Lecture 5: Empirics of the Heckscher-Ohlin Model

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Outline of Lecture 5

1. The Leontief paradox
2. Tests of HOV
3. Allowing for Technological Differences and Intermediates

Suggested further reading: Daniel Bernhofen (2010), "The Empirics of General Equilibrium Trade Theory: What Have We Learned?," CESifo Working Paper 3242

The Leontief Paradox

- HOV predicts that exports are intensive in abundant factors.
- Leontief (1953) builds input-output matrices to compare industries' K and L intensities, assuming US technology for imports.
- He finds a higher K/L ratio in US *imports* ($18,200/worker) than in US exports ($13,700) in 1947.
- But this does not violate HOV when the country has a trade surplus!

Leamer's resolution of the Leontief paradox

- Relaxing trade balance, Leamer (1980) shows that under HOV a K-abundant country may export *both* K and L services.
- This was the case in the US in 1947 with a large trade surplus.
- But Leamer's corollary of HOV

$$\frac{K}{L} > \frac{K^w}{L^w} \Rightarrow \underbrace{\frac{K}{L}}_{\text{factor content of production}} > \underbrace{\frac{K - F_K}{L - F_L}}_{\text{factor content of consumption}}$$

does not depend on trade balance.

- Results are consistent with the US being K-abundant under HOV.

	Production	**Consumption**
Capital ($ billion)	$327	$305
Labor (person-years)	47 million	45 million
Capital/Labor ($/person)	$6,949	$6,737

Partial Tests of HOV

- Leamer (1984):
  - regression of net exports T^c on endowments (11 goods, 11 factors) following $T^c = A^{-1}(V_v^c - s^c V_v^w)$
  - results are consistent with HOV
    - increases in capital and unskilled labor favor manufacturing exports.
    - increases in land favor agriculture over manufacturing.
    - increases in skilled labor favor non-traded services over manufacturing.
- Harrigan (1995): estimates Rybczynski effects on OECD panel data on *output*, with similar results. But low R^2 and large country FE's suggest technological differences matter.

A Complete Test: Bowen, Leamer and Sveikauskas (1987)

- BLS (1987) test the HOV theorem using data on endowments, trade *and* productivity in 27 countries in 1967.
- They perform two tests:
  - a sign test: $sign(F_v^c) = sign(V_v^c - s^c V_v^w), \forall c, v$
  - a rank test: $F_v > F_{v'} \Leftrightarrow V_v^c - s^c V_v^w > V_{v'}^c - s^c V_{v'}^w$
- The sign test is satisfied in only 61% of the $\{c, v\}$ pairs, the rank test in only 49% of the cases!
- This result killed off interest in HOV empirics for several years!

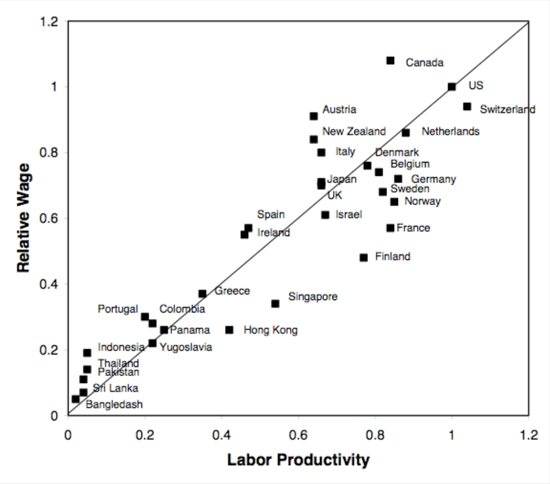
Technological Differences: Trefler (1993, 1995)

- Leontief blamed the identical technology assumption for his 'paradox'.
- Trefler (1993) offers a variant of HOV in *efficiency units* of factors:

$$F_v^c = V_v^{*c} - s^c \sum_{c=1}^{C} V_v^{*c} \equiv \pi_v^c V_v^c - s^c \sum_{c=1}^{C} \pi_v^c V_v^c, \forall c, v$$

  where the $\pi_v^c > 0$ capture productivity differences.
- Trefler solves for the π's using data on trade, technology and endowments.
- The BLS sign and rank tests hold trivially, but the π's are positive and highly correlated with factor prices differences across countries.

Trefler (1993) Estimates of Productivity Differences



'Adjusted FPE': there is a cross-country correlation of 0.9 between factor prices and productivity estimates π_v^c (both measured relative to the US).

The 'Case of the Missing Trade': Trefler (1995)

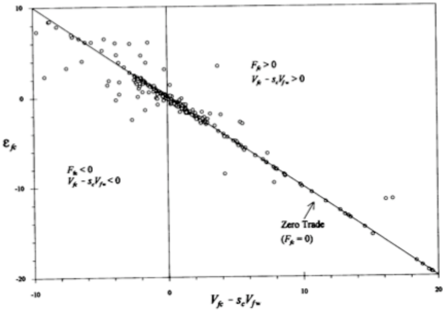


FIGURE 1. PLOT OF $\varepsilon_{fc} = F_{fc} - (V_{fc} - s_c V_{fw})$ AGAINST $V_{fc} - s_c V_{fw}$

- The figure plots the HOV predictor of F_v^c against the prediction error $\varepsilon_{cv} = F_v^c - (V_v^c - s^c V_v^w)$.
- Under HOV ε_{cv} should have mean zero. In fact F_v^c seems to have mean zero: endowments explain only 3.2% of the net factor content.
- The *trade in factor services* predicted by HOV is missing!

The 'Case of the Missing Trade': Trefler (1995)

- Like BLS, Trefler (1995) tests various extended HOV models.
  - (T1) Hicks-neutral technological differences $\pi_v^c = \delta^c$ in

$$F^c = \pi_v^c V^c - s^c(\sum_{k=1}^{C} \pi_v^k V^k)$$

  - (T2) Non-neutral technological differences $\pi_v^c = \delta^c \phi_v$
  - (C1) Non-homotheticity. Estimate consumption shares β^c to fit the data.

$$F^c = V^c - \beta^c(\sum_{k=1}^{C} V^k)$$

  - (C2) Home bias. Estimate the fixed share of imports in consumption.

$$F^c = V^c - s^c\left(\sum_{k=1}^{C}(1-\alpha^c)\frac{Y^w}{Y^k}V^k + \alpha V^w\right)$$

- Model selection is based on sign and correlation tests and likelihood.

The 'Case of the Missing Trade': Trefler (1995)

Table I—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.

- Variant TC_2 (T_2 and C_2) works best.

Technological Differences: Davis and Weinstein (2001)

- Davis and Weinstein (2001) test a version of DFS (1980) i.e. HOV when $N > V$ and FPE fails.
- The model predicts that a_{vi}'s depend on endowments and that *all* exports are intensive in the abundant factor.
- They *estimate* the A matrix using OECD data on factor use:

$$\ln a_{vi}^c = \alpha^c + \beta_{vi} + \gamma_v \left(\frac{K^c}{L^c}\right) + \zeta_v Trad_i * \left(\frac{K^c}{L^c}\right) + \epsilon_{iv}^c \qquad \text{(DW)}$$

- This yields 'measured' factor contents of production and net trade:

$$\hat{A}^c Y^c = V^c \qquad \text{(FE)}$$

$$\hat{A}^c T^c = V^c - s^c V^w \qquad \text{(HOV)}$$

- 7 versions of (DW) are compared using sign tests and regressions of measured factor content on predicted factor content (see next slide).

Table 2—Key Specifications

	Key assumption	Production specifications		Trade specifications
(P1)	Conventional HOV with U.S. technology	$\mathbf{B}^{US}\mathbf{Y}^c = \mathbf{V}^c$	(T1)	$\mathbf{B}^{US}\mathbf{T}^c = \mathbf{B}^{US}(\mathbf{Y}^c - \mathbf{D}^c) = \mathbf{V}^c - s^c\mathbf{V}^W$
(P2)	Average technology matrix	$\hat{\mathbf{B}}^{\mu}\mathbf{Y}^c = \mathbf{V}^c$	(T2)	$\hat{\mathbf{B}}^{\mu}\mathbf{T}^c = \mathbf{V}^c - s^c\mathbf{V}^W$
(P3)	Hicks-neutral efficiency adjustment	$\hat{\mathbf{B}}^{\lambda}\mathbf{Y}^c = \mathbf{V}^{cE}$	(T3)	$\hat{\mathbf{B}}^{\lambda}\mathbf{T}^c = \mathbf{V}^{cE} - s^c\mathbf{V}^{WE}$
(P4)	Continuum model: Different input ratios in traded goods and H-N efficiency	$\hat{\mathbf{B}}^{cDFS}\mathbf{Y}^c = \mathbf{V}^c$	(T4)	$\hat{\mathbf{B}}^{cDFS}\mathbf{Y}^c - [\hat{\mathbf{B}}^{cDFS}\mathbf{D}^{cc} + \Sigma_{c' \neq c}\hat{\mathbf{B}}^{c'DFS}\mathbf{M}^{cc'}] = \mathbf{V}^c - s^c\mathbf{V}^W$
(P5)	Helpman no-FPE model, different input ratios in all, H-NE	$\hat{\mathbf{B}}^{cH}\mathbf{Y}^c = \mathbf{V}^c$	(T5)	$\hat{\mathbf{B}}^{cH}\mathbf{Y}^{cT} - [\hat{\mathbf{B}}^{cH}\mathbf{D}^{ccT} + \Sigma_{c' \neq c}\hat{\mathbf{B}}^{c'H}\mathbf{M}^{cc'}] = [\mathbf{V}^c - s^c\mathbf{V}^W] - [\mathbf{V}^{cN} - s^c\mathbf{V}^{WN}]$
	Forces ROW production model to work		(T6)	As above
	Adds gravity-based demand determination		(T7)	$\hat{\mathbf{B}}^{cH}\mathbf{Y}^c - [\hat{\mathbf{B}}^{cH}\mathbf{D}^{cc} + \Sigma_{c' \neq c}\hat{\mathbf{B}}^{c'H}\mathbf{M}^{cc'}] = \mathbf{V}^c - [\hat{\mathbf{B}}^{cH}\hat{\mathbf{D}}^{cc} + \Sigma_{c' \neq c}\hat{\mathbf{B}}^{c'H}\hat{\mathbf{M}}^{cc'}]$

Note: Hats (ˆ) indicate fitted values from estimation of technology and absorption.

Table 3—Production and Trade Tests
All Factors

Production tests: Dependent variable MFCP

	(P1)	(P2)	(P3)	(P4)	(P5)
Predicted	0.24	0.33	0.89	0.89	0.97
Standard error	0.09	0.11	0.06	0.05	0.01
R^2	0.27	0.29	0.92	0.94	1.00
Median error	0.34	0.21	0.07	0.05	0.03
Observations	20	22	22	22	22

Trade tests: Dependent variable MFCT

	(T1)	(T2)	(T3)	(T4)	(T5)	(T6)	(T7)
Predicted	−0.002	−0.006	−0.05	0.17	0.43	0.59	0.82
Standard error	0.005	0.003	0.02	0.02	0.02	0.04	0.03
R^2	0.01	0.14	0.31	0.77	0.96	0.92	0.98
Sign test	0.32	0.45	0.50	0.86	0.86	0.82	0.91
Variance ratio	0.0005	0.0003	0.008	0.07	0.19	0.38	0.69
Observations	22	22	22	22	22	22	22

Notes: The theoretical coefficient on "predicted" is unity. The theoretical value of the sign test is unity (100-percent correct matches). The variance ratio is Var(MFCT)/Var(PFCT) and has a theoretical value of unity.

- Relative to P3 (Trefler), P4 (nonFPE) fits the factor content of *production* equally well, but fits the factor content of *trade* better.
- Trade costs and nontradables are also important.

Intermediates: Trefler and Zhu (2010)

- HOV theory has no intermediates.
- Empirical applications assume nontradable intermediates. HOV still holds with $F = A(I - B)^{-1}T$, where B is the input-output matrix.
- Trefler and Zhu (2010) show that the HOV formula holds with factor contents that include domestic and foreign input use.
- This model performs much better than standard HOV (sign tests, correlation...), but a few sectors have large deviations.
- Missing trade in these sectors vanishes when accounting for nontradables and nonhomothetic preferences.

Conclusions

- Without relaxing major assumptions, HO performs poorly empirically.
- We have identified missing features: productivity differences, trade costs, specialization, intermediates, product differentiation.
- Recent research directions reflect this:
  - multi-cone model with specialization in goods or varieties of varying quality (Schott 2003)
  - factor content of bilateral trade flows and factor price differences (Choi and Krishna 2004)
  - hybrid HO model with monopolistic competition and trade costs (Romalis 2004)
  - HO models of trade in tasks (see lecture on fragmentation)

Appendix: Summary of Empirical Tests of HOV

	Data used:			Method:
Authors:	Trade	Tech-nology	Factor endowments	
Leontief (1953)	yes	U.S.	no	Compared (K/L) ratio of exports and imports
Leamer (1980)	yes	U.S.	no	Compared (K/L) ratio in production and consumption
Baldwin (1971)	yes	U.S.	no	$\underbrace{T^i}_{\text{data}} = \underbrace{A'}_{\text{data}}(V^i - s^i V^w)$
Leamer (1984)	yes	no	yes	$\underbrace{T^i}_{\text{data}} = A^{-1}\underbrace{(V^i - s^i V^w)}_{\text{data}}$
Bowen, Leamer & Sveikaukas (1987)	yes	U.S.	yes	Sign test and rank test
Trefler (1993)	yes	U.S.	yes	Allow for productivity parameters π_k^i
Trefler (1995)	yes	U.S.	yes	Allow for productivity parameters δ^i (and more)
Davis and Weinstein (2001a)	yes	Many countries	yes	Estimate A^i from data

Figure: From Feenstra (2004), chap. 2.