International Trade - Lecture 3

The Eaton-Kortum Model

August, 2025

Essential Reading

- Eaton, S. and S. Kortum, (2002) "Technology, Geography and Trade," *Econometrica*, 70.

Summary

- Dornbusch, Fischer & Samuelson (1977) developed a tractable Ricardian model of trade with two countries and many goods.
- Easy to conduct comparative statics.
- But how to confront the data with only two countries?
- Eaton and Kortum develop a multi-country and multi-good framework that is easy to bring to the data.

1. Trade diminishes with distance
2. Prices vary across locations, greater differences between places farther apart
3. Factor rewards are far from equal across countries
4. Industry relative productivities vary substantially across countries

Eaton and Kortum (2002)

- Facts 1 and 2 suggest geography plays an important role in international trade
- Facts 3 and 4 suggest that countries are working with different technologies
- Eaton and Kortum provide a Ricardian model of trade with a role for geography
- CA forces promote trade / Geographic barriers inhibit it
- Model is rich enough to take it to data

- General Equilibrium Analysis of:
    - Gains from trade in manufactures
    - How does technology and geography determine the patterns of specialization and trade
    - Role of trade in spreading the benefits of new technology
    - Consequences of tariff reductions

Model: Production

- Continuum of goods $j \in [0, 1]$
- Constant Returns to Scale
- Cost of bundle of inputs in country i: c_i (common across j) - factor intensities are constant across goods
- Country i's efficiency in producing good $j \in [0, 1] : z_i(j)$
- Producing 1 unit of good j in country i costs

$$\frac{c_i}{z_i(j)}$$

- Later, c_i will be determined in equilibrium (it will depend on the cost of labor and on the cost of intermediates)

Model: Geography

- Geographic barriers (iceberg costs): delivering 1 unit of a good j from country i to country n requires d_{ni} units shipped from country i.
  - $d_{ii} = 1$
  - $d_{ni} > 1$ if n$\neq i$
  - $d_{ni} \leq d_{nk} d_{ki}$ (cross border arbitrage)
- Perfect competition $\Longrightarrow p_{ni}(j) = \frac{c_i}{z_i(j)} d_{ni}$
- Shopping around the world for the lowest price:

$$p_n(j) = \min \{ p_{ni}(j) ; i = 1, ..., N \}$$

Model: Demand

- Utility

$$U = \left(\int_0^1 Q\left(j\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

- $\sigma > 0$ is the elasticity of substitution.
- Maximization w.r.t. budget constraint: Let X_n be country n's total spending in manufacturing.

Model: Technology

- Probabilistic and tractable representation of technologies
- Country i's efficieny in producing good j is the realization of a random variable $Z_i(j)$. From now on, the index j will be omitted.
- Z_i is independently drawn from a country specific distribution for each good j:

$$F_i(z) = \Pr(Z_i \leq z)$$

- Law of large numbers: $F_i(z)$ is the fraction of goods for which country i's efficiency is below z.

Model: Technology

- Cost of purchasing a particular good from country i in country n:

$$\text{Random Variable } P_{ni} = \frac{c_i d_{ni}}{Z_i}$$

- $P_n = \min\{P_{ni}; i = 1, ..., N\}$
- π_{ni} = likelihood that country i supplies a given good j at the lowest price to country n.

Model: Technology

- Convenient functional form: the Frechet distribution
  - $F_i(z) = e^{-T_i z^{-\theta}}$
  - $T_i > 0$ and $\theta > 1$
  - T_i is a locational parameter: geometric mean of $Z_i = e^{\gamma/\theta} T_i^{1/\theta}$
  - θ measures dispersion: $\log Z_i$ has S.D. $\frac{\pi}{\theta\sqrt{6}}$
- T_i governs **absolute advantage**
- θ governs **comparative advantage**

Prices

- Distribution of prices in different countries?

$$P_{ni} = \frac{c_i d_{ni}}{Z_i}$$

$$\begin{aligned} G_{ni}(p) &\equiv \Pr(P_{ni} \leq p) \\ &= \Pr\left(\frac{c_i d_{ni}}{p} \leq Z_i\right) \\ &= 1 - F_i\left(\frac{c_i d_{ni}}{p}\right) \end{aligned}$$

Prices

$$
\begin{aligned}
G_n(p) &\equiv \Pr(P_n \leq p) \\
&= \Pr(\min_i \{P_{ni}\} \leq p) \\
&= 1 - \Pr(\min_i \{P_{ni}\} \geqslant p) \\
&= 1 - \prod_{i=1}^{N} (1 - \Pr(P_{ni} \leq p)) \\
&= 1 - \exp\left(-\Phi_n p^{\theta}\right) \\
\Phi_n &= \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta}
\end{aligned}
$$

- Φ_n summarizes how: (1) states of technology around the world; (2) input costs around the world; and (3) geographic barriers; govern prices in each country n

Prices

- Extreme Case 1: No geographic barriers $d_{ni} = 1 \; \forall n, i$
  - The distribution of prices is the same across countries (law of one price)

$$\Phi_n = \sum_{i=1}^{N} T_i c_i^{-\theta} = \Phi$$

- Extreme Case 2: Autarky $d_{ni} \to \infty \; \forall n \neq i$

$$\Phi_n = T_n c_n^{-\theta}$$

Prices

- Three useful properties of the price distribution
- **First**: Probability that country i provides a good at lowest price in country n

$$\pi_{ni} = \frac{T_i (c_i d_{ni})^{-\theta}}{\Phi_n}$$

- **SHOW !!!**

Prices

- **Second**: The price of a good that country n **actually buys** from any country i also follows the distribution $G_n(p)$
- **SHOW !!!**

Prices

- **Third**: The exact price index is

$$p_n = \gamma \Phi_n^{-\frac{1}{\theta}}$$
$$\text{with } \gamma = \left[\Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\right]^{\frac{1}{1-\sigma}}$$

- **SHOW !!!** (but this is not too hard using the observations on footnote 18).

Trade flows and gravity

- Finally, you will show that the second property implies that:

$$X_{ni} = \pi_{ni} X_n$$
$$\Rightarrow \frac{X_{ni}}{X_n} = \pi_{ni}$$

Trade flows and gravity

$$\frac{X_{ni}}{X_n} = \frac{T_i (c_i d_{ni})^{-\theta}}{\sum_{k=1}^{N} T_k (c_k d_{nk})^{-\theta}}$$

- Let $Q_i = \sum_{m=1}^{N} X_{mi}$

$$X_{ni} = \frac{\left(\frac{d_{ni}}{p_n}\right)^{-\theta} X_n}{\sum_{m=1}^{N} \left(\frac{d_{mi}}{p_m}\right)^{-\theta} X_m} Q_i$$

- $\left(\frac{d_{ni}}{p_n}\right)^{-\theta} X_n$ can be seen as the size of market n from country i's perspective.

Equilibrium Input Costs

- Production: Labor + Intermediate Inputs
- Labor: constant share β
- Intermediates: full set of goods aggregated as a CES (with the same elasticity of substitution σ)
- w_i : wage in country i
- Price index p_i : cost of 1 unit of the intermediate aggregate

$$c_i = w_i^{\beta} p_i^{1-\beta}$$

- p_i depends on Φ_i and hence on input costs everywhere

$$\Phi_n = \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta}$$

Price Levels

- Price levels are mutually determined

$$c_i = w_i^{\beta} p_i^{1-\beta}$$
$$\Phi_n = \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta}$$
$$p_n = \gamma \Phi_n^{-\frac{1}{\theta}}$$

- Delivers system of equations:

$$p_n = \gamma \left[\sum T_i \left(d_{ni} w_i^{\beta} p_i^{1-\beta}\right)\right]^{-\frac{1}{\theta}}$$

- Whose numerical solution yields prices as a function of parameters and wages

Trade Shares

- Solving for the trade shares will be important when solving for equilibrium wages.

$$\frac{X_{ni}}{X_n} = \pi_{ni} = \frac{T_i (c_i d_{ni})^{-\theta}}{\sum_{k=1}^{N} T_k (c_k d_{nk})^{-\theta}}$$

$$c_i = w_i^{\beta} p_i^{1-\beta}$$

- These equations deliver

$$\pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta}$$

- p_i's are obtained in terms of wages in the previous slide.

Labor Market Equilibrium

- Manufacturing and Non-Manufacturing
- Trick/Shortcut: Non-manufacturing is the numeraire and can be traded costlessly $\Rightarrow$ price of non-manuf. is equal to 1 in every country.
- It is implicitly assumed that non-manufacturing uses only labor and has CRS.
- Manufacturing labor income

$$w_i L_i = \beta \underbrace{\sum_{n=1}^{N} \pi_{ni} X_n}_{\text{Manufacturing Sales Around the World}} \tag{1}$$

- Aggregate final expenditures
$$Y_n = \underbrace{Y_n^M}_{\text{V.A. in Manuf.}} + \underbrace{Y_n^O}_{\text{V.A. in non-Manuf.}} = w_n L_n + Y_n^O$$
- α = Fraction spent on manufactures

$$X_n = \underbrace{\frac{1-\beta}{\beta} w_n L_n}_{\text{Demand for manuf. as intermediates}} + \alpha Y_n$$

Labor Market Equilibrium

- Case I: Workers can freely move between manufacturing and non-manufacturing
- Trick/Shortcut: w_n is exogenously pinned down by productivity in non-manufacturing. Total income is exogenous (it is just the wage rate times the country size).
- $w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left(\left(1-\beta\right) w_n L_n + \alpha\beta Y_n \right)$
- We obtain labor employment in manufacturing L_i
- In that case, wages are exogenous. Use equations (16) and (17) in order to solve for prices and trade shares in terms of exogenous wages. Plug them into the equation above in order to get equilibrium manufacturing employment.

Eaton and Kortum (2002) - Equilibrium

Mobile Workers

- Substituting $c_i = w_i^{\beta} p_i^{1-\beta}$ into the price indices and into the trade shares deliver:

$$p_n = \gamma \left[\sum T_i \left(d_{ni} w_i^{\beta} p_i^{1-\beta} \right) \right]^{-\frac{1}{\theta}}$$

$$\pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta}$$

- The model must be closed looking at the labor market equilibrium.
- Mobile workers between manfuacturing and non-manufacturing:

$$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left((1-\beta) w_n L_n + \alpha \beta Y_n \right)$$

- Wages and GDP's are exogenous
- First, solve for prices in terms of wages, get π_{ni} in terms of wages.
- Second, use labor market equilibrium equation in order to get manufacturing employment L_i.

Labor Market Equilibrium

- Case II: Workers are immobile between manufacturing and non-manufacturing.
- Trick/Shortcut: The number of manufacturing workers is fixed at L_n and Y_n^O is exogenous.
- $w_i L_i = \beta \sum_{n=1}^{N} \pi_{ni} X_n$
- $X_n = \frac{1-\beta}{\beta} w_n L_n + \alpha \left(w_n L_n + Y_n^O \right)$
- $w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left((1 - \beta + \alpha\beta) w_n L_n + \alpha\beta Y_n^O \right)$
- This system of equations pins down w_i for all i. However, it still depends on the endogenous π_{ni}.
- In order to solve for the equilibrium, one must jointly solve:
    - equations (16): prices in terms of wages
    - equations (17): trade shares in terms of prices and wages
    - equations (21): wages in terms of trade shares

Eaton and Kortum (2002) - Equilibrium

Immobile Workers

- Substituting $c_i = w_i^{\beta} p_i^{1-\beta}$ into the price indices and into the trade shares deliver:

$$p_n = \gamma \left[\sum T_i \left(d_{ni} w_i^{\beta} p_i^{1-\beta} \right) \right]^{-\frac{1}{\theta}}$$
$$\pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta}$$

- Immobile workers between manfuacturing and non-manufacturing:

$$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left(\left(1 - \beta + \alpha\beta \right) w_n L_n + Y_n^O \right)$$

- L_n's and Y_n^O's are exogenous
- Have to solve for the three equations above **simultaneously**.

Example: Zero Gravity

Closed-Form Solution

- $d_{ni} = 1 \; \forall n, i \Rightarrow \Phi_i = \Phi$ and $p_i = p \; \forall i$
- $\frac{w_i}{w_n} = \left(\frac{T_i / L_i}{T_n / L_n} \right)^{\frac{1}{1+\theta\beta}}$
- Mobile labor $\Rightarrow$ Pattern of specialization (manufacturing versus non-manufacturing)

$$\frac{L_i}{L_n} = \frac{T_i}{T_n} \left(\frac{w_n}{w_i} \right)^{1+\theta\beta}$$

- Immobile labor $\Rightarrow$ Relative wages

- Suppose $\alpha = 1$ (there is only manufacturing)
- Real GDP per worker: $W_i = \frac{(Y_i/L_i)}{p} = \frac{w_i}{p}$
- $W_i = \gamma^{-\frac{1}{\beta}} T_i^{\frac{1}{1+\theta\beta}} \left[\sum_{k=}^{N} T_k^{\frac{1}{1+\theta\beta}} \left(\frac{L_k}{L_i} \right)^{\frac{\theta\beta}{1+\theta\beta}} \right]^{\frac{1}{\theta\beta}}$
- How much country i benefits from an increase in T_k depends on $\frac{L_k}{L_i}$
- Autarky $\Rightarrow W_i = \gamma^{-\frac{1}{\beta}} T_i^{\frac{1}{\theta\beta}}$: gains from trade for every country.

What's Next?

- In order to conduct counter-factual simulations we need:
  - Comparative Advantage parameter θ
  - Technology T_i for $i = 1, ..., N$
  - Geographic barriers d_{ni} for $n, i = 1, ..., N$
- Use data on bilateral trade flows, prices, determinants of geographic barriers, wages
  - Use structural equations to estimate θ (EK actually estimate θ in 3 different ways)
  - Estimate T_i's
  - Estimate d_{ni}

Taking the Model to the Data

- Using the trade share equation we obtain "normalized trade shares":

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta}$$

- This equation can be taken to the data in order to recover θ.
- If country n buys all of its goods from country i, it will face price index $p_i d_{ni}$. Country n optimizes across potential suppliers for the lowest prices:

$$p_n \leq p_i d_{ni}$$

- As θ increases (less dispersion, weaker CA force), trade shares become more sensitive to geographic barriers and to relative prices.

Data: a First Look

- Measure *LHS* $\frac{X_{ni}/X_n}{X_{ii}/X_i}$ using data on bilateral trade shares for 19 OECD countries. Year 1990. There are 342 observations for $n \neq i$. For $n = i$ we have a vacuous identity.
- Plot $\frac{X_{ni}/X_n}{X_{ii}/X_i}$ vs. distance between country n and country i.


normalized Import share: (Xni / Xn) / (Xii / Xi)
1
0.1
0.01
0.001
0.0001
100
1000
10000
100000

Data: a First Look

- Not yet conclusive on the magnitudes of geographic barriers and CA i.e., not enough to identify θ.
- Strong negative relationship could be because:
  - Geographic barriers raise rapidly with distance overcoming strong CA forces (low θ);
  - CA exerts weak force (high θ) so that mild geographic barriers cause trade to drop rapidly with distance.
- We have to look at price data in order to obtain a measure of $\frac{p_i d_{ni}}{p_n}$.

Taking the Model to the Data: Using Price Data

- Data: Retail prices in each of the 19 countries countries.
- 50 manufactured products
- Look at this sample of prices as $p_i\left(j\right)$, the prices of individual goods in the model.
- Note that

$$\frac{p_n(l)}{p_i(l)} \leq d_{ni} \text{ for all } l$$

- For a fixed good l, $\frac{p_n(l)}{p_i(l)}$ gives a lower bound for d_{ni}

Taking the Model to the Data: Using Price Data

- Best estimate of d_{ni} : $\widehat{d}_{ni} = \max_{l} \frac{p_n(l)}{p_i(l)}$
- Approximate $\ln p_i$: $\ln \widehat{p}_i = \frac{1}{L} \sum \ln p_i \left(l \right)$
- $\ln \left(\frac{p_i d_{ni}}{p_n} \right)$ can then be approximated by

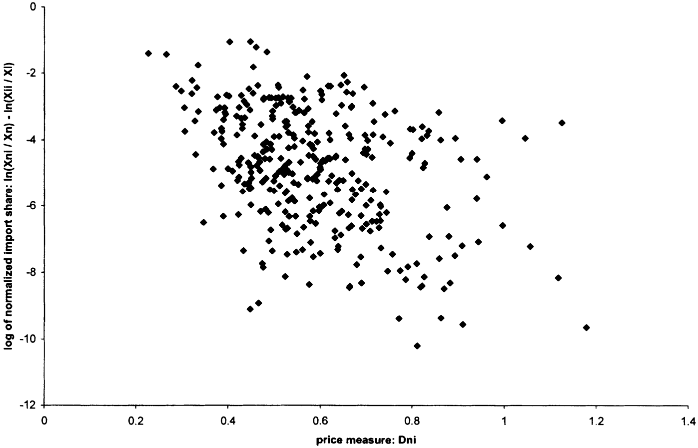
$$\ln \widehat{d}_{ni} + \ln \left(\widehat{p}_i \right) - \ln \left(\widehat{p}_n \right)$$

Taking the Model to the Data: Using Price Data

- Define $r_{ni}(j) = \ln(p_n(j)) - \ln(p_i(j))$
- Eaton and Kortum actually use:

$$D_{ni} = \frac{\max_j 2\{r_{ni}(j)\}}{\frac{1}{50}\sum r_{ni}(j)}$$

- $exp(D_{ni})$ approximates $\frac{p_i d_{ni}}{p_n}$
- $\max 2$ is taken instead max in order to minimize errors due to outliers.



- OLS regression imposing a zero intercept delivers:

$$\widehat{\theta} = 8.28$$

- Simonovska and Waugh (2011) "The Elasticity of Trade: Estimates and Evidence", argue that this estimate is upward biased (small sample bias) and provide an estimator that corrects for this bias, obtaining smaller estimates.

- We still need to recover the technology parameters.
- Eaton and Kortum also estimate θ using different approaches.
- Remember:

$$\frac{X_{ni}}{X_n} = \pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta}$$

- Write the expression for $\frac{X_{nn}}{X_n}$ and divide the two to get:

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i}{T_n} \left(\frac{w_i}{w_n} \right)^{-\theta\beta} \left(\frac{p_i}{p_n} \right)^{-\theta(1-\beta)} d_{ni}^{-\theta}$$

- Use the first equation above in order to obtain:

$$\frac{p_i}{p_n} = \frac{w_i}{w_n} \left(\frac{T_i}{T_n} \right)^{-\frac{1}{\theta\beta}} \left(\frac{X_i/X_{ii}}{X_n/X_{nn}} \right)^{-\frac{1}{\theta\beta}}$$

- Use these two equations to get:

$$\ln \frac{X'_{ni}}{X'_{nn}} = -\theta \ln d_{ni} + \frac{1}{\beta} \ln \frac{T_i}{T_n} - \theta \ln \frac{w_i}{w_n}$$
$$\ln X'_{ni} \equiv \ln X_{ni} - \frac{1-\beta}{\beta} \ln \left(\frac{X_i}{X_{ii}} \right)$$

- Define $S_i \equiv \frac{1}{\beta} \ln T_i - \theta \ln w_i$ and get:

$$\ln \frac{X'_{ni}}{X'_{nn}} = -\theta \ln d_{ni} + S_i - S_n$$

- $S_i =$ measure of country i's competitiveness - state of technology adjusted for labor costs.
- $\ln \frac{X'_{ni}}{X'_{nn}}$ computed from the data
- Set $\beta = 0.21$ (average share of wages in total manufacturing production)
- Now, how do we handle d_{ni}?
- We model its determinants.

Modeling Geographic Barriers

- $\ln d_{ni} = d_k + b + l + e_h + m_n + \delta_{ni}$
    - d_k = coefficient on the k^{th} distance interval
    - b = effect of n and i sharing a border
    - l = effect of n and i sharing a language
    - e_h = effect of n and i belonging to trade area h
    - m_n = overall destination effect
    - δ_{ni} = error term, geo barriers due to other factors
    - $\delta_{ni} \perp$ all regressors

Modeling Geographic Barriers

- We would like to allow for δ_{ni} to be correlated with δ_{in}
- Let $\delta_{ni} = \delta_{ni}^1 + \delta_{ni}^2$
  - $\delta_{ni}^2 = \delta_{in}^2$
  - δ_{ni}^2 affects two-way trade
  - δ_{ni}^1 affects one-way trade
  - $\mathsf{E}(\delta_{ni}\delta_{ni}) = \sigma_1^2 + \sigma_2^2$
  - $\mathsf{E}(\delta_{ni}\delta_{in}) = \sigma_2^2$
- The final estimating equation becomes:

$$\ln \frac{X'_{ni}}{X'_{nn}} = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta l - \theta e_h + \theta \delta_{ni}^2 + \theta \delta_{ni}^1$$

- Correlation between errors $\Rightarrow$ Estimate using Feasible GLS

TABLE III

BILATERAL TRADE EQUATION

Variable		est.	s.e.
Distance [0, 375)	$-\theta d_1$	−3.10	(0.16)
Distance [375, 750)	$-\theta d_2$	−3.66	(0.11)
Distance [750, 1500)	$-\theta d_3$	−4.03	(0.10)
Distance [1500, 3000)	$-\theta d_4$	−4.22	(0.16)
Distance [3000, 6000)	$-\theta d_5$	−6.06	(0.09)
Distance [6000, maximum]	$-\theta d_6$	−6.56	(0.10)
Shared border	$-\theta b$	0.30	(0.14)
Shared language	$-\theta l$	0.51	(0.15)
European Community	$-\theta e_1$	0.04	(0.13)
EFTA	$-\theta e_2$	0.54	(0.19)

	Source Country			Destination Country		
Country		est.	s.e.		est.	s.e.
Australia	S_1	0.19	(0.15)	$-\theta m_1$	0.24	(0.27)
Austria	S_2	−1.16	(0.12)	$-\theta m_2$	−1.68	(0.21)
Belgium	S_3	−3.34	(0.11)	$-\theta m_3$	1.12	(0.19)
Canada	S_4	0.41	(0.14)	$-\theta m_4$	0.69	(0.25)
Denmark	S_5	−1.75	(0.12)	$-\theta m_5$	−0.51	(0.19)
Finland	S_6	−0.52	(0.12)	$-\theta m_6$	−1.33	(0.22)
France	S_7	1.28	(0.11)	$-\theta m_7$	0.22	(0.19)
Germany	S_8	2.35	(0.12)	$-\theta m_8$	1.00	(0.19)
Greece	S_9	−2.81	(0.12)	$-\theta m_9$	−2.36	(0.20)
Italy	S_{10}	1.78	(0.11)	$-\theta m_{10}$	0.07	(0.19)
Japan	S_{11}	4.20	(0.13)	$-\theta m_{11}$	1.59	(0.22)
Netherlands	S_{12}	−2.19	(0.11)	$-\theta m_{12}$	1.00	(0.19)
New Zealand	S_{13}	−1.20	(0.15)	$-\theta m_{13}$	0.07	(0.27)
Norway	S_{14}	−1.35	(0.12)	$-\theta m_{14}$	−1.00	(0.21)
Portugal	S_{15}	−1.57	(0.12)	$-\theta m_{15}$	−1.21	(0.21)
Spain	S_{16}	0.30	(0.12)	$-\theta m_{16}$	−1.16	(0.19)
Sweden	S_{17}	0.01	(0.12)	$-\theta m_{17}$	−0.02	(0.22)
United Kingdom	S_{18}	1.37	(0.12)	$-\theta m_{18}$	0.81	(0.19)
United States	S_{19}	3.98	(0.14)	$-\theta m_{19}$	2.46	(0.25)

Total Sum of squares	2937	Error Variance:	
Sum of squared residuals	71	Two-way ($\theta^2\sigma_2^2$)	0.05
Number of observations	342	One-way ($\theta^2\sigma_1^2$)	0.16

Notes: Estimated by generalized least squares using 1990 data. The specification is given in equation (30) of the paper. The parameter are normalized so that $\sum_{i=1}^{19} S_i = 0$ and $\sum_{n=1}^{19} m_n = 0$. Standard errors are in parentheses.

- We still need an estimate of θ in order to recover the parameters of the model.
- We already obtained one such estimate: $\widehat{\theta} = 8.28$
- Eaton and Kortum propose different methods in order to assess the stability of the estimates.

Estimates using wage data

- In a first step obtain the coefficients on the source countries S_i (Table III).
- Remember that

$$S_i = \frac{1}{\beta} T_i - \theta \ln w_i$$

- Model T_i : it will be related to national stocks of R&D and to human capital (years of schooling)
  - $S_i = \alpha_0 + \alpha_R \ln R_i - \alpha_H \frac{1}{H_i} - \theta \ln w_i + \tau_i$
  - R_i = Country i's stock of R&D
  - H_i = average years of schooling at i
  - w_i = wage adjusted by education at i
  - τ_i = error term
- $\widehat{\theta}_{OLS} = 2.84$ and $\widehat{\theta}_{2SLS} = 3.6$, but only 19 observations!!!

Estimates using price data

- $\ln \frac{X'_{ni}}{X'_{nn}} = -\theta \ln d_{ni} + S_i - S_n$
- Use D_{ni} instead of $\ln d_{ni}$
- They obtain $\widehat{\theta} = 12.86$

- Given an estimate of θ: obtain technology estimates of T_i and geographic barriers

$$S_i = \frac{1}{\beta} T_i - \theta \ln w_i$$

- Use estimates of S_i in Table III and data on wages
- Divide geographic proxy coefficients by θ to get estimates for d_{ni}
- Use $\widehat{\theta} = 8.28$ - it is in the middle of the range of estimates 2.84 to 12.86

TABLE VI

STATES OF TECHNOLOGY

Country	Estimated Source-country Competitiveness	Implied States of Technology $\theta = 8.28$	$\theta = 3.60$	$\theta = 12.86$
Australia	0.19	0.27	0.36	0.20
Austria	−1.16	0.26	0.30	0.23
Belgium	−3.34	0.24	0.22	0.26
Canada	0.41	0.46	0.47	0.46
Denmark	−1.75	0.35	0.32	0.38
Finland	−0.52	0.45	0.41	0.50
France	1.28	0.64	0.60	0.69
Germany	2.35	0.81	0.75	0.86
Greece	−2.81	0.07	0.14	0.04
Italy	1.78	0.50	0.57	0.45
Japan	4.20	0.89	0.97	0.81
Netherlands	−2.19	0.30	0.28	0.32
New Zealand	−1.20	0.12	0.22	0.07
Norway	−1.35	0.43	0.37	0.50
Portugal	−1.57	0.04	0.13	0.01
Spain	0.30	0.21	0.33	0.14
Sweden	0.01	0.51	0.47	0.57
United Kingdom	1.37	0.49	0.53	0.44
United States	3.98	1.00	1.00	1.00

Notes: The estimates of source-country competitiveness are the same as those shown in Table III. For an estimated parameter $\widehat{S}_i$, the implied state of technology is $T_i = (e^{\widehat{S}_i} w_i^{\theta})^{\beta}$. States of technology are normalized

TABLE VII

GEOGRAPHIC BARRIERS

Source of Barrier	Estimated Geography Parameters	Implied Barrier's % Effect on Cost $\theta = 8.28$	$\theta = 3.60$	$\theta = 12.86$
Distance [0, 375)	−3.10	45.39	136.51	27.25
Distance [375, 750)	−3.66	55.67	176.74	32.97
Distance [750, 1500)	−4.03	62.77	206.65	36.85
Distance [1500, 3000)	−4.22	66.44	222.75	38.82
Distance [3000, 6000)	−6.06	108.02	439.04	60.25
Distance [6000, maximum]	−6.56	120.82	518.43	66.54
Shared border	0.30	−3.51	−7.89	−2.27
Shared language	0.51	−5.99	−13.25	−3.90
European Community	0.04	−0.44	−1.02	−0.29
EFTA	0.54	−6.28	−13.85	−4.09
Destination country:				
Australia	0.24	−2.81	−6.35	−1.82
Austria	−1.68	22.46	59.37	13.94
Belgium	1.12	−12.65	−26.74	−8.34
Canada	0.69	−7.99	−17.42	−5.22
Denmark	−0.51	6.33	15.15	4.03
Finland	−1.33	17.49	44.88	10.94
France	0.22	−2.61	−5.90	−1.69
Germany	1.00	−11.39	−24.27	−7.49
Greece	−2.36	32.93	92.45	20.11
Italy	0.07	−0.86	−1.97	−0.56
Japan	1.59	−17.43	−35.62	−11.60
Netherlands	1.00	−11.42	−24.33	−7.51
New Zealand	0.07	−0.80	−1.83	−0.52
Norway	−1.00	12.85	32.06	8.10
Portugal	−1.21	15.69	39.82	9.84
Spain	−1.16	14.98	37.85	9.40
Sweden	−0.02	0.30	0.69	0.19
United Kingdom	0.81	−9.36	−20.23	−6.13
United States	2.46	−25.70	−49.49	−17.40

Notes: The estimated parameters governing geographic barriers are the same as those shown in Table III. For an estimated parameter $\hat{d}$, the implied percentage effect on cost is $100(e^{-\hat{d}/\theta} - 1)$.

Counterfactuals

- $\text{Welfare}_n = \text{Real GDP}_n = W_n = \frac{Y_n}{p_n^{\alpha}}$
- $\ln \frac{W_n^{'}}{W_n} = \ln \frac{Y_n^{'}}{Y_n} - \alpha \ln \frac{p_n^{'}}{p_n} \approx \left(\frac{w_n^{'} - w_n}{w_n} \right) \frac{w_n L_n}{Y_n} - \alpha \ln \frac{p_n^{'}}{p_n}$
    - Using $\ln \frac{Y_n^{'}}{Y_n} \approx \frac{Y_n^{'} - Y_n}{Y_n}$
- Baseline Wages: wages that are consistent with equations (16), (17) and (20), given data on manufacturing employment and GDP

$$p_n = \gamma \left[\sum T_i \left(d_{ni} w_i^{\beta} p_i^{1-\beta} \right) \right]^{-\frac{1}{\theta}}$$

$$\pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta}$$

$$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left((1-\beta) w_n L_n + \alpha \beta Y_n \right)$$

Counterfactuals

- Mobile Labor
  - Total GDP and wages are fixed
  - Total GDP is set to actual levels
  - Wages to baseline levels
- Immobile Labor
  - Non-manufacturing GDP and Manufacturing employment are fixed
  - Set manufacturing employment to actual level
  - Non-Manufacturing GDP = Actual GDP - (baseline wage)×(Actual employment in manufacturing)

Gains From Trade

- 2 Experiments
  - Look at Welfare COSTS of moving to autarky
  - Look at Welfare GAINS of lowering geographic barriers

Gains From Trade

- Move to Autarky: $d_{ni} \to \infty$
- Costs of moving to Autarky
- $\widehat{W} \in [-10\%; -0.25\%] = \left[\widehat{W}_{Belgium}, \widehat{W}_{Japan}\right]$
- Manufacturing labor rises everywhere, except in Germany, Japan, Sweden, UK
- These 4 have overall CA in manufactures

TABLE IX

THE GAINS FROM TRADE: RAISING GEOGRAPHIC BARRIERS

	Percentage Change from Baseline to Autarky					
	Mobile Labor			Immobile Labor		
Country	Welfare	Mfg. Prices	Mfg. Labor	Welfare	Mfg. Prices	Mfg. Wages
Australia	−1.5	11.1	48.7	−3.0	65.6	54.5
Austria	−3.2	24.1	3.9	−3.3	28.6	4.5
Belgium	−10.3	76.0	2.8	−10.3	79.2	3.2
Canada	−6.5	48.4	6.6	−6.6	55.9	7.6
Denmark	−5.5	40.5	16.3	−5.6	59.1	18.6
Finland	−2.4	18.1	8.5	−2.5	27.9	9.7
France	−2.5	18.2	8.6	−2.5	28.0	9.8
Germany	−1.7	12.8	−38.7	−3.1	−33.6	−46.3
Greece	−3.2	24.1	84.9	−7.3	117.5	93.4
Italy	−1.7	12.7	7.3	−1.7	21.1	8.4
Japan	−0.2	1.6	−8.6	−0.3	−8.4	−10.0
Netherlands	−8.7	64.2	18.4	−8.9	85.2	21.0
New Zealand	−2.9	21.2	36.8	−3.8	62.7	41.4
Norway	−4.3	32.1	41.1	−5.4	78.3	46.2
Portugal	−3.4	25.3	25.1	−3.9	53.8	28.4
Spain	−1.4	10.4	19.8	−1.7	32.9	22.5
Sweden	−3.2	23.6	−3.7	−3.2	19.3	−4.3
United Kingdom	−2.6	19.2	−6.0	−2.6	12.3	−6.9
United States	−0.8	6.3	8.1	−0.9	15.5	9.3

Notes: All percentage changes are calculated as $100\ln(x'/x)$ where x' is the outcome under autarky ($d_{ni} \to \infty$ for $n \neq i$) and x is the outcome in the baseline.

TABLE X

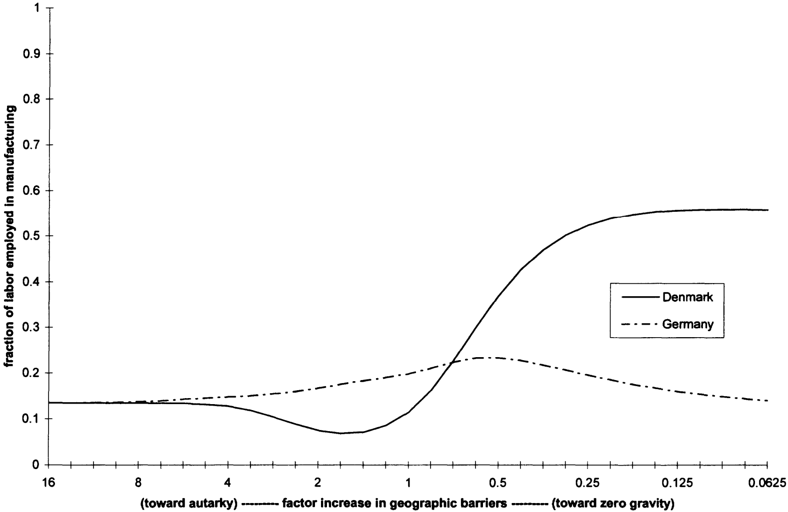
THE GAINS FROM TRADE: LOWERING GEOGRAPHIC BARRIERS

	Percentage Changes in the Case of Mobile Labor					
	Baseline to Zero Gravity			Baseline to Doubled Trade		
Country	Welfare	Mfg. Prices	Mfg. Labor	Welfare	Mfg. Prices	Mfg. Labor
Australia	21.1	−156.7	153.2	2.3	−17.1	−16.8
Austria	21.6	−160.3	141.5	2.8	−20.9	41.1
Belgium	18.5	−137.2	69.6	2.5	−18.6	68.8
Canada	18.7	−139.0	11.4	1.9	−14.3	3.9
Denmark	20.7	−153.9	156.9	2.9	−21.5	72.6
Finland	21.7	−160.7	172.1	2.8	−20.9	44.3
France	18.7	−138.3	−7.0	2.3	−16.8	15.5
Germany	17.3	−128.7	−50.4	1.9	−14.3	12.9
Greece	24.1	−178.6	256.5	3.3	−24.8	29.6
Italy	18.9	−140.3	6.8	2.2	−16.1	5.7
Japan	16.6	−123.5	−59.8	0.9	−6.7	−24.4
Netherlands	18.5	−137.6	67.3	2.5	−18.5	65.6
New Zealand	22.2	−164.4	301.4	2.8	−20.5	50.2
Norway	21.7	−161.0	195.2	3.1	−22.9	69.3
Portugal	22.3	−165.3	237.4	3.1	−22.8	67.3
Spain	20.9	−155.0	77.5	2.4	−18.0	−4.4
Sweden	20.0	−148.3	118.8	2.7	−19.7	55.4
United Kingdom	18.2	−134.8	3.3	2.2	−16.4	28.5
United States	16.1	−119.1	−105.1	1.2	−9.0	−26.2

Notes: All percentage changes are calculated as $100\ln(x'/x)$ where x' is the outcome under lower geographic barriers and x is the outcome in the baseline.

Technology vs Geography

- In this exercise we are interested in the pattern of specialization: mobile labor
- If zero gravity
  - Fraction of employment in manufacturing is proportional to $\frac{T_i}{w_i^{\frac{1}{1+\theta\beta}}}$
- If autarky
  - Fraction of manufacturing employment is α
- In between autarky and zero gravity, the pattern of specialization as we drop geographic barriers is different for large and small countries



fraction of labor employed in manufacturing
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
16
8
4
2
1
0.5
0.25
0.125
0.0625
(toward autarky) -------- factor increase in geographic barriers -------- (toward zero gravity)
Denmark
Germany

Benefits From Foreign Technology

- How much does trade spread the benefit of a local improvement in technology?
- Suppose T_i increases in 20% is the US and Germany (separately)
- Mobile labor: no income effect, so welfare increases everywhere
- Immobile labor: negative income effect through lower wages in manufacturing

TABLE XI

THE BENEFITS OF FOREIGN TECHNOLOGY

	Welfare Consequences of Improved Technology			
	Higher U.S. State of Technology		Higher German State of Technology	
Country	Mobile Labor	Immobile Labor	Mobile Labor	Immobile Labor
Australia	27.1	14.9	12.3	4.4
Austria	9.3	2.9	61.8	5.4
Belgium	13.2	3.0	50.7	4.8
Canada	87.4	19.9	9.3	1.3
Denmark	12.2	6.2	62.5	7.1
Finland	11.3	4.3	37.5	3.0
France	10.1	4.2	39.2	3.0
Germany	9.7	−11.6	100.0	100.0
Greece	14.0	18.3	38.9	8.0
Italy	9.7	3.9	38.4	3.0
Japan	6.6	−0.8	5.9	−0.2
Netherlands	12.8	6.8	63.5	8.3
New Zealand	33.8	13.5	15.6	3.9
Norway	13.2	11.7	43.8	6.1
Portugal	14.3	8.6	39.6	4.7
Spain	9.6	7.0	27.3	3.3
Sweden	12.8	1.1	42.7	2.3
United Kingdom	14.6	0.5	38.3	1.6
United States	100.0	100.0	9.7	1.4

Notes: All numbers are expressed relative to the percentage welfare gain in the country whose technology expands. Based on a counterfactual 20 per cent increase in the state of technology for either the United States