International Trade: Lecture 4

Empirical Studies of the Trade Pattern

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Empirical Studies of Competitive Trade Theory: Overview

How would we wish to test predictions of a theory of trade?

- Ideally, have grand "maintained hypothesis" with some particular hypothesis H_0 tested against a wider alternative H_1 (For example, do scale economies contribute to an explanation of trade beyond what is explained by factor endowment differences?)

In practice, several difficulties in carrying out this program.

- Until relatively recently, "tests of HOV" could be subject to several criticisms.
- Over time, a lot of progress has been made.

Overview of Empirical Studies (cont'd)

Issues to keep in mind:

- Predictions of theory may be too sharp (e.g., full specialization or full FPE) or too fuzzy (e.g., signs of correlations).
- Empirical studies then may "test" something that is not a rigorous implication of theory.
- Typically H_0 is a joint hypothesis, with the point at issue only one component (e.g., factor endowment theory has clear testable predictions in conjunction with FPE and identical homothetic tastes)
- Different theories can yield the same observable predictions
- Often H_1 is not specified at all. Instead, we have estimation of the model and some vague judgment about goodness of fit.

Leontief Paradox

Leontief (1953) sought to examine the predictions of the HO Theorem empirically.

- Compare the amount of capital and labor embodied in US exports and imports with US factor abundance

Leontief's Proposition:

$$\text{If } \frac{K_{US}}{L_{US}} > \frac{K_W}{L_W},$$

$$\text{Expect } \frac{a_K(\omega)x}{a_L(\omega)x} > \frac{a_K(\omega)m}{a_L(\omega)m},$$

where $a_\ell(\omega)$ is 1 x n vector of unit input requirements for factor ℓ, x is an n x 1 vector of exports, and m is an n x 1 vector of imports.

Leontief Paradox (cont'd)

- In 1947, US exports less capital intensive than US imports
- See Table 1 for a similar result in 1962

Table 1: Factor Content of US Exports and Imports for 1962

	Imports	Exports
Capital per million \$	2,132,000	1,876,000
Labor (person-years) per million \$	119	131
Capital-labor ratio (\$ per worker)	17,916	14,321
Average years of education per worker	9.9	10.1
Proportion of engineers and scientists in workforce	0.0189	0.0255

Source: Baldwin (1971)

Leontief's Solution

- Problem of mismeasurement of labor
  - If US labor is more productive than labor in the rest of the world, the effective labor force is greater than the actual labor force in the US
  - Taking account of these factor augmenting productivity differences might make the US labor abundant
- Define π^{W} as the (appropriately weighted) productivity of workers in the ROW relative to the productivity of US workers ($\pi^{US} = 1$)
- We observe $\frac{K^{US}}{L^{US}} > \frac{K^{W}}{L^{W}}$.
- It may be that $\frac{K^{US}}{L^{US}} < \frac{K^{W}}{\pi^{W} L^{W}}$, where $0 < \pi^{W} < 1$.
- Return to consider this idea formally below.
- Related literature emphasizes the omission of information on other factor endowments (e.g., human capital).

Leamer (1980)'s Solution

- Even if HO model is true, capital and labor embodied in US exports and imports should not be compared in the way Leontief did. Recall the HOV prediction:

$$t^j_V = s^j V^W - V^j \tag{1}$$

$$t^j_K = s^j K^W - K^j \tag{2}$$

$$t^j_L = s^j L^W - L^j. \tag{3}$$

- If country j is capital abundant, so that $\frac{K^j}{K^W} > \frac{L^j}{L^W}$, (2) and (3) imply:

$$\frac{K^j}{L^j} > \frac{K^j + t^j_K}{L^j + t^j_L} \tag{4}$$

- K/L ratio embodied in production in country j should be greater than the K/L ratio embodied in consumption.

Leamer (1980)'s Solution (cont'd)

- In fact, Leontief's data satisfy the inequality in equation (4)!

$$\frac{K^{US}}{K^{W}} > \frac{L^{US}}{L^{W}} \text{ and } \frac{K^{US}}{L^{US}} > \frac{K^{US} + t_K^{US}}{L^{US} + t_L^{US}}$$

- The Leontief Paradox is not a Paradox!
- Leontief's test was misleading because he took the 2x2 intuition to the data without taking into account that it may not hold with many goods and factors
- With n goods and m factors, the relevant theoretical prediction is the HOV result
- Example of the potential importance of estimating theory-based empirical relationships

Predictions for Net Trade in Factor Services

- Derive again the HOV prediction for net trade in factor services
- Allow for trade imbalance
- Index countries by $j \in \{1, \ldots, J\}$, goods by $i \in \{1, \ldots, n\}$, and factors by $\ell \in \{1, \ldots, m\}$
- An economy j's vector of net exports is defined by:

$$e^j \equiv y^j - c^j \tag{5}$$

- Premultiply net exports, e^j, by a country's unit factor input requirement matrix, $A(\omega^j)$, obtain the following expression for the country's net trade in factor services:

$$f^j \equiv A^j e^j = A^j y^j - A^j c^j \tag{6}$$

Predictions for Net Trade in Factor Services (cont'd)

- Full employment of country j resources:

$$A^j y^j = V^j. \tag{7}$$

- Identical and homothetic preferences imply consumer demand in country j is proportional to the world consumer demand vector c^W:

$$c^j = s^j c^W, \tag{8}$$

  where s^j (a scalar) is country j's share of world expenditure

- World market clearing implies vector of world consumer demand equals the vector of world output, $c^W = y^W$. Hence,

$$c^j = s^j y^W. \tag{9}$$

Predictions for Net Trade in Factor Services (cont'd)

- Substituting into the above, we obtain the following expression for net trade in factor services:

$$f^j = A^j t^j = V^j - s^j A^j y^W. \tag{10}$$

- Assume **factor price equalization**.
- With common production technologies, all countries have the same equilibrium unit factor input requirements, $A^j(\omega) = A(\omega)$ for all j

$$A^j y^W = \sum_{j=1}^{J} A y^j = \sum_{j=1}^{J} V^j = V^W. \tag{11}$$

- Solve for a country's share of world expenditure, s^j.
- Premultiply (5) ($e^j = y^j - c^j$) by the vector p^j of world goods prices and use ($c^j = s^j c^W$) to substitute for c^j:

$$(p^j)' e^j = (p^j)' y^j - (p^j)' s^j c^W. \tag{12}$$

Predictions for Net Trade in Factor Services (cont'd)

- Rearranging (12) (noting that s^j is a scalar):

$$s^j = \frac{(p^j)'y^j - (p^j)'e^j}{(p^j)'c^W} \tag{13}$$

$$\Rightarrow \quad s^j = \alpha^j - \lambda^j, \tag{14}$$

where $\alpha^j = \frac{Y^j}{Y^W}$ (a scalar) is the ratio of j's income (GDP) to world income (expenditure) and $\lambda^j = \frac{b^j}{Y^W}$ (a scalar) is the ratio of j's net trade imbalance to world income (expenditure).

- Substituting equations (11) and (14) into the expression for net trade in factor services in (10), we obtain the HOV equations:

$$f^j = V^j - (\alpha^j - \lambda^j)V^W. \tag{15}$$

- LHS is measured factor content of net trade; RHS is predicted factor content of net trade.

Predictions for Net Trade in Factor Services (cont'd)

$$\begin{pmatrix} f_1^j \\ f_2^j \\ \vdots \\ f_m^j \end{pmatrix} = \begin{pmatrix} V_1^j \\ V_2^j \\ \vdots \\ V_m^j \end{pmatrix} - (\alpha^j - \lambda^j) \begin{pmatrix} V_1^W \\ V_2^W \\ \vdots \\ V_m^W \end{pmatrix}$$

- HOV equations relate a country's **net trade in services of an individual factor** to the country's **excess supply of that factor**.
  - Yield predictions for patterns of net trade in the services of individual factors.
- Straightforward to generalize the analysis to allow (see Davis and Weinstein 2003):
  - Non-traded goods;
  - Intermediate inputs.

Bowen et al. (1987)

- The above analysis emphasizes that a full test of the HOV model requires three sets of data:
  1. Trade flows at sectoral level;
  2. Countries' factor endowments;
  3. Factor intensities at sectoral level.
- Bowen *et al.* (1987) was the first paper to successfully integrate all three sets of data in an explicit test of the HOV model.

Early Rejections of the HOV Model

- Stack HOV equations for all countries to yield matrices with the following elements:

$$\underbrace{f_\ell^j}_{m \times J} = \underbrace{V_\ell^j}_{m \times J} - \underbrace{(\alpha^j - \lambda^j)V_\ell^W}_{m \times J}. \tag{16}$$

- Can analyze the model's predictions
  - Across countries for a particular factor (across columns for a row);
  - Across factors for a particular country (across rows for a column).
- Bowen *et al.* (1987) undertake two types of tests of the HOV model's predictions:
  - Qualitative tests;
  - Regression analyses of the HOV equations.

Qualitative Tests: Sign Proposition

- Define trade imbalance-adjusted net factor content of trade, $\tilde{f}^j_\ell = f^j_\ell - \lambda^j V^W_\ell$.
- From HOV equations (16), obtain prediction:

$$\mathrm{Sign}(f^j_\ell - \lambda^j V^W_\ell) = \mathrm{Sign}(V^j_\ell - \alpha^j V^W_\ell).$$

- Examine empirically using data on 27 countries and 12 factors of production in 1967.
- Table 2 reports factor-by-factor the proportion of correct matches in sign. Sometimes little higher than 50%.
- Table 3 presents country-by-country results. The proportion of correct sign matches is generally higher than for factor-by-factor analysis. However, the proportion is below 50% for some countries.

Qualitative Tests: Rank Proposition

- HOV equations (16) also imply:

$$\text{Rank}(f^j_\ell - \lambda^j V^W_\ell) = \text{Rank}(V^j_\ell - \alpha^j V^W_\ell)$$

- Compute the proportion of correct pairwise rankings among two factors of production ℓ and k (Table 2) and any two countries j and j′ (Table 3)
- Proportion of correct rankings in factor-by-factor analysis is often below 50% (Table 2). Proportion in the country-by-country analysis is again higher (Table 3), although remains below 50% for some countries.

Qualitative Tests: Results

TABLE 2—SIGN AND RANK TESTS, FACTOR BY FACTOR

Factor	Sign Test[a]	Rank Tests[b]	
Capital	.52	0.140	.45
Labor	.67	0.185	.46
Prof/Tech	.78	0.123	.33
Managerial	.22	−0.254	.34
Clerical	.59	0.134	.48
Sales	.67	0.225	.47
Service	.67	0.282[c]	.44
Agricultural	.63	0.202	.47
Production	.70	0.345[c]	.48
Arable	.70	0.561[c]	.73
Pasture	.52	0.197	.61
Forest	.70	0.356[c]	.65

[a] Proportion of 27 countries for which the sign of net trade in factor matched the sign of the corresponding factor abundance.

[b] The first column is the Kendall rank correlation among 27 countries; the second column is the proportion of correct rankings out of 351 possible pairwise comparisons.

[c] Statistically significant at 5 percent level.

TABLE 3—SIGN AND RANK TESTS, COUNTRY BY COUNTRY

Country	Sign Tests[a]	Rank Tests[b]	
Argentina	.33	0.164	.58
Australia	.33	−0.127	.44
Austria	.67	0.091	.56
Belgium-Luxembourg	.50	0.273	.64
Brazil	.17	0.673[c]	.86
Canada	.75	0.236	.64
Denmark	.42	−0.418	.29
Finland	.67	0.164	.60
France	.25	0.418	.71
Germany	.67	0.527[c]	.76
Greece	.92	0.564[c]	.80
Hong Kong	1.00	0.745[c]	.89
Ireland	.92	0.491[c]	.76
Italy	.58	0.345	.69
Japan	.67	0.382	.71
Korea	.75	0.345	.69
Mexico	.92	0.673[c]	.86
Netherlands	.58	−0.236	.38
Norway	.25	−0.236	.38
Philippines	.50	0.527[c]	.78
Portugal	.67	0.091	.56
Spain	.67	0.200	.62
Sweden	.42	0.200	.62
Switzerland	.67	0.382	.69
United Kingdom	.92	0.527[c]	.78
United States	.58	0.309	.67
Yugoslavia	.83	−0.055	.49

[a] Proportion of 12 factors for which the sign of net trade in factor matched the sign of the corresponding excess supply of factor.

[b] The first column is the Kendall rank correlation among 11 factors (total labor excluded); the second column is the proportion of correct rankings out of 55 possible pairwise comparisons.

[c] Statistically significant at the 5 percent level.

Problems with Testing Qualitative Hypotheses

- What is the alternative hypothesis against which the HOV model is being tested?
- What is the appropriate level of statistical significance in testing these propositions?
- In practice, HOV equations are not equalities.

  How should we assess the degree of departure from the model's predictions?

Regression Analyses of HOV Equations

- Test the null hypothesis of HOV against a well-defined alternative hypothesis.
- Consider the example of neutral technology differences:

  $A(\omega)$ differs by a proportional country-specific constant

$$\delta^j A^j = A^R, \quad \delta^R = 1, \tag{17}$$

  where R denotes the reference country (typically the US) and δ_j is a positive scalar.
- Under the alternative of neutral technology differences, predicted factor content of net trade:

$$f^{j,US} \equiv A^{US} t^j = \delta^j V^j - s^j \sum_{u=1}^{J} \delta^u V^u, \tag{18}$$

  where $f^{j,R}$ is the factor content of trade for country j computed using the US input matrix.
- Given data on $f^{j,US}$, V^j, α^j, and λ^j for countries j in a particular year, we can estimate the δ^j.
  - Test null HOV hypothesis of identical technologies under HOV ($\delta^j = 1$ for all j);
  - Against alternative hypothesis of neutral technology differences ($\delta^j \neq 1$ for some j).

Regression Analyses of HOV Equations (cont'd)

- Bowen *et al.* (1987) consider three sets of alternative hypotheses:
  - Relax identical and homothetic preferences by considering linear Engel curves
  - Allow for measurement error in net trade, country endowments, and in world endowments (incomplete country coverage)
  - Neutral technology differences
- Find empirical evidence supports:
  - Measurement error in net trade and country endowments
  - Neutral technology differences

Regression Analyses of HOV Equations (cont'd)

- But, the form of the estimated technology differences is implausible, implying negative output for some countries!
- "The Heckscher-Ohlin Model does poorly, but we do not have anything that does better. It is easy to find hypotheses that do as well or better in a statistical sense, but these alternatives yield economically unsatisfying parameter values" (Bowen *et al.* 1987)

Trefler (1993): Was Leontief Right After All?

- Take Leontief's suggestion of international factor augmenting productivity differences seriously.
- Under the **null hypothesis** of the HOV model, technology is identical across countries.
    - Factor prices are equalized
    - The factor content of net trade is as predicted by the HOV equations (16): for $j, u = 1, \ldots, J$ and $\ell = 1, \ldots, m$,

$$f_\ell^j = V_l^j - s^j V_l^W \tag{19}$$

$$\omega_\ell^j = \omega_\ell^u. \tag{20}$$

- Existing empirical literature shows that the predictions of (19) and (20) are strongly rejected by the data.

Trefler (1993): Was Leontief Right After All? (cont'd)

Trefler (1993): **alternative hypothesis** of factor augmenting productivity differences.

- Factor prices per efficiency unit (productivity adjusted factor prices) are equalized: *Conditional FPE*.
- The factor content of net trade is as predicted below: for $j, u = 1, \ldots, J$ and $\ell = 1, \ldots, m$,

$$f_\ell^j = \pi_\ell^j V_l^j - s^j \sum_{u=1}^{J} \pi_\ell^u V_l^u \tag{21}$$

$$\frac{\omega_\ell^j}{\pi_\ell^j} = \frac{\omega_\ell^u}{\pi_\ell^u} \tag{22}$$

- Factor augmenting productivity differences imply that there exist production functions ϕ_i independent of country j such that:

$$\phi_i^j \left(V_{1i}^j, \ldots, V_{mi}^j \right) = \phi_i \left(\pi_1^j V_{1i}^j, \ldots, \pi_m^j V_{mi}^j \right)$$

Methodology

- Choose US as base country ($\pi_\ell^{\mathsf{US}} = 1, \forall\, \ell$): Use US matrix of unit factor input requirements, A^{US}.
- Calibrate model by choosing $\mathsf{m} \times \mathsf{J}$ values for $\pi_{\mathsf{j}\ell}$ such that equation (21) holds exactly: Measured equals predicted factor content of net trade
- Examine whether implied values for $\pi_{\mathsf{j}\ell}$ are consistent with observed factor prices in equations (22).
  - Correlate $\frac{\pi_\ell^{\mathsf{US}}}{\pi_\ell^{\mathsf{j}}}$ and $\frac{\omega_\ell^{\mathsf{US}}}{\omega_\ell^{\mathsf{j}}}$ where have actual factor price data (labor and capital).
  - Examine "reasonableness" of π_ℓ^{j} according to a number of criteria (e.g., non-negative values).

Trefler (1993)'s Conclusion

- "There is a simple modification of the HOV model that explains most of the factor content of trade and the cross-country variation in factor prices."
- Major contribution to the literature embodied deep insights about the role of technology differences.
- Now thought to be problematic for reasons discussed below (see in particular Davis and Weinstein 2003).

Trefler (1995)

- A key contribution of Trefler (1995) was to demonstrate that net trade in factor services departs from the HOV predictions in *systematic and informative* ways:
- **The Case of the Missing Trade:** in absolute values, factor service trade is much smaller than its factor-endowments based prediction.
  - Compute HOV's model's prediction error:

$$\varepsilon_\ell^j = f_\ell^j - (V_\ell^j - s^j V_\ell^W).$$

  - Graph ε_ℓ^j against the prediction $(V_\ell^j - s^j V_\ell^W)$ in Figure 1.
    - Under the null of the HOV model, observations should be clustered around the horizontal 0 line.
    - However, observations are instead clustered around the line $\varepsilon_\ell^j = -(V_\ell^j - s^j V_\ell^W)$ or $f_\ell^j = 0$.
    - The measured net factor content of trade is close to 0!

Trefler (1995) (cont'd)

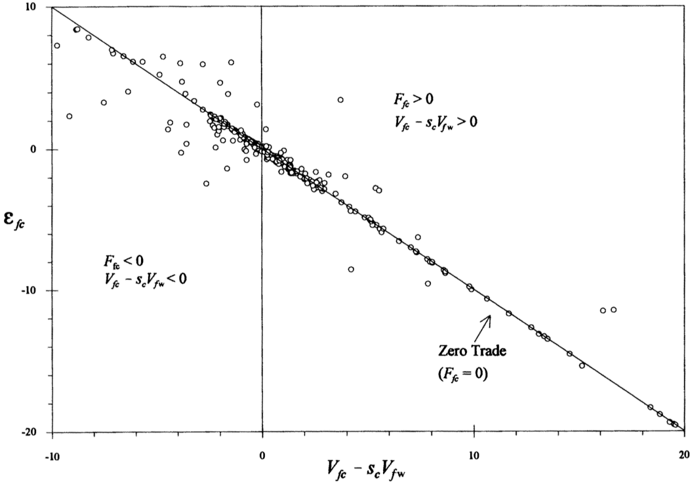

FIGURE 1. PLOT OF $\varepsilon_{fc} = F_{fc} - (V_{fc} - s_c V_{fw})$ AGAINST $V_{fc} - s_c V_{fw}$

Trefler (1995) (cont'd)

- **Note:** this provides a potential explanation why the calibrated factor augmenting productivity differences in Trefler (1993) are so highly correlated with observed factor prices.
  - See Davis and Weinstein (2003).
- **The Endowments Paradox:** rich countries tend to be scarce in most factors and poor countries abundant in most factors.
  - In the HOV model, a country j is abundant in factor ℓ if

$$V_{\ell}^{j} > (\alpha^{j} - \lambda^{j}) V_{\ell}^{W}.$$

  - Graph the number of abundant factors across countries in Figure 2:
    - Rich countries tend to be scarce in most factors;
    - Poor countries tend to be abundant in most factors;
    - Not explained by rich countries running trade deficits ($\lambda^{j} < 0$) and poor countries trade surpluses ($\lambda^{j} > 0$).

Trefler (1995) (cont'd)

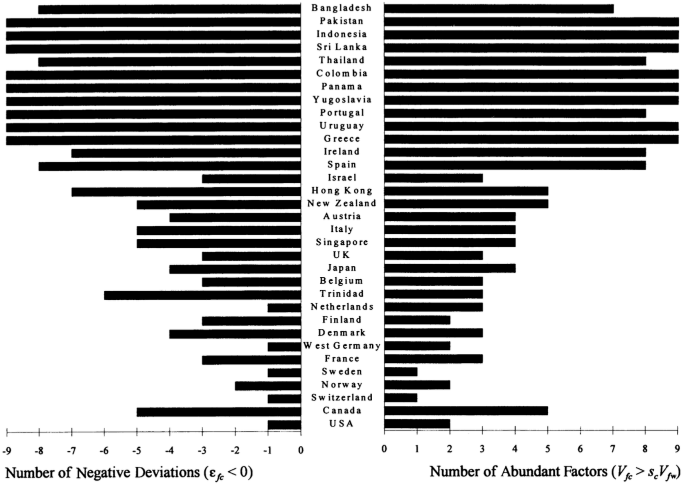

FIGURE 2. DEVIATIONS FROM HOV AND FACTOR ABUNDANCE

Trefler (1995) (cont'd)

- A plausible alternative hypothesis to HOV should be able to explain these systematic patterns in the data.
  - Technology differences may explain why rich countries are scarce in most factors.
- Trefler (1995) also undertakes a regression analysis of the HOV equations.
- Tests the null hypothesis of the HOV model (equation (16)) against the alternatives of:
  - Neutral technology differences;
  - Modify consumer preferences to allow investment, services, and nontraded goods;
  - Modify consumer preferences to introduce Armington Home Bias.

Trefler (1995) (cont'd)

- **Find:** Models that contribute little to explaining observed trade patterns include: those with linear expenditure demand, capital accumulation, nontradeables, and trade in services.
- **Find:** The model that performed best combines home bias in preferences with neutral international technology differences.
- **Claim:** Provides the first rejection of the HOV hypothesis in favor of a satisfying, economically meaningful alternative.

Closing the Gap Between Theory & Data

- Trefler (1995) subsequently criticized by Davis *et al.* (1997) and Davis and Weinstein (2001).
- Main themes of this subsequent work:
  - Examine predictions of the HOV model for production and absorption separately.
  - Begin with a strict HOV model and relax assumptions one at a time.
  - Develop an approach that allows one to make HOV predictions when only a subset of the world shares FPE.
  - Careful attention to data construction to ensure, for example, that identities hold in the data!

International and Japanese Regional Data

- Davis *et al.* (1997) combine international and Japanese regional data.
  - Data on 35 developed and developing countries; Implement tests below for 21 countries excluding Japan.
  - Data on 10 Japanese regions (e.g., Hokaido and Kyushu).
- Consider data on production, absorption, and net trade in factor services: Compare measured with predicted values.
- Test **HOV production theory** (J = Japan):
  - Compare predicted and measured factor endowments.
  - FPE-world

$$A^J y^k = V^k, \forall k \in W.$$

  - FPE-Japan

$$A^J y^r = V^r, \forall r \in J.$$

International and Japanese Regional Data (cont'd)

- Test **HOV absorption theory**:
  - Compare predicted and measured consumption.
  - IHP-world

$$c^k = s^k Y^W, \forall k \in W.$$

  - IHP-Japan

$$c^r = \left(\frac{s^r}{s^J}\right) c^J, \forall r \in J.$$

International and Japanese Regional Data (cont'd)

- Test HOV predictions for net trade in factor services for Japanese regions only.
    - Compared predicted and measured net trade in factor services.
    - IHP-world, FPE-world (HOV equations)

$$A^J e^r = V^r - s^r V^W.$$

- IHP-Japan, FPE-Japan

$$A^J e^r = V^r - \left(\frac{s^r}{s^J}\right) A^J c^J.$$

International and Japanese Regional Data (cont'd)

- Findings for production:
  - Little evidence for HOV assumption of identical $A(\omega)$ across countries.
  - Results improve dramatically when considering the assumption of identical $A(\omega)$ across regions within Japan.
- Findings for consumption:
  - For both Japan as a whole and for regions within Japan, measured consumption compares closely with the predictions of IHP.

International and Japanese Regional Data (cont'd)

- Findings for net trade in factor services of Japanese regions:
  - Assumptions of IHP-world, FPE-world are strongly rejected as in the cross-country studies considered above.
  - Assumptions of IHP-Japan, FPE-Japan yield predictions of net trade in factor services close to measured values.
    - Sign test;
    - Rank test;
    - There is no longer a "puzzle of the missing trade": predictions are now of the right order of magnitude to fit measured net factor trade;
    - There remains a systematic pattern in the errors between measured and predicted net trade in factor services, but it becomes less pronounced.
- Therefore, when we consider the performance of the HOV model in an environment where its assumptions are more likely to be met (trade between regions within a country) and modify the model to allow for local FPE, its empirical performance dramatically improves.

Global Trade in Net Factor Services

- Davis and Weinstein (2001) use actual data on technology matrices and absorption for 10 OECD countries and composite ROW.
    - Strongly reject the assumption of identical technologies, even for the 10 developed OECD countries.
    - Allowing for Hicks-neutral productivity differences greatly improves the fit of the production model but does little to eliminate the mystery of the missing trade.
    - Evidence that industry input use is correlated with country factor abundance in both traded and non-traded sectors.
        - Evidence of non-factor price equalization (even conditional FPE does not hold).
        - Evidence of non-neutral technology differences.
        - Allowing for the above correlation substantially improves the performance of the model.
        - Allow for the fact that the volume of trade in goods is much smaller than predicted by IHP with no trade costs by estimating a gravity equation.

Global Trade in Net Factor Services (cont'd)

- Taken together, the above four sets of modifications increase measured net trade in factor services to roughly 80% of predicted.
- "Our study shows how the Heckscher-Ohlin-Vanek theory, when modified to permit technical differences, a breakdown in factor price equalization, the existence of non-traded goods, and costs of trade, is consistent with data from ten OECD countries and a rest-of-world aggregate ... countries export their abundant factors and in approximately the right magnitudes" (Davis and Weinstein 2001).
- A model of net trade in factor services but not HOV as we know it!

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