, as per Cobb-Douglas production functions in each sector.
  - Allows for extension to non-traded goods produced (and differently so) in each region. This doesn't change anything qualitatively but does dampen the formulae quantitatively.
  - Assuming perfect pass-through of tariffs into local prices, with no change in world prices (so $\hat{p}_i = (\widehat{1 + \tau_i})$)

Kovak (2013): Model

- Kovak defines a region's tariff change (RTC_r) as:

$$RTC_r \equiv \sum_i \beta_{ir} \Delta \ln(1 + \tau_i) \tag{6}$$

- With $\beta_{ir} \equiv \frac{\lambda_{ir} \frac{1}{\theta_i}}{\sum_{i'} \lambda_{i'r} \frac{1}{\theta_{i'}}}$
- Combining above expressions, Kovak (2013) then estimates regression:

$$\Delta \ln w_r = \alpha + \rho_i RTC_r + \varepsilon_r. \tag{7}$$

Kovak (2013): Tariff variation (a la Topalova)

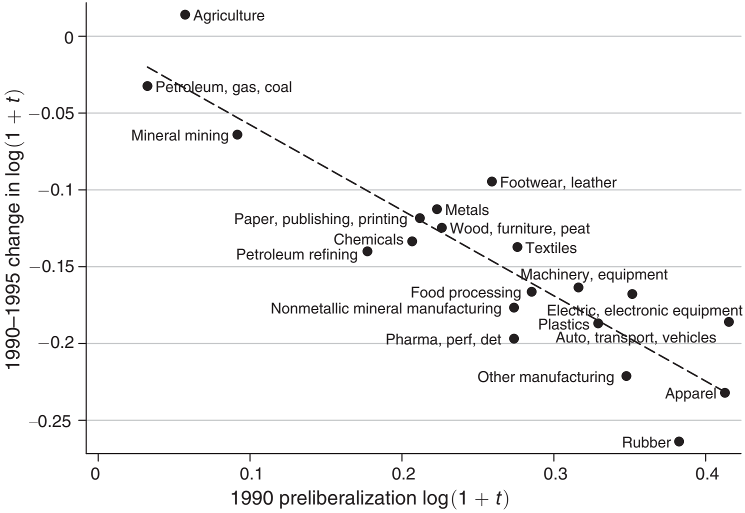


FIGURE 1. RELATIONSHIP BETWEEN TARIFF CHANGES AND PRELIBERALIZATION TARIFF LEVELS

Note: Correlation: −0.899; regression coefficient: −0.556; standard error: 0.064; t: −8.73.

Kovak (2013): RTC_r changes by region r

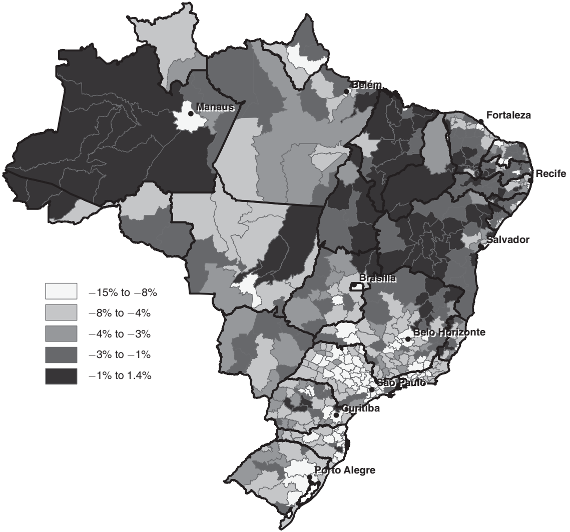


FIGURE 3. REGION-LEVEL TARIFF CHANGES

Notes: Weighted average of tariff changes. See text for details.

Kovak (2013): Main Results

TABLE 1—THE EFFECT OF LIBERALIZATION ON LOCAL WAGES

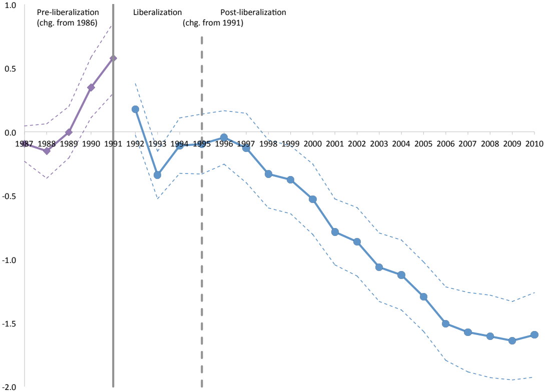
	Main		No labor share adjustment		Nontraded price change set to zero		Nontraded sector workers' wages	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regional tariff change	0.404	0.439	0.409	0.439	2.715	1.965	0.417	0.482
Standard error	(0.502)	(0.146)***	(0.475)	(0.136)***	(1.669)	(0.777)**	(0.497)	(0.140)***
State indicators (27)	—	X	—	X	—	X	—	X
Nontraded sector								
Omitted	X	X	X	X	—	—	X	X
Zero price change	—	—	—	—	X	X	—	—
Labor share adjustment	X	X	—	—	X	X	X	X
R^2	0.034	0.707	0.040	0.711	0.112	0.710	0.037	0.763

Notes: 493 microregion observations (Manaus omitted). Standard errors adjusted for 27 state clusters (in parentheses). Weighted by the inverse of the squared standard error of the estimated change in log microregion wage, calculated using the procedure in Haisken-DeNew, and Schmidt (1997).

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Dix Caneiro and Kovak (AER, 2017): Time-paths of effects, and holding worker fixed-effects constant

Figure 3: Regional log Formal Earnings Premia - 1992-2010



Each point reflects an individual regression coefficient, $\hat{\theta}_t$, following (3), where the dependent variable is the change in regional log formal earnings premium and the independent variable is the regional tariff reduction (RTR), defined in (2). Note that the RTR always reflects tariff reductions from 1990-1995. For blue circles, the changes are from 1991 to the year listed on the x-axis. For purple diamonds, the changes are from 1986 to the year listed. All regressions include state fixed effects, and post-liberalization regressions control for the 1986-1990 outcome pre-trend. Negative estimates imply larger earnings declines in regions facing larger tariff reductions. Vertical bars indicate that liberalization began in 1991 and was complete by 1995. Dashed lines show 95 percent confidence intervals. Standard errors adjusted for 112 mesoregion clusters.

Autor, Dorn and Hanson (2013)

- The US did not embark on a major trade liberalization episode in the 1990s like Brazil or India did. But imports (especially from lower-income countries, and China in particular) surged nevertheless. What impact did this have on US workers?
- Rather than weighting changes in tariffs by initial industrial composition to get a region's "tariff exposure", ADH weight change in imports from China to get "China exposure".
- Potential worry: Demand shocks for US products.
- Solution: IV with change in imports into other OECD countries. (Also alternative IV coming from China exporter fixed-effect in gravity model.)

Autor, Dorn and Hanson (2013):

$1,000 rise in a commuting zone's import exposure per worker reduces manufacturing employment per working-age population by 0.75%

Table 2—Imports from China and Change of Manufacturing Employment in CZs, 1970–2007: 2SLS Estimates

Dependent variable: 10 × annual change in manufacturing emp/working-age pop (in % pts)

	I. 1990–2007			II. 1970–1990 (pre-exposure)		
	1990–2000 (1)	2000–2007 (2)	1990–2007 (3)	1970–1980 (4)	1980–1990 (5)	1970–1990 (6)
(Δ current period imports from China to US)/worker	−0.89*** (0.18)	−0.72*** (0.06)	−0.75*** (0.07)			
(Δ future period imports from China to US)/worker				0.43*** (0.15)	−0.13 (0.13)	0.15 (0.09)

Notes: $N = 722$, except $N = 1{,}444$ in stacked first difference models of columns 3 and 6. The variable "future period imports" is defined as the average of the growth of a CZ's import exposure during the periods 1990–2000 and 2000–2007. All regressions include a constant and the models in columns 3 and 6 include a time dummy. Robust standard errors in parentheses are clustered on state. Models are weighted by start of period CZ share of national population.

Autor, Dorn and Hanson (2013)

- Increased exposure to China reduces employment/wages/LFP in highly exposed CZs relative to less exposed CZs.
- Transfer benefits payments for unemployment, disability, retirement, and healthcare also rise sharply. (And not much of that is TAA.)
  - 10 percent of unemployed move onto disability benefits.
- So has importing from China made US workers worse off? Has it made the US worse off?
- Hard to say, because we have not seen effects from:
  - Commensurate rise in exports (not necessarily to China) caused by need to maintain balanced trade. (And if trade becomes less balanced now: (a) this will reverse in the future, and (b) this means more capital flowing in which should increase aggregate labor demand.)
  - Consumer price reductions
  - Migration-induced spillovers across regions

Some examples of other work using regional exposure approach...

- Adao (2016, WP): adds (nonparametric) Roy-like heterogeneity to Kovak approach
- Feenstra, Ma and Xu (2017, WP): export-side effects
- Autor, Dorn, Hanson and Majlesi (2017, WP): effects on politics
- Caliendo, Dvorkin and Parro (ECMA, forth.): calibrate dynamic model of cross-location and cross-industry adjustment frictions to ADH (2013) in order to estimate national-level aggregate effect
- Adao, Arkolakis and Esposito (2018, WP): methodology for combining above regional exposure approach with migration and trade flow data to estimate national-level aggregate effect

Industry Exposure Approach

- A related approach has simply compared heavily-exposed industries to less-exposed ones.
- Two challenges:
  1. What cross-sectional unit to use in place of region in earlier approaches? Autor, Dorn, Hanson and Song (QJE 2014) use individual-level panel data from social security data.
  2. What is the industry-level date on which trade policy or foreign events changed? Pierce and Schott (AER 2016) use US granting of "Permanent Normal Trade Relations" to China in 2000 and resulting "NTR gap" that varied across industries and was narrowed/removed in 2000.

Autor, Dorn, Hanson and Song (2014): Main Result

Worker in 75th percentile of China import exposure has 46% reduction, relative to 25th percentile, in cumulative earnings over 1992-2007

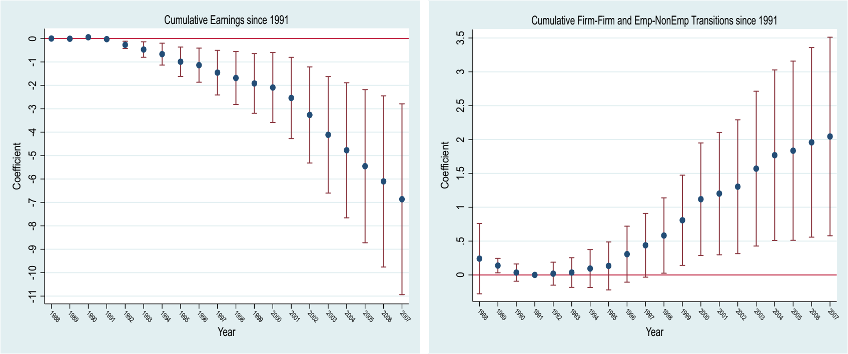


FIGURE III

Cumulative Earnings and Cumulative Job Churning since 1991

Pierce and Schott (2016): "Surprisingly Swift Decline of US Manufacturing"

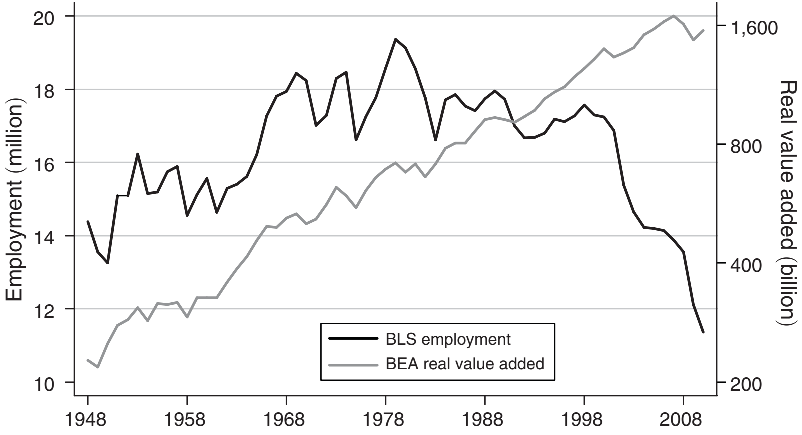


Figure 3. US Manufacturing Employment versus Value Added

Pierce and Schott (2016): Time-path of how (log) manuf. employment relates to NTR gap

Employment in industry with 75th percentile of NTR sees 8% reduction, relative to 25th percentile, in employment from 2000-2007

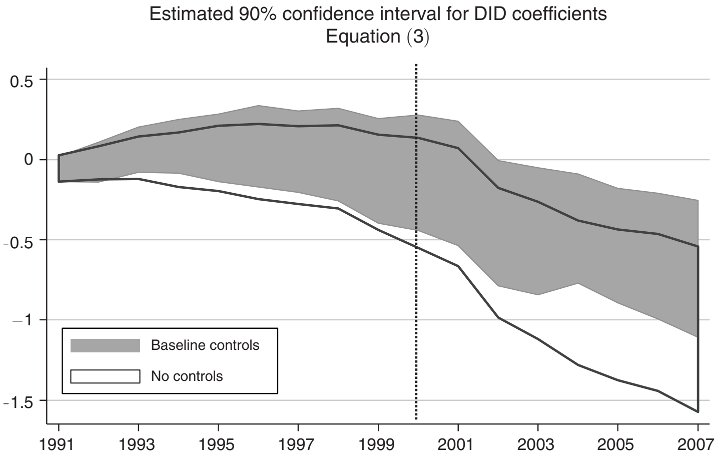


Figure 4. Estimated Timing of the PNTR Effect (*LBD*)

AEA Continuing Education: International Trade — Lecture 4: General Neoclassical Models[1]—

Dave Donaldson (MIT)

[1] All material based on earlier courses taught jointly with Arnaud Costinot (MIT).

General Neoclassical Models

- Models seen so far were extremely restrictive:
  1. One factor of production (Ricardian model), or multiple factors (HO model) but with restrictions on how these enter (e.g. FPE)
  2. Even within Ricardian: simplistic gravity-model structure (either on aggregate, or within nests)
  3. And even then: some of the most important parameters aren't even estimated (e.g. unitary elasticity in upper-tier preferences when doing mulit-sector gravity)

- Traditional approach to generalizing these models ("CGE tradition", e.g. world-leading GTAP project) has been to model everything: demand-side, supply-side, market structure, trade costs

- That leads to an enormous model with parameters (e.g. GTAP has perhaps 13,000 of them) that are extremely difficult to estimate credibly.

How can we make empirical progress? What are unifying principles of models seen so far? Adao, Costinot and Donaldson (AER, 2017)

1. For many counterfactual questions, neoclassical models are exactly equivalent to a *reduced factor exchange economy*

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2. Nonparametric generalization of standard gravity tools:
   - Dekle, Eaton and Kortum (2008): exact hat algebra
   - Arkolakis, Costinot, and Rodriguez-Clare (2012): welfare gains
   - Head and Ries (2001): trade costs

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   - Head and Ries (2001): trade costs
3. Reduced factor demand system is nonparametrically identified using standard data and orthogonality restrictions
4. Empirical application: What was the impact of China's integration into the world economy in the past two decades?
   - Departures from CES modeled in the spirit of BLP (1995)

Neoclassical Trade Model: Notation

- $i = 1, ..., I$ countries
- $k = 1, ..., K$ goods
- $n = 1, ..., N$ factors
- Goods consumed in country i:

$$\boldsymbol{q_i} \equiv \{q_{ji}^k\}$$

- Factors used in country i to produce good k for country j:

$$\boldsymbol{l_{ij}^k} \equiv \{l_{ji}^{nk}\}$$

Neoclassical Trade Model: Primitives

- Preferences (rep. consumer in "country i": whatever is finest level of data at which consumption is observed):

$$u_i = u_i(\boldsymbol{q_i})$$

- Technology (so restriction in previous lectures was that $f_{ij}^k(\cdot)$ is additive, meaning that all factors are perfect substitutes in production):

$$q_{ij}^k = f_{ij}^k(\boldsymbol{l_{ij}^k})$$

- Factor endowments (could be "time"):

$$\nu_i^n > 0$$

Competitive Equilibrium

A $\boldsymbol{q} \equiv \{\boldsymbol{q_i}\}$, $\boldsymbol{l} \equiv \{\boldsymbol{l_i}\}$, $\boldsymbol{p} \equiv \{\boldsymbol{p_i}\}$, and $\boldsymbol{w} \equiv \{\boldsymbol{w_i}\}$ such that:

1. Consumers maximize their utility:

$$\boldsymbol{q_i} \in \text{argmax}_{\boldsymbol{\tilde{q}_i}} u_i(\boldsymbol{\tilde{q}_i})$$
$$\sum_{j,k} p_{ji}^k \tilde{q}_{ji}^k \leq \sum_n w_i^n v_i^n \text{ for all } i;$$

2. Firms maximize their profits:

$$\boldsymbol{l_{ij}^k} \in \text{argmax}_{\boldsymbol{\tilde{l}_{ij}^k}} \{p_{ij}^k f_{ij}^k(\boldsymbol{\tilde{l}_{ij}^k}) - \sum_n w_i^n \tilde{l}_{ij}^{nk}\} \text{ for all } i, j, \text{ and } k;$$

3. Goods markets clear:

$$q_{ij}^k = f_{ij}^k(\boldsymbol{l_{ij}^k}) \text{ for all } i, j, \text{ and } k;$$

4. Factors markets clear:

$$\sum_{j,k} l_{ij}^{nk} = v_i^n \text{ for all } i \text{ and } n.$$

Reduced Exchange Model

- Fictitious endowment economy in which consumers directly exchange factor services
  - Common proof "trick" in GE literature: e.g. Taylor (1938), Rader (1972), Mas-Colell (1991)
  - Used heavily in Wilson's (1980) Ricardian model

- *Reduced preferences* over primary factors of production:

$$U_i(\boldsymbol{L_i}) \equiv \max_{\boldsymbol{\tilde{q}_i}, \boldsymbol{\tilde{l}_i}} u_i(\boldsymbol{\tilde{q}_i})$$

$$\tilde{q}_{ji}^k \leq f_{ji}^k(\boldsymbol{\tilde{l}_{ji}^k}) \text{ for all } j \text{ and } k,$$

$$\sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n \text{ for all } j \text{ and } n,$$

- Easy to check that $U_i(\cdot)$ is strictly increasing and quasiconcave.
  - Not necessarily strictly quasiconcave, even if $u_i(\cdot)$ is.
  - Example: H-O model inside FPE set.

Reduced Equilibrium

Corresponds to $\boldsymbol{L} \equiv \{\boldsymbol{L_i}\}$ and $\boldsymbol{w} \equiv \{\boldsymbol{w_i}\}$ such that:

1. Consumers maximize their reduced utility:

$$\boldsymbol{L_i} \in \operatorname{argmax}_{\tilde{\boldsymbol{L}}_{\boldsymbol{i}}} U_i(\tilde{\boldsymbol{L}}_{\boldsymbol{i}})$$
$$\sum_{j,n} w_j^n \tilde{L}_{ji}^n \leq \sum_n w_i^n \nu_i^n \text{ for all } i;$$

2. Factor markets clear:

$$\sum_j L_{ij}^n = \nu_i^n \text{ for all } i \text{ and } n.$$

Equivalence

- **Proposition 1**: *For any competitive equilibrium,* $(\boldsymbol{q}, \boldsymbol{l}, \boldsymbol{p}, \boldsymbol{w})$*, there exists a reduced equilibrium,* $(\boldsymbol{L}, \boldsymbol{w})$*, with:*
  1. *the same factor prices,* $\boldsymbol{w}$*;*
  2. *the same factor content of trade,* $L_{ji}^n = \sum_k l_{ji}^{nk}$ *for all* i*,* j*, and* n*;*
  3. *the same welfare levels,* $U_i(\boldsymbol{L_i}) = u_i(\boldsymbol{q_i})$ *for all* i*.*

  Conversely, for any reduced equilibrium, $(\boldsymbol{L}, \boldsymbol{w})$*, there exists a competitive equilibrium,* $(\boldsymbol{q}, \boldsymbol{l}, \boldsymbol{p}, \boldsymbol{w})$*, such that 1-3 hold.*

Equivalence

- **Comments:**
  - Proof is similar to First and Second Welfare Theorems. Key distinction is that standard Welfare Theorems go from CE to *global* planner's problem, whereas RE remains a decentralized equilibrium (but one in which countries fictitiously trade factor services and budget is balanced country by country).
  - Key implication of Prop. 1: If one is interested in the factor content of trade, factor prices and/or welfare, then one can always study a RE instead of a CE. One doesn't need *direct* knowledge of primitives u and f but only of how these *indirectly* shape U.

Reduced Counterfactuals

- Suppose that the reduced utility function over primary factors in this economy can be parametrized as

$$U_i(\boldsymbol{L_i}) \equiv \bar{U}_i(\{L_{ji}^n/\tau_{ji}^n\}),$$

where $\tau_{ji}^n > 0$ are exogenous preference shocks

- **Counterfactual question:** *What are the effects of a change from* $(\boldsymbol{\tau}, \boldsymbol{\nu})$ *to* $(\boldsymbol{\tau'}, \boldsymbol{\nu'})$ *on trade flows, factor prices, and welfare?*

Reduced Factor Demand System

- Start from factor demand = solution of reduced UMP:

$$\boldsymbol{L_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i})$$

- Compute associated expenditure shares:

$$\boldsymbol{\chi_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i}) \equiv \{\{x_{ji}^n\}|x_{ji}^n = w_j^n L_{ji}^n / y_i \text{ for some } \boldsymbol{L_i} \in \boldsymbol{L_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i})\}$$

- Rearrange in terms of *effective factor prices*, $\boldsymbol{\omega_i} \equiv \{w_j^n \tau_{ji}^n\}$:

$$\boldsymbol{\chi_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i}) \equiv \boldsymbol{\chi_i}(\boldsymbol{\omega_i}, y_i)$$

Reduced Equilibrium

- RE:

$$\boldsymbol{x_i} \in \boldsymbol{\chi_i}(\boldsymbol{\omega_i}, y_i), \text{ for all } i,$$
$$\sum_j x_{ij}^n y_j = y_i^n, \text{ for all } i \text{ and } n$$

- **Gravity model (e.g. EK 2002):** Reduced factor demand system is CES (perhaps the simplest possible factor demand system you could imagine?)

$$\chi_{ji}(\boldsymbol{\omega_i}, y_i) = \frac{\mu_{ji}(\omega_{ji})^{\epsilon}}{\sum_l \mu_{li}(\omega_{li})^{\epsilon}}, \text{ for all } j \text{ and } i$$

"Exact Hat Algebra" (like DEK, 2008)

- Start from the counterfactual equilibrium:

$$\boldsymbol{x}'_{\boldsymbol{i}} \in \boldsymbol{\chi}_{\boldsymbol{i}}(\boldsymbol{\omega}'_{\boldsymbol{i}}, y'_i) \text{ for all } i,$$
$$\sum_j (x^n_{ij})' y'_j = (y^n_i)', \text{ for all } i \text{ and } n.$$

- Rearrange in terms of proportional changes:

$$\{\hat{x}^n_{ji} x^n_{ji}\} \in \boldsymbol{\chi}_{\boldsymbol{i}}(\{\hat{w}^n_j \hat{\tau}^n_{ji} \omega^n_{ji}\}, \sum_n \hat{w}^n_i \hat{v}^n_i y^n_i) \text{ for all } i,$$
$$\sum_j \hat{x}^n_{ij} x^n_{ij} (\sum_n \hat{w}^n_j \hat{v}^n_j y^n_j) = \hat{w}^n_i \hat{v}^n_i y^n_i, \text{ for all } i \text{ and } n.$$

Counterfactual Trade Flows and Factor Prices

- Wlog, can pick location of preference shocks so that effective factor prices in the initial equilibrium are equal to one in all countries,

$$\omega_{ji}^{n} = 1, \text{ for all } i,\ j, \text{ and } n.$$

Counterfactual Trade Flows and Factor Prices

- **Proposition 2** *Under A1, proportional changes in expenditure shares and factor prices, $\hat{\boldsymbol{x}}$ and $\hat{\boldsymbol{w}}$, caused by proportional changes in preferences and endowments, $\hat{\boldsymbol{\tau}}$ and $\hat{\boldsymbol{\upsilon}}$, solve (with $\omega_{ji}^n = 1$, for all i, j, and n.):*

$$\{\hat{x}_{ji}^n x_{ji}^n\} \in \boldsymbol{\chi_i}(\{\hat{w}_j^n \hat{\tau}_{ji}^n \omega_{ji}^n\}, \sum_n \hat{w}_i^n \hat{\upsilon}_i^n y_i^n) \ \forall \ i,$$

$$\sum_j \hat{x}_{ij}^n x_{ij}^n (\sum_n \hat{w}_j^n \hat{\upsilon}_j^n y_j^n) = \hat{w}_i^n \hat{\upsilon}_i^n y_i^n \ \forall \ i \text{ and } n.$$

Welfare

- Equivalent variation for country i associated with change from $(\boldsymbol{\tau}, \boldsymbol{\nu})$ to $(\boldsymbol{\tau'}, \boldsymbol{\nu'})$, expressed as fraction of initial income:

$$\Delta W_i = \left(e_i(\boldsymbol{\omega_i}, U_i')) - y_i\right) / y_i,$$

with U_i' = counterfactual utility and e_i = expenditure function,

$$e_i(\boldsymbol{\omega_i}, U_i') \equiv \min_{\tilde{\boldsymbol{L}}_i} \sum \omega_{ji}^n L_{ji}^n$$
$$\bar{U}_i(\tilde{\boldsymbol{L}}_i) \geq U_i'.$$

Integrating Below Factor Demand Curves

- To go from $\boldsymbol{\chi_i}$ to ΔW_i, solve system of ODEs
- For any selection $\{x_{ji}^n(\boldsymbol{\omega}, y)\} \in \boldsymbol{\chi_i}(\boldsymbol{\omega}, y)$, Envelope Theorem:

$$\frac{d \ln e_i(\boldsymbol{\omega}, U_i')}{d \ln \omega_j^n} = x_{ji}^n(\boldsymbol{\omega}, e_i(\boldsymbol{\omega}, U_i')) \text{ for all } j \text{ and } n. \tag{1}$$

- Budget balance in the counterfactual equilibrium

$$e_i(\boldsymbol{\omega_i'}, U_i') = y_i'. \tag{2}$$

Counterfactual Welfare Changes

- **Proposition 3** *Under A1, equivalent variation associated with change from* $(\boldsymbol{\tau}, \boldsymbol{\nu})$ *to* $(\boldsymbol{\tau}', \boldsymbol{\nu}')$ *is*

$$\Delta W_i = \left(e(\boldsymbol{\omega}_i, U_i') - y_i\right) / y_i,$$

where $e(\cdot, U_i')$ *is the unique solution of (1) and (2).*

Application to Neoclassical Trade Models

- Suppose that technology in neoclassical trade model satisfies:

$$f_{ij}^k(\boldsymbol{l_{ij}^k}) \equiv \bar{f}_{ij}^k(\{l_{ij}^{nk}/\tau_{ij}^n\}), \text{ for all } i,\ j, \text{ and } k,$$

- Reduced utility function over primary factors of production:

$$\begin{aligned} U_i(\boldsymbol{L_i}) \equiv \max_{\boldsymbol{\tilde{q}_i},\boldsymbol{\tilde{l}_i}} & \, u_i(\boldsymbol{\tilde{q}_i}) \\ & \tilde{q}_{ji}^k \leq \bar{f}_{ji}^k(\{\tilde{l}_{ji}^{nk}/\tau_{ji}^n\}) \text{ for all } j \text{ and } k, \\ & \sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n \text{ for all } j \text{ and } n. \end{aligned}$$

- Change of variable: $U_i(L_i) \equiv \bar{U}_i(\{L_{ji}^n/\tau_{ji}^n\}) \Rightarrow$ factor-augmenting productivity shocks in CE = preference shocks in RE

Taking Stock

- Propositions 2 and 3 provide a system of equations that can be used for counterfactual and welfare analysis in RF economy.
  - Proposition 1 $\Rightarrow$ same system can be used in neoclassical economy.
- Gravity tools—developed for CES factor demands—extend nonparametrically to any factor demand system
- Given data on expenditure shares and factor payments, $\{x_{ji}^n, y_i^n\}$, if one knows factor demand system, $\boldsymbol{\chi_i}$, then one can compute counterfactual factor prices, aggregate trade flows, and welfare.

Other Implications

1. Efficiency plus gravity $\Rightarrow$ gains from trade are pretty small (e.g. cost of autarky for US would be 1.8%)
    - If want to get larger gains from trade than in ACR, need either inefficiencies or non-gravity at aggregate level (so fact that aggregate gravity thought to fit pretty well is sobering).
2. All one-factor models are Armington models (and for multi-factor models: just think of each factor as a country)
3. Terms-of-trade motive for tariff protection might be larger than you'd expect, even for small countries—every country is a monopolist in its own "good" (its factor services).

Estimating Factor Demand Systems: Shocks

- Data generated by neoclassical trade model at different dates t
- At each date, preferences and technology such that:

$$u_{i,t}(\boldsymbol{q_{i,t}}) = \bar{u}_i(\{q^k_{ji,t}/\theta_{ji}\}), \text{ for all } i,$$
$$f^k_{ij,t}(\boldsymbol{l^k_{ij,t}}) = \bar{f}^k_{ji}(\{l^{nk}_{ij,t}/\tau^n_{ij,t}\}), \text{ for all } i, j, \text{ and } k.$$

- This implies the existence of a vector of effective factor prices, $\boldsymbol{\omega}_{i,t} \equiv \{w^n_{j,t}\tau^n_{ji,t}\}$, such that factor demand in any country i and at any date t can be expressed as $\chi_i(\boldsymbol{\omega}_{i,t}, y_{i,t})$.

Estimating Factor Demand Systems: Exogeneity

- Observables:
  1. $x^n_{ji,t}$: factor expenditure shares
  2. $y^n_{i,t}$: factor payments
  3. $(z^\tau)^n_{ji,t}$: trade cost shifters
  4. $(z^y)^n_{ji,t}$: income shifters
- Effective factor prices, $\omega_{ji,t}$, unobservable, but related to $(z^\tau)^n_{ji,t}$:

$$\ln\omega^n_{ji,t} = \ln(z^\tau)^n_{ji,t} + \varphi^n_{ji} + \xi^n_{j,t} + \eta^n_{ji,t}, \text{ for all } i,\ j,\ n, \text{ and } t$$

- **A1. [Exogeneity]** $E[\eta^n_{ji,t}|\boldsymbol{z_t}] = 0.$

Estimating Factor Demand Systems: Completeness

- Following Newey and Powell (2003, ECMA), need to impose the following completeness condition.
- **A2. [Completeness]** *For any importer pair* (i_1, i_2), *and any function* $g(\boldsymbol{x}_{i_1,t}, y_{i_1,t}, \boldsymbol{x}_{i_2,t}, y_{i_2,t})$ *with finite expectation,* $E[g(\boldsymbol{x}_{i_1,t}, y_{i_1,t}, \boldsymbol{x}_{i_2,t}, y_{i_2,t})|\boldsymbol{z}_t] = 0$ *implies* $g(\boldsymbol{x}_{i_1,t}, y_{i_1,t}, \boldsymbol{x}_{i_2,t}, y_{i_2,t}) = 0$.
- A2 = rank condition in estimation of parametric models.

Estimating Factor Demand Systems: Identification

- Argument follows the same steps as in Berry and Haile (2014)
- **A3 [Invertibility].** *In any country i, for any $\boldsymbol{x} > 0$ and $y > 0$, there exists a unique vector of relative factor prices, ${\boldsymbol{\chi_i}}^{-1}(\boldsymbol{x}, y)$, such that all $\boldsymbol{\omega}_i$ satisfying $\boldsymbol{x} \in \boldsymbol{\chi_i}(\boldsymbol{\omega}_i, y_i)$ also satisfy $\omega_{ji}^n / \omega_{1i}^1 = (\chi_{ji}^n)^{-1}(\boldsymbol{x}, y)$.*
- Sufficient conditions:
  - A3 holds if $\boldsymbol{\chi_i}$ satisfies connected substitutes property (Arrow and Hahn 1971, Howitt 1980, and Berry, Gandhi and Haile 2013)
  - $\boldsymbol{\chi_i}$ satisfies connected substitutes property in a Ricardian economy if preferences satisfy connected substitutes property

Estimating Factor Demand Systems: Identification

- A3 $\Rightarrow$
$$\omega^n_{ji,t}/\omega^1_{1i,t} = (\chi^n_{ji})^{-1}(\boldsymbol{x}_{i,t}, y_{i,t}).$$
- Taking logs and using definition of $\eta^n_{ji,t}$:
$$\Delta\eta^n_{ji,t} = \ln(\chi^n_{ji})^{-1}(\boldsymbol{x}_{i,t}, y_{i,t}) - \Delta\ln(z^\tau)^n_{ji,t} - \Delta\varphi^n_{ji} - \Delta\xi^n_{j,t}.$$
- Taking a second difference $\Rightarrow$
$$\begin{aligned}\Delta\eta^n_{ji_1,t} - \Delta\eta^n_{ji_2,t} = & \ln(\chi^n_{ji_1})^{-1}(\boldsymbol{x}_{i_1,t}, y_{i_1,t}) - \ln(\chi^n_{ji_2})^{-1}(\boldsymbol{x}_{i_2,t}, y_{i_2,t}) \\ & - (\Delta\ln(z^\tau)^n_{ji_1,t} - \Delta\ln(z^\tau)^n_{ji_2,t}) - (\Delta\varphi^n_{ji_1} - \Delta\varphi^n_{ji_2}).\end{aligned}$$
- Using A1, we obtain the following moment condition
$$\begin{aligned}E[\ln(\chi^n_{ji_1})^{-1}(\boldsymbol{x}_{i_1,t}, y_{i_1,t}) - \ln(\chi^n_{ji_2})^{-1}(\boldsymbol{x}_{i_2,t}, y_{i_2,t}) - \zeta^n_{ji_1i_2}|\boldsymbol{z}_t] \\ = \Delta\ln(z^\tau)^n_{ji_1,t} - \Delta\ln(z^\tau)^n_{ji_2,t}.\end{aligned}$$
- A2 $\Rightarrow$ unique solution $(\bar{\chi}^n_j)^{-1}$ to (3) (up to a normalization)

Estimating Factor Demand Systems: Identification

- Once the inverse factor demand is known, both factor demand and effective factor prices are known as well, with prices being uniquely pinned down by normalization in the initial equilibrium.

- **Proposition 4** *Suppose that A1-A3 hold. Then factor demand and relative effective factor prices are identified.*

From Asymptopia...

- **ACD's counterfactual question:** *What would have happened if China had not integrated into the world economy?*
- **Available data:**
  - $x_{ji,t}$ and $y_{i,t}$ from WIOD
  - $z^{\tau}_{ji,t}$ = freight costs (Hummels and Lugovsky 2006, Shapiro 2014)
  - i = Australia and USA
  - t = 1995-2010
  - j = 36 large exporters + ROW
- With this little data, even though model is non-parametrically identified, estimation needs to proceed parametrically (or need some other means of dimensionality-reduction)

... to Mixed CES

- Inspired by Berry (1994) and BLP's (1995) work on mixed logit, ACD consider the following "Mixed CES" system:

$$\chi_{ji}(\boldsymbol{\omega}_{i,t}) = \int \frac{(\kappa_j)^{\sigma_\alpha \alpha}(\mu_{ji}\omega_{ji,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}}{\sum_{l=1}^{N}(\kappa_l)^{\sigma_\alpha \alpha}(\mu_{li}\omega_{li,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}} dF(\alpha,\epsilon)$$

- Where:
  - $\omega_{ji,t}$ = effective price for exporter j in importer i at year t;
  - κ_j = "characteristic" of exporter j (per-capita GDP in 1995);
  - $F(\alpha,\epsilon)$ is a bivariate distribution of parameter heterogeneity: α has mean zero, $\ln\epsilon$ mean zero, and covariance matrix is identity

Comments

$$\chi_{ji}(\boldsymbol{\omega}_{i,t}) = \int \frac{(\kappa_j)^{\sigma_\alpha \alpha}(\mu_{ji}\omega_{ji,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}}{\sum_{l=1}^{N}(\kappa_l)^{\sigma_\alpha \alpha}(\mu_{li}\omega_{li,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}} dF(\alpha, \epsilon)$$

- **Costs**:
  - Ricardian $\Rightarrow$ Only cross-country price elasticities
  - Homothetic preferences $\Rightarrow$ Factor shares independent of income
- **Benefits**:
  - $\sigma_\alpha = \sigma_\epsilon = 0 \Rightarrow$ CES demand system is nested
  - $\sigma_\alpha \neq 0 \Rightarrow$ Departure from IIA (independence of irrelevant alternatives): more similar exporters in terms of $|\kappa_j - \kappa_l|$ are closer substitutes
  - $\sigma_\epsilon \neq 0 \Rightarrow$ Departure from IIA: more similar exporters in terms of $|\omega_j - \omega_l|$ are closer substitutes

reduced-form results

GMM Estimation

- Start by inverting mixed CES demand system:

$$\Delta\eta_{ji,t} - \Delta\eta_{j1,t} = \ln \chi_j^{-1}(\boldsymbol{x}_{i,t}) - \ln \chi_j^{-1}(\boldsymbol{x}_{1,t}) \\ -(\Delta \ln(z^{\tau})_{ji,t} - \Delta \ln(z^{\tau})_{j1,t}) + \zeta_{ji}$$

- Construct structural error term $e_{ji,t}(\boldsymbol{\theta})$ and solve for:

$$\hat{\boldsymbol{\theta}} = \text{argmin}_{\theta}\ \boldsymbol{e}(\theta)' \boldsymbol{Z} \boldsymbol{\Phi} \boldsymbol{Z} \boldsymbol{e}(\theta)$$

- Parameters:
    - $\boldsymbol{\theta} \equiv (\sigma_{\alpha}, \sigma_{\epsilon}, \bar{\epsilon}, \{\zeta_{ji}\})$
- Instruments (by A1):
    - $\Delta \ln(z^{\tau})_{ji,t} - \Delta \ln(z^{\tau})_{j1,t}$, $\{|\kappa_j - \kappa_l|(\ln z^{\tau}_{li,t} - \ln z^{\tau}_{l1,t})\}$, $\boldsymbol{d}_{ji,t}$

Departures from IIA in Standard Gravity

TABLE 1—REDUCED-FORM ESTIMATES AND VIOLATION OF IIA IN GRAVITY ESTIMATION

Dependent var.: $\Delta\Delta$ log(exports)	(1)	(2)	(3)	(4)
$\Delta\Delta$ log(freight cost)	-5.955	-6.239	-1.471	-1.369
	(0.995)	(1.100)	(0.408)	(0.357)
Test for joint significance of interacted competitors' freight costs ($H_0 : \gamma_l = 0$ *for all* l)				
F-stat		110.34		768.63
p-value		< 0.001		< 0.001
Disaggregation level	exporter		exporter-industry	
Observations	576		8,880	

Notes: Sample of exports from 37 countries to Australia and United States between 1995 and 2010 (aggregate and 2-digit industry-level). The notation $\Delta\Delta$ refers to the double-difference (first with respect to one exporting country, the United States, and second across the two importing countries). All models include a full set of dummy variables for exporter(-industry). Standard errors clustered by exporter are reported in parentheses.

Demand System Parameter Estimates

Table 2—GMM Estimates of Mixed CES Demand

	$\overline{\epsilon}$	σ_α	σ_ϵ
Panel A. CES			
	−5.955		
	(0.950)		
Panel B. Mixed CES (restricted heterogeneity)			
	−6.115	2.075	
	(0.918)	(0.817)	
Panel C. Mixed CES (unrestricted heterogeneity)			
	−6.116	2.063	0.003
	(0.948)	(0.916)	(0.248)

Notes: Sample of exports from 37 countries to Australia and United States between 1995 and 2010. All models include 36 exporter dummies. One-step GMM estimator described in Appendix B. Standard errors clustered by exporter are reported in parentheses.

Estimates of Chinese Trade Costs

- Non-parametric generalization of Head and Ries (2001) index:

$$\frac{(\tau_{ji,t}/\tau_{ii,t})}{(\tau_{jj,t}/\tau_{ij,t})} = \frac{(\bar{\chi}_j^{-1}(\boldsymbol{x}_{i,t})/\bar{\chi}_i^{-1}(\boldsymbol{x}_{i,t}))}{(\bar{\chi}_j^{-1}(\boldsymbol{x}_{j,t})/\bar{\chi}_i^{-1}(\boldsymbol{x}_{j,t}))}, \text{ for all } i,\ j, \text{ and } t.$$

- To go from (log-)difference-in-differences to levels of trade costs:

$$\begin{aligned} \tau_{ii,t}/\tau_{ii,95} &= 1 \text{ for all } i \text{ and } t, \\ \tau_{ij,t}/\tau_{ij,95} &= \tau_{ji,t}/\tau_{ji,95} \text{ for all } t \text{ if } i \text{ or } j \text{ is China.} \end{aligned}$$

Estimates of Chinese Trade Costs

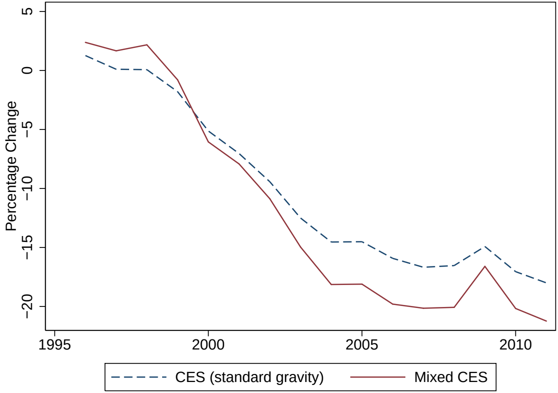

Figure 2: Average trade cost changes since 1995: China, 1996-2011.

Notes: Arithmetic average across all trading partners in the percentage reduction in Chinese trade costs between 1995 and each year $t = 1996, \ldots, 2011$. "CES (standard gravity)" and "Mixed CES" plot the estimates of trade costs obtained using the factor demand system in Panels A and C, respectively, of Table 2.

Counterfactual Shock: Chinese Integration

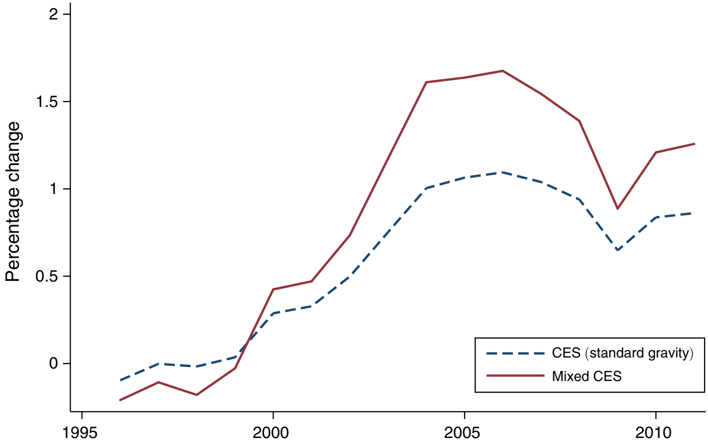

FIGURE 3. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: CHINA, 1996–2011

Notes: Welfare gains in China from reduction in Chinese trade costs relative to 1995 in each year $t = 1996, \ldots, 2011$. CES (standard gravity) and mixed CES plot the estimates of welfare changes obtained using the factor demand system in panels A and C, respectively, of Table 2.

Counterfactual Shock: Chinese Integration

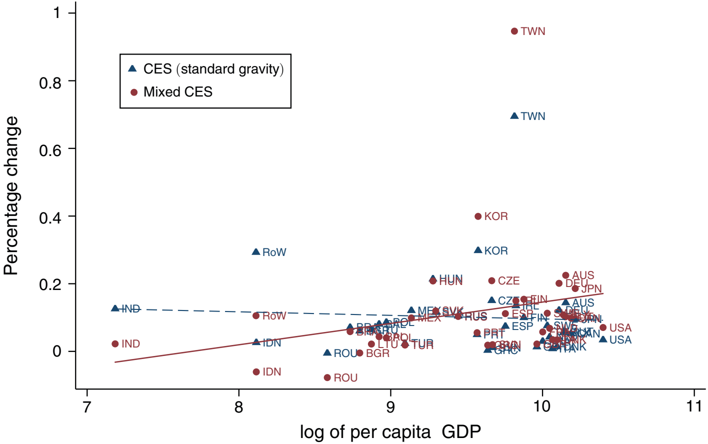

FIGURE 4. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: OTHER COUNTRIES, 2007

Notes: Welfare gains in other countries from reduction in Chinese trade costs relative to 1995 in year $t = 2007$. CES (standard gravity) and mixed CES plot the estimates of welfare changes obtained using the factor demand system in panels A and C, respectively, of Table 2. The solid line shows the line of best fit through the mixed CES points, and the dashed line the equivalent for the CES case. Bootstrapped 95 percent confidence intervals for these estimates are reported in Table A2.

Summary

- Knowledge of *reduced factor demand system* is sufficient for answering many counterfactual questions

- Away from CES, we obtain:
    - Nonparametric generalizations of standard gravity tools
    - Nonparametric identification from standard data

- This approach to counterfactual analysis allows us to:
    - Think about complex GE trading environments using simple economics of (factor) supply and demand
    - Use standard tools from IO to estimate (factor) demand

- Other applications:
    - Distributional consequences of trade
    - Revealed comparative advantage

Reduced-Form Estimates

Table 1: Reduced-Form Estimates: Violation of IIA in Gravity Estimation

Dependent variable: log(exports)	(1)	(2)	(3)	(4)
log(freight cost)	-6.103**	-6.347**	-1.301**	-1.277**
	(1.046)	(1.259)	(0.392)	(0.381)
Joint significance of interacted competitors' fright costs: $\gamma_l = 0$ for all l				
F-stat		42.60**		209.24**
p-value		<0.001		<0.001
Disaggregation level	exporter-importer		exporter-importer-sector	
Observations	1,184		18.486	

Notes: Sample of exports from 37 countries to Australia and USA between 1995 and 2010 (aggregate and sector-level). All models include a full set of dummies for exporter-importer(-sector), importer-year(-sector), and exporter-year(-sector). Standard errors clustered by exporter-importer. ** p<0.01.

back