BUSN 33946 & ECON 35101
International Macroeconomics and Trade

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Today: Multiple factors of production

With multiple factors of production, we can talk about distributional consequences of trade

- Ricardo-Viner specific-factors model
- 2×2 Heckscher-Ohlin model
- High-dimensional factor-proportions theory
- Trade and regional outcomes (empirics with R-V lens)
- Heckscher-Ohlin-Vanek empirics

Factor proportions theory

- The law of comparative advantage establishes the relationship between relative autarky prices and trade flows
- Factor proportions theory is an account of factor endowments as the source of relative autarky prices
    1. Countries differ in terms of factor abundance (relative factor supply)
    2. Goods differ in terms of factor intensity (relative factor demand)
- The interplay between these differences governs relative autarky prices and hence trade

Factor proportions theory

- To focus on factor endowments, shut down other channels:
  - Identical production functions (no Ricardian forces)
  - Identical homothetic preferences
- Two canonical models:
  - Ricardo-Viner model with 2 goods and 3 factors (2 of which are specific to a good)
  - Heckscher-Ohlin model with 2 goods and 2 factors
- Neary (1978), among others, treats the specific-factors model as a short-run case, whereas all factors are mobile in longer run

Ricardo-Viner model: Environment

- Two goods ($g = 1, 2$) with prices p_1, p_2
- Three factors with endowments L, K_1, K_2 and prices w, r_1, r_2
- Output of good g is

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

  where L_g is (endogenous) labor working in g and f^g is HD1 (payments to specific factors under CRS are profits in DRS)
- Profit maximization (where $f_L^g \equiv \frac{\partial f^g}{\partial L_g}$):

$$p_g f_L^g\left(L_g, K_g\right) = w \qquad p_g f_{K_g}^g\left(L_g, K_g\right) = r_g$$

- Labor market clearing:

$$L = L_1 + L_2$$

- "Small open economy": p_1, p_2 exogenous

Ricardo-Viner model: Equilibrium

Combine the expressions for MRPL and $L = L_1 + L_2$ to solve:

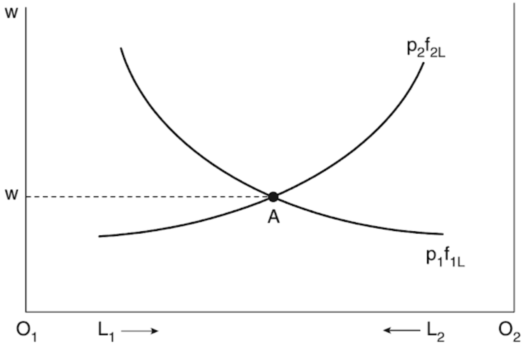

Figure 3.2

See pages 71-75 of Feenstra textbook (first edition)

Ricardo-Viner model: Comparative statics

Suppose that p_1 increases

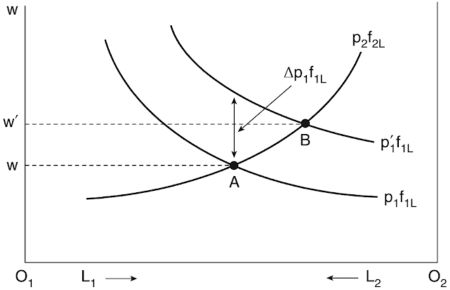

Figure 3.3

- w increases, L_1 increases, L_2 decreases
- Differentiate $w = p_1 f_L^1 (L_1, K_1)$ wrt p_1 to find $\hat{w} < \hat{p}_1$
- From $p_g f_{K_g}^g (L_g, K_g) = r_g$ we know that r_1/p_1 rises while r_2 (and thus r_2/p_1) falls (e.g., "Dutch disease")

Similar exercises for changes in endowments, etc.

2×2 Heckscher-Ohlin model: Environment

Production functions (HD1) using factors L and K are

$$y_g = f_g\left(L_g, K_g\right) \quad g = 1, 2$$

Unit cost functions are given by

$$c_g\left(w, r\right) = \min_{L_g, K_g} \left\{wL_g + rK_g | f_g\left(L_g, K_g\right) \geq 1\right\}$$

We write the solution in terms of unit factor demands a_{gf}

$$c_g\left(w, r\right) = wa_{gL}\left(w, r\right) + ra_{gK}\left(w, r\right)$$

From the envelope theorem, we know

$$\frac{\mathrm{d}c_g}{\mathrm{d}w} = a_{gL} \qquad \frac{\mathrm{d}c_g}{\mathrm{d}r} = a_{gK}$$

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

2×2 HO: Equilibrium in SOE

- Start with "small open economy" for which p_g are exogenous
- Profit maximization:

$$p_1 \leq c_1(w, r) \quad \text{equal if produced}$$
$$p_2 \leq c_2(w, r) \quad \text{equal if produced}$$

- Labor and capital markets clear:

$$a_{1L}y_1 + a_{2L}y_2 = L$$
$$a_{1K}y_1 + a_{2K}y_2 = K$$

- These are four nonlinear equations in four unknowns; unique solution not generally guaranteed

Four theorems

1. Factor price equalization: Can trade in goods substitute for trade in factors?
2. Stolper-Samuelson: Who wins and who loses from a change in goods prices?
3. Rybczynski: How does output mix respond to change in endowments?
4. Heckscher-Ohlin: What is the pattern of specialization and trade?

Factor price insensitivity

- Good 1 is called labor-intensive if $\frac{a_{1L}(w,r)}{a_{1K}(w,r)} > \frac{a_{2L}(w,r)}{a_{2K}(w,r)}$ and capital-intensive if $\frac{a_{1L}(w,r)}{a_{1K}(w,r)} < \frac{a_{2L}(w,r)}{a_{2K}(w,r)}$
- A factor intensity reversal occurs if $\exists w, r, w', r'$ such that good 1 is labor-intensive for (w, r) and capital-intensive for (w', r')

Lemma

If both goods are produced, and factor intensity reversals do not occur, then factor prices $\omega \equiv (w, r)$ are uniquely determined by goods 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 $\det[A(\omega)] \neq 0\ \forall\omega$, which no factor intensity reversals guarantees.

Factor intensity reversals

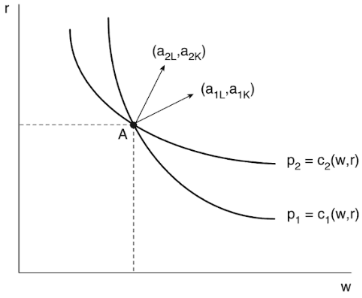

Figure 1.5

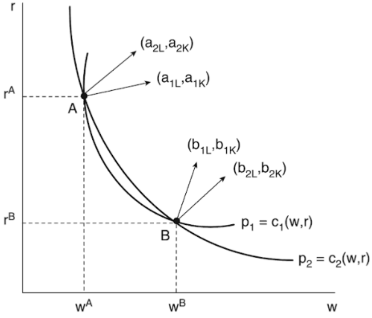

Figure 1.6

Factor price equalization

Theorem

If two countries both produce both goods under free trade with the same technology and there are no factor intensity reversals, then factor prices in the two countries are the same.

- This follow directly from the previous lemma and the no-FIR diagram:
  - By free trade, goods prices are the same
  - By identical technologies, isocost lines are the same
- Hence, trade in goods is a perfect substitute for factor mobility in this model in the sense that it also equalizes factor prices

Stolper-Samuelson Theorem

Theorem

An increase in the relative price of one good raises the real return of the factor used intensively in producing that good and lowers the real return of the other factor.

Proof:

WLOG, let $\frac{a_{1L}(\omega)}{a_{1K}(\omega)} > \frac{a_{2L}(\omega)}{a_{2K}(\omega)}$ and $\hat{p}_1 > \hat{p}_2$, where $\hat{x} \equiv \frac{\mathrm{d}x}{x}$.
Differentiating the zero-profit conditions yields

$$\mathrm{d}p_i = a_{iL}\mathrm{d}w + a_{iK}\mathrm{d}r$$

Define the cost share $\theta_{iL} = \frac{wa_{iL}}{c_i}$ to obtain

$$\hat{p}_i = \theta_{iL}\hat{w} + (1 - \theta_{iL})\,\hat{r}$$

Goods price changes are weighted averages of factor price changes.
$\frac{a_{1L}}{a_{1K}} > \frac{a_{2L}}{a_{2K}} \Rightarrow \theta_{1L} > \theta_{2L}$ so

$$\hat{r} < \hat{p}_2 < \hat{p}_1 < \hat{w}$$

Notes on 2 × 2 Stolper-Samuelson Theorem

- A change in product prices has a magnified effect on factor prices
- Jones (1965) referred to these inequalities as "magnification effect" (This is the original "hat algebra")
- Trade liberalization that alters goods prices will thus produce winners and losers across factors
- Like FPI and FPE, Stolper-Samuelson result follows from zero-profit condition (+ "no joint production")

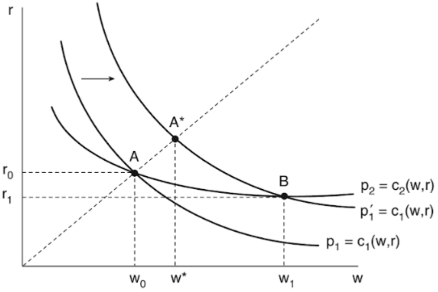

Figure 1.7

Rybczynski Theorem

Theorem

For given goods prices, an increase in the endowment of one factor causes a more-than-proportionate increase in the output of the good using this factor intensively and a decrease in the output of the other good.

Differentiating the factor market clearing conditions yields,

$$\mathrm{d}L = a_{1L}\mathrm{d}y_1 + a_{2L}\mathrm{d}y_2 \text{ and } \mathrm{d}K = a_{1K}\mathrm{d}y_1 + a_{2K}\mathrm{d}y_2$$

Defining $\lambda_{iL} = \frac{a_{iL}y_i}{L}$ and $\lambda_{iK} = \frac{a_{iK}y_i}{K}$ this implies,

$$\hat{L} = \lambda_{1L}\hat{y}_1 + (1 - \lambda_{1L})\,\hat{y}_2 \text{ and } \hat{K} = \lambda_{1K}\hat{y}_1 + (1 - \lambda_{1K})\,\hat{y}_2$$

If (w.l.o.g.) $\frac{a_{1L}}{a_{1K}} > \frac{a_{2L}}{a_{2K}}$, then $\lambda_{1L} > \lambda_{1K}$ so that,

$$\hat{y}_1 > \hat{L} > \hat{K} > \hat{y}_2 \text{ or } \hat{y}_1 < \hat{L} < \hat{K} < \hat{y}_2$$

Hence, if also (w.l.o.g.) $\hat{K} > \hat{L}$, we obtain,

$$\hat{y}_1 < \hat{L} < \hat{K} < \hat{y}_2$$

Rybczynski Theorem and cone of diversification

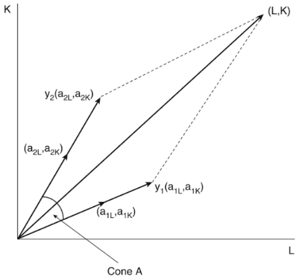

Figure 1.8

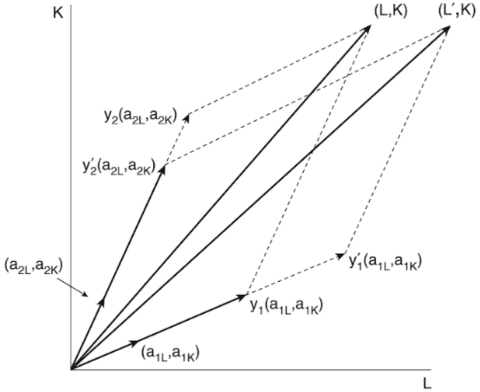

Figure 1.9

- Produce both goods iff (L, K) lies between factor requirements vectors (a_{2L}, a_{2K}) and (a_{1L}, a_{1K}), the "cone of diversification"
- At unchanged factor intensities, increase in labor endowment necessitates decrease in output of capital-intensive good

Heckscher-Ohlin theorem

- We now consider world economy with two countries and free trade (prior results derived for small open economies)
- This is a $2 \times 2 \times 2$ model
- Identical technologies and homothetic preferences
- What is the pattern of trade in this global economy?
  - Rather than starting from autarky, let's start from the integrated equilibrium
  - Integrated world economy with world endowment of factors yields integrated equilibrium (good prices, factor prices, resource allocations, etc)

The FPE set

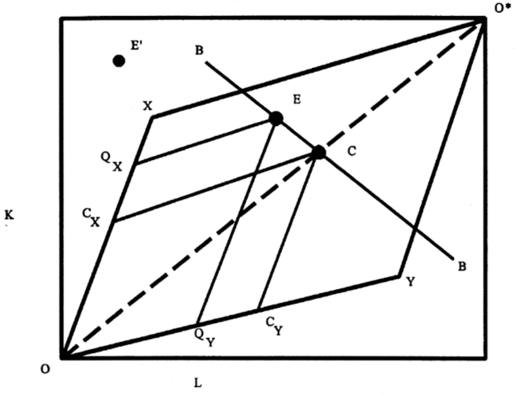

Figure 1.1.

- World endowed with K and L
- Integrated factor allocations OX and OY
- Samuelson's angel can fragment world into two countries by endowments E or E'.
- Can trade reproduce the integrated equilibrium? If FPE holds!

Heckscher-Ohlin theorem

Theorem

In the free-trade equilibrium, each country exports the good that uses its abundant factor intensively.

- If endowments are in the FPE set, this is a simple corollary of the Rybczynski theorem and homothetic preferences (no assumption on FIRs required).
- Outside the FPE set, need to also consider FIRs.
- To state the prediction in terms of autarky relative factor prices, return to general theorem of Deardorff (1980)
- Is the autarky relative price of the labor-intensive good lower in the labor-abundant country?
- See Feenstra Figure 2.1 and Jones and Neary equation (2.10)

Higher dimensions

What if there are C countries, G goods, and F factors?

- If $F = G$ (“even case”), situation is qualitatively similar
- Integrated equilibrium and FPE set are helpful devices here
- If $F > G$, then FPE set is “measure zero” ($F = 2, G = 1$ on diagonal of Samuelson’s angel diagram)
- If $G > F$, then production and trade are indeterminate, but factor content of trade known

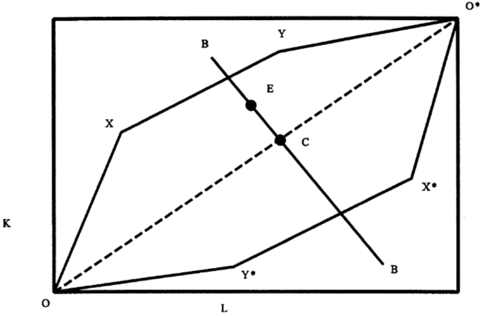

Figure 1.2.

High-dimensional predictions

- High-dimensional predictions are not much loved, since they are either weak or unintuitive.
- See Ethier (Handbook 1984) for a survey. Lots of comparative statics depend on whether F or G is greater.

Stolper-Samuelson in higher dimensions is Jones and Scheinkman (JPE 1977) "friends and enemies" result:

- SS theorem follows from differentiating zero-profit condition
- With arbitrary F and G, still true that (no joint production)

$$\hat{p}_g = \sum_f \theta_{fg} \hat{w}_f$$

- Suppose $\hat{p}_1 \leq \cdots < \hat{p}_G$. Then there exist f_1 and f_2 such that

$$\hat{w}_{f_1} < \hat{p}_1 \leq \cdots < \hat{p}_G < \hat{w}_{f_2}$$

- In uneven cases, cannot always identify "friends" and "enemies"
- E.g., in Ricardo-Viner, labor is intermediate, $\hat{p}_1 < \hat{w} < \hat{p}_2$

Heckscher-Ohlin-Vanek Theorem

- Without $G = F$, we have results about factor content of trade rather than goods trade
- Define net exports of factor by the vector $T_F^c = AT^c$, where A is the $F \times G$ matrix of unit factor requirements and T^c is net exports of goods by c
- Heckscher-Ohlin-Vanek theorem: In any country c, net exports of factors satisfy $T_F^c = V^c - s^c V^{\text{world}}$ where s^c is c's share of world income
- Countries export factors in which they are relatively abundant: $V^c > s^c V^{\text{world}}$
- This prediction derives from identical technology, FPE, and homothetic preferences. Good luck.

The Ricardo-Roy setup in one slide

Primitives:

- Technologies $A(\omega, \sigma, \gamma_{A,c})$
- Endowments $L(\omega, \gamma_{L,c})$
- Demands $D(p, I_c|\sigma, \gamma_{D,c})$

Equilibrium:

- Profit maximization by firms

$$Q(\sigma, c) = \int_{\Omega} A(\omega, \sigma, \gamma_{A,c}) L(\omega, \sigma, c) d\omega$$

$$\Rightarrow p(\sigma) \leq \min_{\omega \in \Omega} \{w(\omega, c)/A(\omega, \sigma, \gamma_{A,c})\}$$

$$\Omega(\sigma, c) \equiv \{\omega \in \Omega : L(\omega, \sigma, c) > 0\} \subseteq \arg\min_{\omega \in \Omega} \{w(\omega, c)/A(\omega, \sigma, \gamma_{A,c})\}$$

- Market clearing

$$\int_{\Sigma} L(\omega, \sigma, c) d\sigma = L(\omega, \gamma_{L,c}) \quad \forall \omega, c$$

$$\int_{\mathbb{C}} D(p, I_c|\sigma, \gamma_{D,c}) dc = \int_{\mathbb{C}} Q(\sigma, c) dc \quad \forall \sigma$$

Core R-R results

Cross-sectional predictions

- Factor assignments
- Factor prices (FPE)
- Output quantities (Rybczynski)

Comparative statics

- Price changes (Stolper-Samuelson)
- Endowment and taste changes

Factor assignments

Taking $p(\sigma)$ as given, who makes what?

Assumption 1: $A(\omega, \sigma, \gamma_{A,c})$ *is strictly log-supermodular in* (ω, σ) *and in* $(\sigma, \gamma_{A,c})$

Under this assumption:

- PAM (I). $\Omega(\sigma, c)$ is increasing in σ.

  Recall $\Omega(\sigma, c) \subseteq \arg\min_{\omega \in \Omega}\{w(\omega, c)/A(\omega, \sigma, \gamma_{A,c})\}$ and property 3 of LSM

- PAM(II). $\Sigma(\omega, \gamma_{A,c})$ is increasing in $\gamma_{A,c}$.

  Similarly, $\Sigma(\omega, \gamma_{A,c}) \subseteq \arg\max_{\sigma}\{p(\sigma)A(\omega, \sigma, \gamma_{A,c})\}$ and property 3 of LSM

Thus, we can say that

- High-ω factors are employed in high-σ activities
- High-$\gamma_{A,c}$ locations specialize in high-σ activities

Factor prices

- Since factors of production are perfect substitutes within each task, factor price equalization necessarily holds in terms of (Hicks-neutral-adjusted) efficiency units.
- Just analyze the integrated economy, basically.
- Factor prices equalize for common technologies:

$$\omega \in \Omega(\sigma, c) \Rightarrow w(\omega, c) = \max_{\sigma} p(\sigma) A(\omega, \sigma, \gamma_{A,c})$$
$$\gamma_{A,c} = \gamma_{A,c'} \Rightarrow w(\omega, c) = w(\omega, c')$$

- Assuming a continuum of factors, factor prices are governed by

$$w(\omega, c) = p(M(\omega, c)) A(\omega, M(\omega, c)), \gamma_{A,c})$$
$$\Rightarrow \frac{d \ln w(\omega, c)}{d\omega} = \frac{\partial \ln A(\omega, M(\omega, c), \gamma_{A,c})}{\partial \omega}$$

Output quantities

We have assignments, but we need a further assumption to get quantities

Assumption 2: $L(\omega, \gamma_{L,c})$ *is log-supermodular*

This means high-$\gamma_{L,c}$ locations are relatively abundant in high-ω factors

$$\begin{aligned} Q(\sigma, c) &= \int_{\Omega} A(\omega, \sigma, \gamma_{A,c}) L(\omega, \sigma, \gamma_{L,c}) d\omega \\ &= \int_{\Omega(\sigma,c)} A(\omega, \sigma, \gamma_{A,c}) L(\omega, \gamma_{L,c}) d\omega \qquad \text{by } \Sigma(\omega, c) \text{ singleton} \\ &= \int_{\Omega(\sigma)} A(\omega, \sigma, \gamma_{A,c}) L(\omega, \gamma_{L,c}) d\omega \qquad \text{by common technologies} \end{aligned}$$

Rybczynski: Under Assumptions 1 and 2, $Q(\sigma, c)$ is log-supermdular in $(\sigma, \gamma_{L,c})$

Rybczynski + identical preferences $\Rightarrow$ Heckscher-Ohlin theorem

Price changes

Consider a small open economy c facing prices $p(\sigma, \phi)$, so that assignments $M(\omega, c, \phi)$ and wages $w(\omega, c, \phi)$ respond to an external change from ϕ to ϕ'.

Assumption 3: *$p(\sigma, \phi)$ is log-supermodular*

$$\begin{aligned} w(\omega, c, \phi) &= \max_{\sigma}\{p(\sigma, \phi)A(\omega, \sigma, \gamma_{A,c})\} \\ &= p(M(\omega, c, \phi), \phi)A(\omega, M(\omega, c, \phi), \gamma_{A,c}) \\ \Rightarrow \frac{d \ln w(\omega, c, \phi)}{d\phi} &= \frac{\partial \ln p(M(\omega, c, \phi), \phi)}{\partial \phi} \\ \frac{d}{d\omega}\left(\frac{\partial \ln p(M(\omega, c, \phi), \phi)}{\partial \phi}\right) &= \frac{\partial^2 \ln p}{\partial \sigma \partial \phi}\frac{dM}{d\omega} \geq 0 \end{aligned}$$

Assumptions 1 (A LSM) and 3 (p LSM) imply $w(\omega, c, \phi)$ is LSM in (ω, ϕ)

Taste and endowment changes

Assignments and wages follow from pair of differential equations

$$\frac{d \ln w(\omega, c)}{d\omega} = \frac{\partial \ln A(\omega, M(\omega, c), \gamma_{A,c})}{\partial \omega}$$
$$\frac{dM(\omega, c)}{d\omega} = \frac{(A(\omega, M(\omega, c), \gamma_{A,c}))^{1-\epsilon}(w(\omega, c))^{\epsilon} L(\omega, \gamma_{L,c})}{B(M(\omega, c), \gamma_{D,c}) \int_{\Omega} w(\omega', c) L(\omega', \gamma_{L,c}) d\omega'}$$

Assumption 4: $B(\sigma, \gamma_{D,c})$ *is log-submodular*

Comparative statics under Assumptions 1, 2, 4 for CES demand:

- **Assignments**. $M(\omega, c)$ is decreasing in $\gamma_{D,c}$ and $\gamma_{L,c}$
- **Prices**. $w(\omega, c)$ is log-submodular in $(\omega, \gamma_{D,c})$ and $(\omega, \gamma_{L,c})$

See Costinot & Vogel (*JPE* 2010) for polarization cases

Empirics

Trade and regional outcomes (empirics with R-V lens)

- Recent work looking at trade's effects on regional labor markets can be interpreted as using a Ricardo-Viner view
- Cross-sectional regressions testing HO model take long-run view, but recent labor literature exploiting panel data lets us take factor specificity more seriously
- Suppose a trade-policy change affects p (nationwide goods prices)
- What happens to economic outcome in different regions?
- Topalova (2010) on India, Kovak (2013) on Brazil, Autor, Dorn, and Hanson (2013) on US

Topalova (2010)

Regression for outcome y in district d in year t

$$y_{dt} = \alpha_d^D + \alpha_t^T + \beta \text{tariff}_{dt} + \epsilon_{dt}$$

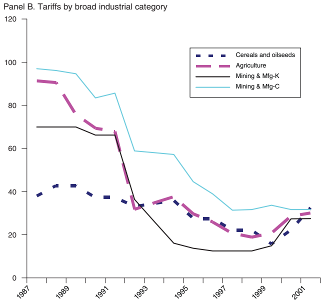

FIGURE 1. EVOLUTION OF INDIA'S TARIFF AND NTBS (*Continued*)

- y is poverty rate and tariff is employment-weighted average of national industry import tariffs
- India has long-running poverty surveys, many districts, and a large trade liberalization in 1991
- IV for tariffs: initial level, because tariff harmonization meant "the higher the tariff, the bigger the cut"

Table 3A—Trade Liberalization, Poverty, and Average Consumption in Rural India

Data	Pre & post (1)	Pre & post (2)	Pre & post (3)	Pre & post (4)	Pre only (5)	Pre & post (6)	Pre & post (7)	Pre & post (8)
Panel A. Dependent variable: poverty rate								
Tariff	−0.242*		−0.710***	−0.467*	0.038	−0.479**	−0.424*	−0.381***
	[0.122]		[0.250]	[0.247]	[1.000]	[0.236]	[0.229]	[0.139]
Traded tariff		−0.223**						
		[0.084]						
NTB (share of free HS codes)						0.073		
						[0.202]		
Panel B. Dependent variable: log average per capita consumption								
Tariff	−0.055		0.512	0.677*	−0.085	0.683*	0.657*	0.583**
	[0.353]		[0.639]	[0.400]	[0.463]	[0.373]	[0.333]	[0.216]
Traded tariff		0.161						
		[0.207]						
NTB (share of free HS codes)						−0.036		
						[0.248]		
IV with traded tariff	No	No	Yes	Yes	Yes	Yes	Yes	Yes
IV with traded tariff and initial traded tariff	No	No	No	No	No	No	No	Yes
District indicators	Yes	Yes	Yes	Yes	NA	Yes	Yes	Yes
Initial district conditions × post	No	No	No	Yes	NA	Yes	Yes	Yes
Region indicators	NA	NA	NA	NA	Yes	NA	NA	NA
Initial region indicators × post	NA	NA	NA	NA	Yes	NA	NA	NA
Other reforms controls	No	No	No	No	No	No	Yes	Yes
N	728	728	728	728	128	728	728	728

Notes: Standard errors (in brackets) are clustered at the state-year level. Regressions are weighted by the number of households in a district. All specifications include a post-reform indicator. Initial district conditions that are interacted with the post-reform indicator include percentage of workers in a district employed in agriculture, employed in mining, employed in manufacturing, employed in trade, employed in transport, and employed in services (construction is the omitted category), as well as the share of district's population that is schedule caste/tribe, the percentage of literate population, and state labor laws indicators. Other reform controls include controls for industry licensing, foreign direct investment, and number of banks per 1,000 people. Regressions in column 5 replace all district-level variables with their equivalents at the regional level and use only pre-reform data for the outcomes of interest.

***Significant at the 1 percent level.

Kovak (2013)

Look at Brazil's import liberalization

- Topalova finds little geographical or intersectoral migration
- In Brazil, substantial migratory responses

Estimating equation explicitly derived from a RV model

- Good i with specific factor K_i and labor L
- Factor market clearing:

$$a_{K_i} Y_i = K_i \qquad \sum_i a_{Li} Y_I = L$$

- Differentiating, $\hat{L} = \sum_i \lambda_i (\hat{a}_{Li} - \hat{a}_{K_i})$ where $\lambda_i \equiv L_i / L$
- $\hat{p}_i = (1 - \theta_i)\hat{w} + \theta_i \hat{r}_i$, where $\theta_i \equiv \frac{r_i K_i}{p_i Y_i}$ is specific factor's cost share

Kovak (2013): Model, continued

If σ_i is elasticity of substitution btw K_i and L then

$$\hat{a}_{K_i} - \hat{a}_{Li} = \sigma_i \left(\hat{w} - \hat{r}_i\right)$$

Combining with expression for $\hat{L}$, we get

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

Solve for $\hat{w}$ using some matrix algebra

$$\hat{w} = -\frac{1}{\sum_{i'} \lambda_{i'} \frac{\sigma_{i'}}{\theta_{i'}}} \hat{L} + \sum_i \frac{\lambda_i \frac{\sigma_i}{\theta_i}}{\sum_{i'} \lambda_{i'} \frac{\sigma_{i'}}{\theta_{i'}}} \hat{p}_i$$

- In baseline, no migration, so $\hat{L} = 0$
- Idiot's law of elasticities says $\sigma_i = 1 \; \forall i$
- Extend to address non-traded goods

Estimate using region's tariff change assuming full passthrough

$$\Delta \ln w_r = \alpha + \beta \cdot \mathrm{RTC}_r + \epsilon_r \qquad \mathrm{RTC}_r \equiv \sum_i \frac{\lambda_i \frac{1}{\theta_i}}{\sum_{i'} \lambda_{i'} \frac{1}{\theta_{i'}}} \Delta \ln \left(1 + \tau_i\right)$$

Kovak (2013): Identifying variation

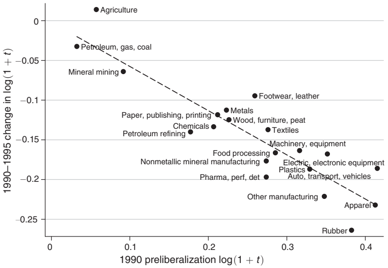

FIGURE 1. RELATIONSHIP BETWEEN TARIFF CHANGES AND PRELIBERALIZATION TARIFF LEVELS

Note: Correlation: −0.899; regression coefficient: −0.556; standard error: 0.064; t: −8.73.
Source: Author's calculations based on data from Kume, Piani, and de Souza (2003).

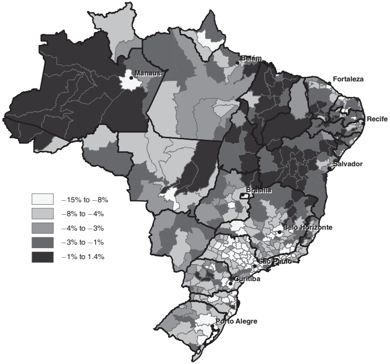

FIGURE 3. REGION-LEVEL TARIFF CHANGES

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

Kovak (2013): Empirical estimates

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).

Dix-Carneiro and Kovak (2017) estimate dynamic version:

$$w_{r,t} - w_{r,1991} = \alpha_{st} + \beta_t \cdot \mathrm{RTC}_r + \gamma_t(w_{r,1990} - w_{r,1986}) + \epsilon_{rt}$$

Autor, Dorn, Hanson (2013)

- Use of trade quantities (China shock) rather than prices, so a gravity-based model rather than specific-factor SOE
- Exogenous Chinese export supply shock in industry j is $\hat{A}_{Cj}$ and Chinese import demand shock is $\hat{E}_{Cj}$
- Look at outcomes for wages $\hat{w}_i$, employment in traded goods $\hat{L}_i^T$, and employment in non-traded goods $\hat{L}_i^N$
- Treatment is exposure to import competition:

$$\Delta\text{IPW}_{uit} = \sum_j \frac{L_{ijt}}{L_{ujt}} \frac{\Delta M_{ucjt}}{L_{it}}$$

- Instrument using non-US exposure:

$$\Delta\text{IPW}_{oit} = \sum_j \frac{L_{ijt-1}}{L_{ujt-1}} \frac{\Delta M_{ocjt}}{L_{it-1}}$$

ADH (2013): Manufacturing employment falls

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, Hanson (2013): Population response

TABLE 4—IMPORTS FROM CHINA AND CHANGE OF WORKING-AGE POPULATION IN CZ, 1990–2007: 2SLS ESTIMATES

Dependent variables: Ten-year equivalent changes in log population counts (in log pts)

	I. By education level			II. By age group		
	All (1)	College (2)	Noncollege (3)	Age 16–34 (4)	Age 35–49 (5)	Age 50–64 (6)
Panel A. No census division dummies or other controls						
(Δ imports from China to US)/worker	−1.031** (0.503)	−0.360 (0.660)	−1.097** (0.488)	−1.299 (0.826)	−0.615 (0.572)	−1.127*** (0.422)
R^2	—	0.03	0.00	0.17	0.59	0.22
Panel B. Controlling for census division dummies						
(Δ imports from China to US)/worker	−0.355 (0.513)	0.147 (0.619)	−0.240 (0.519)	−0.408 (0.953)	−0.045 (0.474)	−0.549 (0.450)
R^2	0.36	0.29	0.45	0.42	0.68	0.46
Panel C. Full controls						
(Δ imports from China to US)/worker	−0.050 (0.746)	−0.026 (0.685)	−0.047 (0.823)	−0.138 (1.190)	0.367 (0.560)	−0.138 (0.651)
R^2	0.42	0.35	0.52	0.44	0.75	0.60

Notes: $N = 1{,}444$ (722 CZs $\times$ two time periods). All regressions include a constant and a dummy for the 2000–2007 period. Models in panel B and C also include census division dummies while panel C adds the full vector of control variables from column 6 of Table 3. Robust standard errors in parentheses are clustered on state. Models are weighted by start of period commuting zone share of national population.

Autor, Dorn, Hanson (2013): Margins of adjustment

TABLE 5—IMPORTS FROM CHINA AND EMPLOYMENT STATUS OF WORKING-AGE POPULATION WITHIN CZS, 1990–2007: 2SLS ESTIMATES

Dependent variables: Ten-year equivalent changes in log population counts and population shares by employment status

	Mfg emp (1)	Non-mfg emp (2)	Unemp (3)	NILF (4)	SSDI receipt (5)
Panel A. 100 × log change in population counts					
(Δ imports from China to US)/worker	−4.231***	−0.274	4.921***	2.058*	1.466***
	(1.047)	(0.651)	(1.128)	(1.080)	(0.557)
Panel B. Change in population shares					
All education levels					
(Δ imports from China to US)/worker	−0.596***	−0.178	0.221***	0.553***	0.076***
	(0.099)	(0.137)	(0.058)	(0.150)	(0.028)
College education					
(Δ imports from China to US)/worker	−0.592***	0.168	0.119***	0.304***	—
	(0.125)	(0.122)	(0.039)	(0.113)	
No college education					
(Δ imports from China to US)/worker	−0.581***	−0.531***	0.282***	0.831***	—
	(0.095)	(0.203)	(0.085)	(0.211)	

Notes: N = 1,444 (722 CZs × two time periods). All statistics are based on working age individuals (age 16 to 64). The effect of import exposure on the overall employment/population ratio can be computed as the sum of the coefficients for manufacturing and nonmanufacturing employment; this effect is highly statistically significant ($p \leq 0.01$) in the full sample and in all reported subsamples. All regressions include the full vector of control variables from column 6 of Table 3. Robust standard errors in parentheses are clustered on state. Models are weighted by start of period CZ share of national population.

Empirical work on factor content of trade

- Leontief (1953) and Leamer (1980)
- Bowen, Leamer and Sveikauskas (1987)
- Trefler (1993)
- Trefler (1995)
- Davis and Weinstein (2001)

Net factor content of trade

- HOV says net exports of factors are $T_F^c = AT^c = V^c - s^c V^{\text{world}}$
- In reality, production uses intermediate inputs
- Let $A(\omega)$ denote input-output matrix for commodity production and $B(\omega)$ denote matrix of direct factor inputs
- If only final goods are traded, (Leontief shows that) the HOV theorem applies with $\bar{B}(\omega) = B(\omega)\left(I - A(\omega)\right)^{-1}$ in place of $A(\omega)$
- Trefler and Zhu (2010) show that the "only final goods are traded"assumption is not innocuous and propose extensions to address
- Also note recent work by Johnson and Noguera on gross vs value-added trade
- Prediction of $\bar{B}(\omega)T^c = V^c - s^c V^{\text{world}}$ is $C \times F$ equalities.
- One can imagine many different tests, and there have been.

Leontief (1953)

- Leontief (1953) was the first to empirically examine HOV, since Leontief had just computed (for the first time) the input-output table for the 1947 US economy
- Leontief's table only had K and L as factor inputs, and he only had $\bar{B}^{\mathrm{US}}(\omega^{\mathrm{US}})$, so he assumed $\bar{B}^{c}(\omega^{c}) = \bar{B}^{\mathrm{US}}(\omega^{\mathrm{US}})\ \forall c$
- The US had been presumed to be a capital-abundant economy

Table 2.1: Leontief's (1953) Test

	Exports	Imports
Capital ($ million)	$2.5	$3.1
Labor (person-years)	182	170
Capital/Labor ($/person)	$13,700	$18,200

Note: Each column shows the amount of capital or labor needed per $1 million worth of exports or imports into the United States, for 1947.

Leamer (1980): "The Leontief Paradox, Reconsidered"

- Leontief's intuitively appealing application of HOV to exports and imports was not particularly robust
- If trade is unbalanced or $F > 2$, then US can be a net exporter of both K and L services
- The HOV $T_F^c = V^c - s^c V^{\text{world}}$ equation implies that if $\frac{K^{\text{US}}}{K^{\text{world}}} > \frac{L^{\text{US}}}{L^{\text{world}}}$, then

$$\frac{K^{\text{US}}}{L^{\text{US}}} > \frac{K^{\text{US}} - T_K^{\text{US}}}{L^{\text{US}} - T_L^{\text{US}}}$$

  which says capital intensity of production exceeds the capital intensity of consumption

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Bowen, Leamer and Sveikauskas (1987)

- Data on 12 factors and 27 countries $\Rightarrow$ many tests of $\bar{B}(\omega)T^c = V^c - s^c V^{\text{world}}$
- Only observe $\bar{B}(\omega)$ in US in 1967, so assume it applies to all countries in 1967
- How to test an equality, since it won't hold exactly?
  - Sign test: How often does sign of T_f^c coincide with sign of $V_f^c - s^c V_f^{\text{world}}$? 61% of the time.
  - Rank test: If $T_f^c > T_{f'}^c$, is $V_f^c - s^c V_f^{\text{world}} > V_{f'}^c - s^c V_{f'}^{\text{world}}$? 49%!
- This "poor performance of the HOV hypothesis" was disappointing
- Maskus (1985) made a similar point in an article titled "A test of the Heckscher-Ohlin-Vanek theorem: The Leontief commonplace"
- BLS (1987) suggest technologies not likely identical

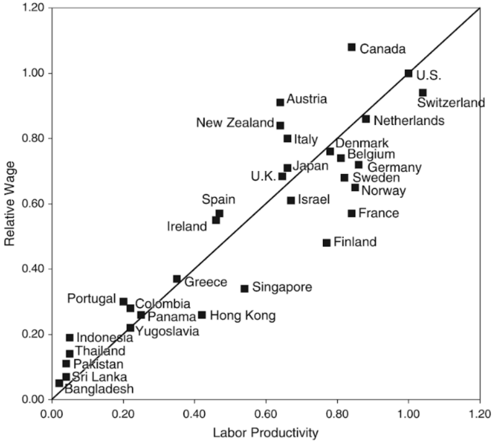
Trefler (1993)

- Trefler (JPE, 1993) and Trefler (AER, 1995) relaxed the strong assumption that technologies were identical
- The key was to theoretically incorporate heterogeneous productivities in while keeping attractive properties of HOV
- Trefler (1993) introduces country-factor-specific productivity differences π_f^c so that effective endowments are $\pi_f^c V_f^c$ and effective factor prices are w_f^c/π_f^c.
- Conditional FPE in terms of efficiency units and HOV similarly

$$T_f^c = \bar{B}(\omega) T^c = \pi^c \cdot V^c - s^c \sum_{c'} \pi^{c'} \cdot V^{c'}$$

- There is a (unique) set of π_f^c terms that make the HOV equations hold with equality ($\pi_f^{\mathrm{US}} = 1$ normalization)
- If HOV cannot be wrong, what do we learn from π_f^c?

Trefler (1993): Sensible π_f^c?



- Trefler shows that estimated π_f^c could be negative. Only 10/384 are.
- Logic thus far hasn't used factor prices. Conditional FPE looks pretty good.
- US is typically more productive ($\pi_f^c < 1$)

Trefler (1995)

Trefler (1995) revisits HOV:

- Why have factor-content predictions failed? Trefler points to two key sources of failure
- What parsimonious extensions of theory (as opposed to the generous π_f^c) could resurrect HOV with decent fit?

First failure:

- Define $\epsilon_f^c = T_f^c - (V_f^c - s^c V_f^{\text{world}})$ as HOV deviations
- Plot ϵ_f^c against $V_f^c - s^c V_f^{\text{world}}$: vertical line is perfect fit; diagonal is $T_f^c = 0$
- 100% "sign test" would put all points in lower left or upper right
- Perfect HOV fit is horizontal axis for $\epsilon_f^c = 0$

Trefler (1995): “The Case of the Missing Trade”

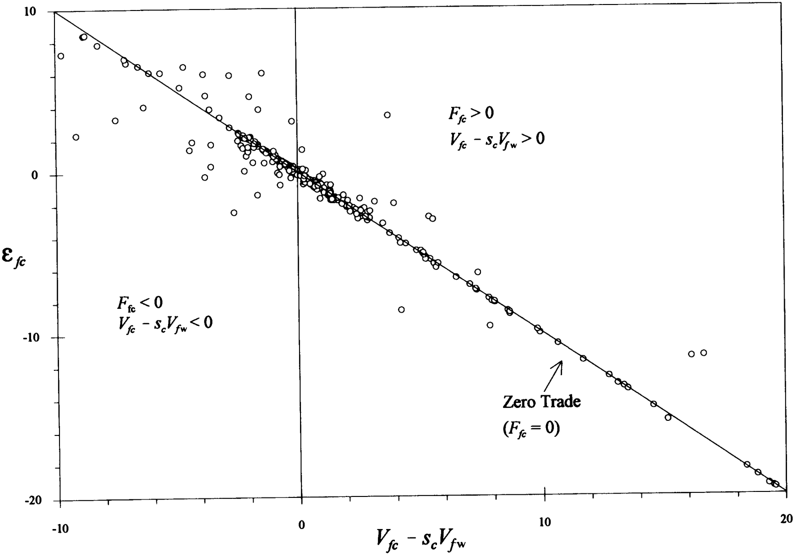


FIGURE 1. PLOT OF $\varepsilon_{fc} = F_{fc} - (V_{fc} - s_c V_{fw})$ AGAINST $V_{fc} - s_c V_{fw}$

Trefler (1995)

Second, plot HOV deviations by country

- How often is $\epsilon_f^c < 0$?
- By missing trade, this is mirrored by $V_f^c - s^c V_f^{\text{world}} > 0$

Visualize a failing of HOV equations:

- Poor countries appear to be abundant in all factors.
- This cannot be true with balanced trade, and it is not true that poor countries run higher trade imbalances (in Trefler's sample).
- Is there an omitted factor that is scarce in poor countries? Perhaps we need productivity differences again

Trefler (1995): "Endowments Paradox"

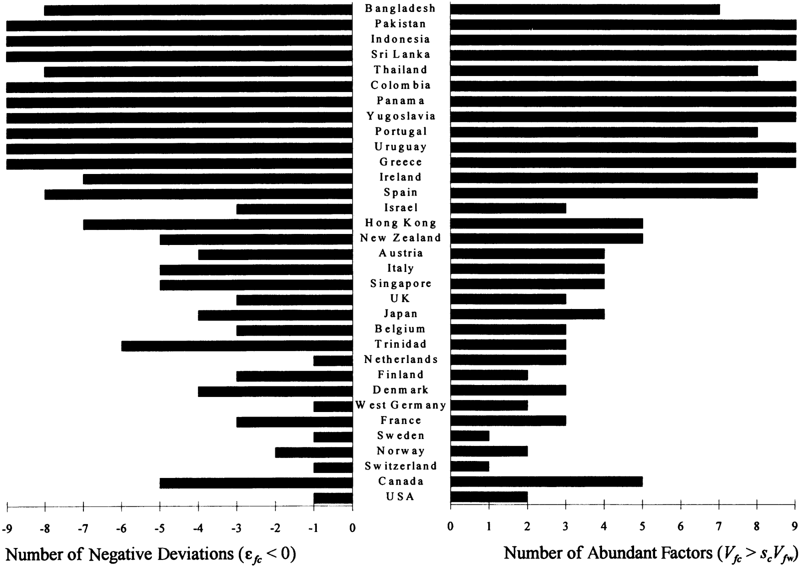


FIGURE 2. DEVIATIONS FROM HOV AND FACTOR ABUNDANCE

Trefler (1995) considers five parsimonious extensions

1. T1: restrict π_f^c in Trefler (1993) to $\pi_f^c = \delta^c$. ('Neutral technology differences').
2. T2: restrict π_f^c in Trefler (1993) to $\pi_f^c = \delta^c \phi_f$ for less developed countries (cutoff estimated) and $\pi_f^c = \delta^c$ for developed countries.
3. C1: allow the s^c terms to be adjusted to fit the data (variation in countries' demand for investment, services, non-traded goods)
4. C2: Armington/home bias/trade costs to explain missing trade.
5. TC2: C2 + $\delta^c = y^c / y^{\mathrm{US}}$

Trefler (1995): TC2 improves fit considerably

TABLE 1—HYPOTHESIS TESTING AND MODEL SELECTION

Hypothesis	Description: Parameters (k_i)	Description: Equation	Likelihood: $\ln(L_i)$	Likelihood: Schwarz criterion	Mysteries: Endowment paradox	Mysteries: Missing trade	Goodness-of-fit: Weighted sign	Goodness-of-fit: $\rho(F, \hat{F})$
Endowment differences								
H_0: unmodified HOV theorem	(0)	(1)	−1,007	−1,007	−0.89	0.032	0.71	0.28
Technology differences								
T_1: neutral	δ_c (32)	(4)	−540	−632	−0.17	0.486	0.78	0.59
T_2: neutral and nonneutral	ϕ_f, δ_c, κ (41)	(6)	−520	−637	−0.22	0.506	0.76	0.63
Consumption differences								
C_1: investment/services/ nontrade.	β_c (32)	(7)	−915	−1,006	−0.63	0.052	0.73	0.35
C_2: Armington	α_c^* (24)	(11)	−439	−507	−0.42	3.057	0.87	0.55
Technology and consumption								
TC_1: $\delta_c = y_c/y_{US}$	(0)	(4)	−593	−593	−0.10	0.330	0.83	0.59
TC_2: $\delta_c = y_c/y_{US}$ and Armington	α_c^* (24)	(12)	−404	−473	0.18	2.226	0.93	0.67

Notes: Here k_i is the number of estimated parameters under hypothesis i. For "likelihood," $\ln(L_i)$ is the maximized value of the log-likelihood function, and the Schwarz-model selection criterion is $\ln(L_i) - k_i \ln(297)/2$. Let $\hat{F}_{fc}$ be the predicted value of F_{fc}. The "endowment paradox" is the correlation between per capita GDP, y_c, and the number of times $\hat{F}_{fc}$ is positive for country c (see Fig. 2). "Missing trade" is the variance of F_{fc} divided by the variance of $\hat{F}_{fc}$ (see Fig. 1). "Weighted sign" is the weighted proportion of observations for which F_{fc} and $\hat{F}_{fc}$ have the same sign. Finally, $\rho(F, \hat{F})$ is the correlation between F_{fc} and $\hat{F}_{fc}$. See Section V for further discussion.

Gabaix (unpublished, 1997)

- "Missing trade" of Trefler (1995) influenced later empirical work on net factor content of trade considerably
- Ironically, Gabaix (1997) shows that "missing trade" makes the impressive fit of π_f^c in Figure 1 of Trefler (1993) less impressive
- If trade is entirely missing, $T_f^c = 0$, then Trefler (1993) finds π_f^c such that $\pi_f^c V_f^c = s^c \sum_{c'} \pi_f^{c'} V_f^{c'}$
- If countries are small, this is basically

$$\frac{\pi_f^c}{\pi_f^{c'}} = \frac{Y^c / V_f^c}{Y^{c'} / V_f^{c'}}$$

relative productivity is relative GDP per factor, so Trefler (1993) fit is unsurprising

Davis and Weinstein (2001)

- Davis, Weinstein, Bradford and Shimpo (1997) found that FCT of trade did reasonably well within Japan, where we may believe FPE is more likely to hold
- Davis and Weinstein (2001) seek to understand departures from FPE within the OECD
- Prior studies have always applied $\bar{B}(\omega)$ from one country to all others; we don't simply want each country's $\bar{B}^c(\omega)$, since that would make the production side of HOV an identity
- Davis and Weinstein (2001) try to parsimoniously parameterize the cross-country differences in $\bar{B}^c(\omega)$ by considering seven nested hypotheses that sequentially drop standard HO assumptions about how endowments affect both *technology* $\bar{B}^c(\cdot)$ and *technique* $\bar{B}^c(\omega)$.

Davis and Weinstein (2001)

They need to relax a good bit:

> *"a model that allows for technical differences, a breakdown of factor price equalization, the existence of nontraded goods, and costs of trade, is consistent with data for ten OECD countries and a rest-of-world aggregate"*

Hypthoses where "P" denotes production specification and "T" denotes trade specification

- Let $\mathbf{B}^c$ denote the total factor input matrix
- $\mathbf{V}^c$ is the endowment vector
- $\mathbf{Y}^c$ is the net output vector

Assume common technology, free trade, and identical homothetic preferences $\Rightarrow$ standard HOV theorem

- P1: $\mathbf{B}^{\mathrm{US}}\mathbf{Y}^c = \mathbf{V}^c$
- T1: $\mathbf{B}^{\mathrm{US}}\mathbf{T}^c = \mathbf{V}^c - s^c\mathbf{V}^{\mathrm{world}}$

Davis and Weinstein (2001) hypotheses

Common technology matrix measured with error: $\ln \mathbf{B}^c = \ln \mathbf{B}^\mu + \epsilon^c$

- P2: $\mathbf{B}^\mu \mathbf{Y}^c = \mathbf{V}^c$
- T2: $\mathbf{B}^\mu \mathbf{T}^c = \mathbf{V}^c - s^c \mathbf{V}^{\text{world}}$

Hicks-neutral technical differences: $\mathbf{V}^{cE} = \mathbf{V}^c / \lambda^c$

- P3: $\mathbf{B}^\lambda \mathbf{Y}^c = \mathbf{V}^{cE}$
- T3: $\mathbf{B}^\lambda \mathbf{T}^c = \mathbf{V}^{cE} - s^c \mathbf{V}^{\text{world}E}$

Heterogeneous techniques for traded goods, a la DFS (1980) $\Rightarrow P4, T4$

Violate FPE $\Rightarrow$ heterogeneous techniques for non-traded goods
$\Rightarrow P5, T5$

Trade costs $\Rightarrow P6, T6$

I'm surely out of time, please look at the paper.

Next week

- Increasing returns and home-market effects
- Print Krugman (1980) and bring to class