International Knowledge Spillovers and Trade
Correlation Between Technological States in a Ricardian Trade Framework

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Trade relationships may be predicted by stock of knowledge, relative costs and distance between countries.

- Explains intrasectoral trade, more productive exporting firms, large volume of trade between close countries.
- Assumes that there are no knowledge spillovers.
Eaton and Kortum’s Empirical Paper

- *Econometrica*, 2002
- Explains a country’s trading relationship using a Ricardian framework incorporating
  - Technology
  - Relative wages and prices
  - Distance
My Question

- Are knowledge spillovers important in explaining trading relationships?
- Add a measure of technological spillovers.
  - Each country’s share of internationally coauthored patents with a given country.
Why Does Technology Explain Trade?

- In the EK framework, a country with more technology has higher average productivity.
- Higher productivity generates lower costs.
- Lower costs result in more exports.
How Does this Change the Results in the EK Model?

- Technology measured by a country’s stock of R&D expenditure and average educational attainment.
- R&D and human capital measures only capture the stock of local knowledge.
  - knowledge spillovers
  - underrepresent technological attainment
- Countries with small research stocks may be more productive than local variables can measure.
Review of the Static Eaton and Kortum Model

- All \( N \) countries in the model can produce any good \( k \in [0, 1] \) from a spectrum of goods.
- The representative consumer purchases \( Q_i(k) \) to maximize preferences of the standard CES form:

\[
U_i = \left[ \int_0^1 Q(j)^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}}
\]

where \( \sigma > 0 \) is the elasticity of substitution.
- Goods are produced by combining labor and intermediate goods such that the cost of an input bundle in country \( i \) is \( c_i = w_i^\beta p_i^{1-\beta} \) where \( p_i \) is the price index in country \( i \).
Countries differ in their underlying efficiency in production, 
\( z_i(k) \), which is a draw from an underlying distribution

\[
F_i(z) = \exp\left(-T_i z^{-\theta}\right)
\]

Delivery of one unit of good \( k \) from country \( i \) to country \( j \) requires producing \( d_{ji} \geq 1 \) units of good \( k \) in country \( i \).

Under perfect competition, the price paid for a unit of good \( k \) from country \( i \) in country \( j \) must be

\[
P_{ji}(k) = \left(\frac{c_i}{z_i(k)}\right) d_{ji}
\]

The distribution of these prices are

\[
G_{ji}(p) = 1 - \exp\left(-T_i [w_i d_{ji}]^{-\theta} p^\theta\right)
\]
1. derive a price index
2. assume competitive labor markets

This gives us an expression for country $j$’s expenditure on goods from country $i$, $X_{ji}$, as a fraction of country $j$’s total expenditure, $X_j$:

$$\frac{X_{ji}}{X_j} = \frac{T_i (c_i d_{ji})^{-\theta}}{\sum_{i=1}^{N} T_i (c_i d_{ji})^{-\theta}}$$

and a relationship between the relative prices between countries:

$$\frac{p_i}{p_j} = \frac{w_i}{w_j} \left( \frac{T_i}{T_j} \right)^{-\frac{1}{\theta \beta}} \left( \frac{X_{ji} / X_i}{X_{jj} / X_j} \right)^{-\frac{1}{\theta \beta}}$$
Combining the expressions for normalized import shares and relative prices we find

$$\ln \frac{X'_{ji}}{X'_{jj}} = -\theta \ln d_{ji} + \frac{1}{\beta} \ln \frac{T_i}{T_j} - \theta \ln \frac{w_i}{w_j}$$

where $$\ln X'_{ji} = \ln X_{ji} - \frac{1-\beta}{\beta} \ln \frac{X_i}{X_{ii}}.$$
Eaton and Kortum measure the stock of technology $T_i$ in each country as a function of the research stock $R_i$ and human capital measure $H_i$.

The new stock of technology $\tilde{T}_i$ contains a geometric average of all $N$ countries’s technology stock:

$$\tilde{T}_i = \prod_{n=1}^{N} T_n^{\alpha_{in}}$$

where $\alpha_{in}$ is the spillover component and is measured using the international coauthoring patent share.

Should there be no spillovers from a given country $n$, then $\alpha_{in} = 0$. 

1. Bilateral manufacturing imports from the STAN database (OECD)
2. Geographic distances in thousands of miles measured between central cities in each country (Eaton and Tamura, 1994)
3. Stocks of research for each country from Coe and Helpman (1995)
4. Average years of schooling in each country in 1985 from Kyriacou (1991)
5. Annual compensation per worker in manufacturing from the OECD
6. Aggregate workforce and workforce density from Summers and Heston (1991)
1. Shares of domestic patent applications to the EPO with at least one foreign co-inventor, by country of co-inventor.
   - Available from the patent database of the OECD
For each pair of countries $i, j$, we have a function of the data $x$ and the parameters $\theta$,

$$f_{ij}(x, \theta) = \varepsilon_{ij}$$

where $x = \left\{ \ln \frac{X_i^j}{X_j^i}, d_{ji}, \ln R_i, \frac{1}{H_i}, \ln w_i \right\}$ and $\theta = \{\theta, \beta\}$.

Eaton and Kortum estimate this system in two parts.
Estimating Distance

- Eaton and Kortum estimate for all \(i \neq j\)

\[
\ln \frac{X'_{ji}}{X'_{jj}} = S_i - S_j - \theta (d_k + b + l + e_h + m_j + \delta_{ji})
\]

where \(S_i\) and \(S_j\) are country fixed effects, \(d_k\) is a measure of interval distance, \(b\) the effect of sharing a border, \(l\) sharing a language, \(e\) both being members of a trading area, \(m\) an overall destination effect and \(\delta_{ji}\) a measurement error term.

- To capture reciprocity in measurement errors in this distance measure, \(\delta_{ji}\) is assumed to have a two-part structure where

\[
\delta_{ji} = \delta^1_{ji} + \delta^2_{ji}
\]

\[
E[\delta_{ji}] = 0
\]

\[
E[\delta_{ji} \delta_{ji}] = \sigma^2_1 + \sigma^2_2
\]

\[
E[\delta_{ji} \delta_{ij}] = \sigma^2_2
\]
Then the authors break down each country’s fixed effect as follows

\[
\ln S_i = \frac{1}{\beta} \ln R_i + \left( \frac{1}{\beta H_i} \right) - \theta \ln w_i + \tau_i
\]

where \( \tau_i \) is a measurement error term following the classical assumptions, so that \( E[\tau_i] = 0 \) and \( E[\tau_i^2] = \sigma^2_\tau \).

\( \beta \), the labor share of expenditure, is calibrated to 0.21 from the sample data.

Since the wages and the state of technology are correlated, the authors use the size and density of the labor force as instruments for the wage.
Estimating the Equations Jointly

- The simplest assumption to make regarding the error \( \varepsilon_{ij} \) is that it contains only the error from the distance, such that

\[
\varepsilon_{ij} = \delta_{ji}^1 + \delta_{ji}^2
\]

- Following that structure, I have estimated the equations jointly, finding results nearly identical to the authors’ reported results.
Introduction of the Technology Measurement Error

- The introduction of a geometric mean

\[
\tilde{T}_i = \prod_{n=1}^{N} T_n^{\alpha_{in}}
\]

results in correlation between these errors:

\[
\ln \tilde{T}_i = \sum_{n=1}^{N} \alpha_{in} \left[ \ln R_n + \left( \frac{1}{H_n} \right) + \tau_n \right]
\]

\[
= \sum_{n=1}^{N} \alpha_{in} \left[ \ln R_n + \left( \frac{1}{H_n} \right) \right] + \sum_{n=1}^{N} \alpha_{in} \tau_n
\]

where \( \alpha_{in} \) is measured by the percentage of international coauthorships with country \( i \) provided by country \( n \).
Error Structure

Given that

\[ f_{ij} (x, \theta) = \ln \frac{X'_{ji}}{X'_{jj}} - \theta (d_k + b + l + e_h + m_j) \]

\[ + \frac{1}{\beta} \sum_{n=1}^{N} (\alpha_{in} - \alpha_{jn}) \left( \ln R_n + \left( \frac{1}{H_n} \right) \right) \]

\[ - \theta \ln \frac{w_i}{w_j} \]

we have

\[ \varepsilon_{ji} = \frac{1}{\beta} \sum_{n=1}^{N} (\alpha_{in} - \alpha_{jn}) \tau_n - \theta \delta_{ji} \]
Further Work

- Empirical results.
- Estimate the error structure when spillovers are a function of distance.
- Move to a dynamic model.
Since country $n$ will buy from the cheapest manufacturer, or

$$P_n (j) = \min \{ P_{n1} (j), ..., P_{nN} (j) \} ,$$

then the extreme value distribution form gives us that the price of good $j$ in country $n$ is drawn from distribution

$$G_n (p) = 1 - \exp \left( -\Phi_n p^\theta \right)$$

where

$$\Phi_j = \sum_{i=1}^{N} \tilde{T}_i (w_i d_{ji})^{-\theta}$$
Import Shares and Export Sales

- For a given country $j$, the share of goods purchased from country $i$ is equal to:

$$
\pi_{ji} = \frac{\tilde{T}_i (c_id_{ji})^{-\theta}}{\sum_{i=1}^{N} \tilde{T}_i (c_id_{ji})^{-\theta}} = \frac{\tilde{T}_i (c_id_{ji})^{-\theta}}{\Phi_j}
$$

- The fraction of goods country $j$ purchases from $i$ is also the fraction of its expenditure on goods from $i$.

$$
\frac{X_{ji}}{X_j} = \frac{\tilde{T}_i (c_id_{ni})^{-\theta}}{\Phi_n}
$$

- Total export sales in country $i$ are given by

$$
Q_i = \tilde{T}_ic_i^{-\theta} \sum_{m=1}^{N} \frac{\tilde{T}_id_{mi}^{-\theta}}{\Phi_m} X_m
$$
Due to our CES objective function, the price index in country $j$ is

$$p_j = \gamma \Phi_j^{-\frac{1}{\theta}}$$

where $\gamma = \left[ \Gamma \left( \frac{\theta + 1 - \sigma}{\theta} \right) \right]^{\frac{1}{1-\sigma}}$. This comes from the definition of the moment generating function of $x = -\ln p$.

To be well-defined, this requires $\sigma < 1 + \theta$. Once this condition is satisfied, we may ignore the elasticity of substitution, as it appears only in the constant term.

This gives us a version of the standard gravity equation

$$X_{ji} = \frac{\left( \frac{d_{ji}}{p_j} \right)^{-\theta} X_j}{\sum_{m=1}^{N} \left( \frac{d_{mi}}{p_m} \right)^{-\theta} X_m} Q_i$$
If we recall that

\[
\frac{X_{ji}}{X_j} = \frac{\tilde{T}_i \left(c_i d_{ji}\right)^{-\theta}}{\Phi_j}
\]

\[p_j = \gamma \Phi_j^{-\frac{1}{\theta}}\], and \(d_{ii} = 1\), then we see that

\[
\frac{X_{ji}}{X_j} \frac{X_{ii}}{X_i} = \frac{\Phi_i}{\Phi_j} d_{ji}^{-\theta} = \left(\frac{p_i d_{ji}}{p_j}\right)^{-\theta}
\]

(1)
In order to establish how world price levels are determined, the authors introduce a structure on the labor market as we have mentioned above, such that the cost of an input bundle in country $i$ is

$$c_i = w_i^\beta p_i^{1-\beta}$$  \hspace{1cm} (2)$$

where $\beta$ is labor’s share of production. Since

$$\pi_{ii} = \frac{\tilde{T}_i (c_i)^{-\theta}}{\Phi_i}$$

and

$$p_i = \gamma \Phi_i^{-\frac{1}{\theta}}$$  \hspace{1cm} (3)$$

the real wage in country $i$ is

$$\frac{w_i}{p_i} = \gamma^{-\frac{1}{\beta}} \left( \frac{\tilde{T}_i}{\pi_{ii}} \right)^{\frac{1}{\beta\theta}}$$

where $\pi_{ii}$ is the share of home production.
Parameters and Estimation in the Original Model

- The authors calibrate $\beta = 0.21$, and use data on normalized import shares, geographic distance, price levels and wages to estimate $\theta$ and $T_i$ for each country.

- Combining (1), (2) and (3), we are left with an expression for the relative prices of inputs

$$\frac{p_i}{p_n} = \frac{w_i}{w_n} \left( \frac{\tilde{T}_i}{\tilde{T}_n} \right)^{-\frac{1}{\beta \theta}} \left( \frac{X_i}{X_{ii}} \right)^{-\frac{1}{\beta \theta}} \left( \frac{X_i}{X_{nn}} \right)^{-\frac{1}{\beta \theta}}$$

that can be used in the expenditure share equation

$$\frac{X_{ni}}{X_n} = \frac{\tilde{T}_i (c_i d_{ni})^{-\theta}}{\Phi_n}$$

to find

$$\ln \frac{X'_{ni}}{X'_{nn}} = -\theta \ln d_{ni} + \frac{1}{\beta} \ln \frac{\tilde{T}_i}{\tilde{T}_n} - \theta \ln \frac{w_i}{w_n}$$

where $X'_{ni} = \ln X_{ni} - \frac{1-\beta}{\beta} \ln \frac{X_i}{X_{ii}}$. 