

Global Factor Service Trade

The FPE theory is extraordinarily ambitious. It proposes to describe the endowments, technologies, production, absorption, and trade of all the countries in the world. The HOV theorem predicts that a country's net export of factor services will equal the difference between its endowment and the average endowment for a country of that size.

Leontief (1953) found a paradox – United States relatively capital abundant but a net importer of capital services. Maskus (1985) dubbed the paradox commonplace, not an artifact of countries, time periods, etc. Bowen et al. (1987) argued that the theory does no better than a coin toss at predicting the factor content of exports.

Trefler (1995) identifies the “mystery of the missing trade”: the amount of factors traded indirectly through trade in goods is much smaller than the volume suggested by theory. He finds rejects the standard theory in favor of a modification that allows for a home bias in consumption and differences in technologies across countries. Gabaiz (1997) shows that even these modifications of the theory do not fit the data well. Empirical work has failed to find simple amendments to the theory that make it match the data.

If you have faith in the theory, then you consider the model so intuitive that you would wonder how it could

ever be wrong. If you have faith in the data, then you consider the evidence so overwhelming that you would wonder why any more needs to be done. This paper shows that the HOV model is down but not out; that it can jump back up and win the fight. But how can the fight still be won?

This paper gathers richer information about technology differences across countries. Previous studies generally had technology data for just the United States and no information on how consumption differed across countries. Here, there is sufficient data on technology and absorption to estimate a structural model and impose the resulting restrictions on the model. One-by-one, these assumptions can be relaxed to determine precisely where the problems with fitting the model to the data occur. The end result finds that countries export their abundant factors in roughly the correct magnitude, so the study finds strong support for a suitably amended version of the HOV theory.

Theory

We begin with a quick review of the factor content predictions of the standard HOV model.

Standard HOV Model

Suppose the standard assumptions are met:

1. The markets for goods and services are perfectly competitive.
2. The number of traded goods is at least as large as the number of nontraded factors.

3. The distribution of endowments is consistent with all countries producing all goods.
4. All countries have identical, constant returns to scale production functions.
5. There are no barriers to trade and transportation costs are zero.
6. All countries share the same homothetic preferences over the goods.

Under FPE, all countries will use the same techniques of production, captured by the matrix of total factor inputs B^W . Full employment requires a country's factor demand $B^W Y$ to equal the endowment vector V , where Y is the production vector.¹

$$B^W Y = V \quad (9.1)$$

Under identical and homothetic preferences, a country's demand D must be proportional to total world output Y^W .

$$D = sY^W \quad (9.2)$$

From these equations

$$B^W D = sB^W Y^W = sV^W \quad (9.3)$$

Then the factor content of a country's exports $T \equiv Y - D$ must be

$$B^W T = B^W (Y - D) = V - sV^W \quad (9.4)$$

Definition 1 *The term $B^W T$ is the measured factor content of trade (MFCT), while $V - sV^W$ is its predicted value, the predicted factor content of trade (PFCT).*

¹In terms of our previous notation, technology matrix B is like A , factor endowment vector V is K , production vector Y is S , and export vector T is $X - M$.

Proposition 2 *Production Specification (P1).* The factor content of a country's production is its endowment of factors $B^W Y = V$.

Proposition 3 *Trade Specification (T1).* A country's net export of factor services will equal the difference between its endowment and the average endowment scaled by the country's size $B^W T = V - sV^W$.

Technology
Measured with
Error

Suppose a country's measured technology matrix is the common technology matrix B^W multiplied by a matrix of errors ϵ .

$$B = B^W \epsilon \tag{9.5}$$

Then the true technology matrix B^W is replaced by a weighted average technology matrix \bar{B} .

Proposition 4 *Production Specification (P2).* $\bar{B}Y = V$.

Proposition 5 *Trade Specification (T2).* $\bar{B}T = V - sV^W$.

Hicks-Neutral
Technical Dif-
ferences

Countries seem to have systematic differences in productivity. Suppose the technologies of countries differ only by a country-specific Hicks-neutral shift term λ .

$$B = \lambda B^W \tag{9.6}$$

If express a country's endowments in efficiency terms,

$$\tilde{V} = \frac{V}{\lambda} \tag{9.7}$$

then the standard results should hold (use efficiency units henceforth).

Proposition 6 *Production Specification (P3).* $BY = \tilde{V}$.

Proposition 7 *Trade Specification (T3).* $BT = \tilde{V} - s\tilde{V}^W$.

Continuum Model

Capital intensity of sectors appear to differ across countries. Following Dornbusch, Fisher and Samuelson (1980), order a continuum of industries to be strictly increasing in their capital-labor ratios. Following Xu (1993), suppose that if $\tau > 1$ units of a good are shipped, one unit arrives due to iceberg style transportation costs (needed to pin down production and thus trade volume), and suppose that τ is arbitrarily close to one so that the transportation costs are trivial in magnitude. All goods having the same proportional transport costs implies that countries will achieve the HOV-predicted factor flows through the smallest volume of trade to minimize the transport cost involved. The capital abundant country will export an interval of the most capital intensive goods, the labor abundant country will export an interval of the most labor intensive goods, and an intermediate range of goods will not be traded.

There is an aggregation problem: goods produced in different countries that are classified as being in the same industry might not really be the same at all. In this setting, the estimated technology matrix will tend to understate the capital content and overstate the labor content of exports from the capital abundant country (such as the United States), and similarly (but in reverse) for the labor abundant country. So the estimates of the factor content of trade will be biased toward zero for both countries, thus contributing to the “mystery of the missing trade.”

An important implication of this theory is that **industry factor usage for tradables will vary systematically with the country’s capital abundance**. A second implication is that the factor content of absorption needs to be measured bilaterally using the producing country’s technology matrix.

Factor
Price Equaliza-
tion Violated

Helpman (1998) allows departures from FPE due to specialization cones where countries with substantially different endowments produce different baskets of goods. In his model, **nontradables will be produced using different techniques in different countries.**

Demand and
Gravity

Any model where trade is frictionless is apt to grossly overstate the volume of trade. Data on trade costs is appears inadequate, so use distance as a proxy for trade costs. Anderson (1979) has shown how a gravity equation can be derived. The factor content of absorption must be generated bilaterally, taking into account the factor usage of the trading partners involved.

Data Sources and Issues

For ten countries (Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the United Kingdom, and the United States), have data on technology, net output, endowments, absorption, and trade that is comparable across countries. The data comes from the OECD: Input-Output, Intersectoral, and STAN. Twenty other countries make up the rest of the world (ROW). Capital comes from Summers and Heston, and labor from the ILO. Gross output is from the UN's Industrial Statistics. Bilateral trade flows come from Feenstra, Lipsey and Bowen (1997).

The major accomplishment is having data on absorption and multiple observations on technology so can distinguish between alternative theories. The data also has

a higher degree of consistency than previous studies. A weakness is that do not distinguish between skilled and unskilled labor; data on usage by industry is not available for most countries. This problem may be lessened by measuring labor in efficiency units. Omitting land and minerals should only work against the goal of finding a good fit with the data. Other work for regions in Japan (DWBS 1997) tackled these other factors and found very similar results.

Statistical Tests on Technology and Absorption

Estimating Technology

1. P1: hypothesis that all countries use the same production techniques.

2. P2: hypothesis that the technologies are measured with error

$$\ln \beta = \beta^W + \epsilon. \quad (9.8)$$

3. P3: hypothesis that the technologies exhibit Hicks-neutral differences

$$\ln \beta = \theta + \beta^W + \psi, \quad (9.9)$$

where $\exp \theta = \lambda$ and $\lambda = 1$ for the United States.

4. P4: hypothesis that the industry input-output coefficients in tradeables (or in nontradables as well P5) depend on a country's capital abundance

$$\ln \beta = \theta + \beta^W + \gamma \ln k + \phi, \quad (9.10)$$

where $\sum \gamma = 0$.

5. P5: hypothesis that the industry input-output coefficients in both tradeables and nontradables depend on a country's capital abundance.

Schwartz criterion selects P5: continuum model with Hicks-neutral technical difference and FPE breaking down so that industry input-output coefficients depend on a country's capital abundance across both tradeables and nontradables. A one percent increase in a country's capital to labor ratio increases capital intensity 0.8 percent in tradeables and 0.9 percent in nontradables. The United States has the best technology, which is twice as good as Italy's technology (the worst).

Estimating Demand

The data supports the gravity model for absorption and soundly rejects the restrictions entailed were trade costless. So a continuum model with trade costs and FPE violated is the preferred model of production and trade.

Implications for Net Factor Trade

But can this specification explain actual factor service flows. Does it fit the data on net factor trade? Well? Here are a series of criteria for testing the fit with the data.

Definition 8 *The Slope Test for production regresses the measured factor content of production on the predicted factor content of production to see if the slope turns out to be one (with good fit).*

Definition 9 *The Median Error Test for production examines the absolute prediction error as a proportion of the predicted factor content of trade to see if it turns out to be zero percent.*

Definition 10 *The Sign Test for trade checks whether countries are measured to be exporting the services of the predicted factor.*

Definition 11 *The Slope Test for trade regresses the measured factor content of trade on the predicted factor content of trade to see if the slope turns out to be one (with good fit).*

Definition 12 *The Variance Ratio Test compares the variance of the measured factor content of trade to the variance of the predicted factor content of trade to see if this ratio turns out to be one (values less than one suggest missing trade).*

Production and Trade Tests

Here are the findings regarding to what degree adding each step of generality to the HOV helps to achieve a better fit with the data on the factor content of trade.

Standard HOV Model

Figure 1 plots P1. Measured factor content of production is always less than predicted for all countries, and the gap is the worst for the ROW. Countries would need much less of each factor if they were to use the U.S. technology to produce. The slope is 0.24 (or 0.67 excluding ROW), which falls substantially short of one.

Figure 2 plots T1. The sign test is right only 32 percent of the time, which does worse than a coin flip. The variance of the predicted factor flows are 2,000 times larger than measure, so there is missing trade BIG TIME. The slope coefficient is zero, not one. The data exhibit all of the pathologies of the previous studies.

Average Technology Matrix

Figure 3 plots P2. Excluding the United States and the ROW, the slope is 0.9 (with R^2 above 0.9) and median prediction error of about 20 percent. A big improvement, but still plenty of room for improvement.

Figure 3' plots T2.² The sign test correctly predicts the direction of net factor trade only 45 percent of the time. The variance ratio remains essentially zero, so still missing trade big time. The slope is -0.006, so factor abundance conveys essentially no information about the factor content of trade. The model is still an empirical failure.

Hicks-Neutral Technical Differences

Figure 4 plots P3. There remains substantial prediction errors for Canada and the UK (in addition to ROW). Median prediction error is 7 percent. Slope is around 0.9 (excluding ROW R^2 is 0.999). Systematic biases reflect capital abundance: underestimating capital content for capital abundant countries and underestimating labor content for labor abundant countries.

Figure 4' plots T3. Trade side is still a flop. Sign test is 50 percent. Variance ratio is 0.008, which implies predicted exceeds measured by a factor of over 100. And the slope is still essentially zero. So we are definitely not done yet.

Continuum Model

Figure 5 plots P4. Slope is 0.89, median prediction error 5 percent.

Figure 6 plots T4. Sign test is 86 percent (19 of 22),

²Figure 3' for T2 and Figure 4' for T3 do not appear in the published version of the paper – they can be found in NBER working paper no. 6785.

which beats the coin flip! Variance ratio improves to 0.07, so substantial trade is still missing. The slope at 0.17, while not one, is at least not zero either.

FPE Violated

Figure 7 plots P5. Slope is 0.97, median prediction error is 3 percent.

Figure 8 plots T5. Sign test is 86 percent, variance ratio 19 percent, and slope is 0.43.

Correction to ROW Technology

Prediction errors for ROW are large, so force technology for ROW to match its endowments.

Figure 9 plots T6. Slope 0.59 and variance ratio 0.38.

Adding Gravity

Figure 10 plots T7. Sign test over 90 percent, slope 0.82, variance ratio 0.7. Much trade is no longer missing, once account for trade restriction.

Production	P1	P2	P3	P4	P5
Slope	0.24	0.33	0.89	0.89	0.97
Median Error	0.34	0.21	0.07	0.05	0.03

Trade	T1	T2	T3	T4	T5	T6	T7
Slope	-0.002	-0.006	-0.05	0.17	0.43	0.59	0.82
Sign Test	0.32	0.45	0.50	0.86	0.86	0.82	0.91
Variance Ratio	0.0005	0.0003	0.008	.007	0.19	0.38	0.69