# Technology, Geography, and Trade <br> Jonathan Eaton and Samuel Kortum 

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## Goal

- Develop a model incorporating realistic geographic features into General Equilibrium
- Derive structural equations for bilateral trade
- Estimate parameters of the model
- Counterfactuals
- Eaton and Kortum are not the first to give the gravity equation a structural interpretation.
- Helpman (1987)
assumes monopolistic competition with firms in different countries choosing to produce differentiated products. Implication is that each source should export a specific good everywhere.

Haveman and Hummels (2002) report evidence to the contrary.

- In Eaton and Kortum (2002), more than one country may produce the same good, with individual countries supplying different parts of the world.


## Model

- Building on Dornbusch, Fischer, Samuelson (1977) model of Ricardian trade with a continuum of goods, 2 country model only.
- Countries have differential access to technology, efficiency varies across commodities and countries.
- Denote country i’s efficiency in producing $\operatorname{good} j \in[0,1]$ as $\mathrm{z}_{\mathrm{i}}(j)$.
- Denote input cost in country i as $\mathrm{c}_{\mathrm{i}}$
(Later c will be broken into the cost of labor and of intermediate inputs).
- Cost of a bundle of inputs is the same across commodities within a country (because country inputs are mobile across activities and activities do not differ in their input shares).
- With CRS, the cost of producing a unit of good j in country i is $\frac{c_{i}}{z_{i}(j)}$.
- Geographic barriers: Iceberg transportation cost, delivering a unit from country i to country $n$ requires producing $d_{n i}$ units in i, ( $d_{i i}=1$ for all i , $d_{n i}>1$ for $n \neq i$.).
- Assume the triangle inequality, for any 3 countries $\mathrm{i}, \mathrm{k}$ and n holds: $d_{n i} \leq d_{n k} \cdot d_{k i}$.
- Delivering a unit of good j produced in country i to country n costs: $p_{n i}(j)=\left(\frac{c_{i}}{z_{i}(j)}\right) \cdot d_{n i}$
- Perfect Competition: $p_{n i}(j)$ is what buyers in country n would pay if they chose to buy good j from country i .
- Shopping around the world for the best deal, yields price of $j$ :

$$
p_{n}(j)=\min \left\{p_{n i}(j), i=1, \ldots . N\right\},
$$

where N is the number of countries.

- Facing these prices, buyers (final consumers or firms buying intermediate inputs) purchase goods in amounts Q(j) to max CES objective:

$$
U=\left[\int_{0}^{1} Q(j)^{\frac{\sigma-1}{\sigma}} d j\right]^{\frac{\sigma}{\sigma-1}}
$$

where $\mathrm{S}>0$ is the elasticity of substitution.

- Maximization is subject to a budget constraint. It aggregates across buyers in country n to $\mathrm{X}_{\mathrm{n}}$, country n's total spending.
- Probabilistic representation of technologies: country i's efficiency in producing good $j$ is the realization of a random variable $\mathrm{Z}_{\mathrm{i}}$.
- $\mathrm{Z}_{\mathrm{i}}$ is drawn independently for each j from its country specific distribution: $F_{i}(z)=\operatorname{Pr}\left[Z_{i} \leq z\right]$.
- The cost of purchasing a particular good from country i in country n is the realization of the random variable: $P_{n i}(j)=\left(\frac{c_{i}}{Z_{i}}\right) \cdot d_{n i}$
- The lowest price is the realization of: $P_{n}(j)=\min \left\{P_{n i} ; i=1, \ldots . . N\right\}$.
- $\pi_{n i}$ is the probability that country i supplies a particular good to country n (probability that i's price turns out to be the lowest).
- Probability theory of extremes provides a form for $F_{i}(z)$ that yields a simple expression for $\pi_{n i}$ and for the resulting distribution of prices.


## Aside:

- Kortum (1997) and Eaton and Kortum (1999) show how a process of innovation and diffusion can give rise to Frechet distribution, with $\mathrm{T}_{\mathrm{i}}$ reflecting a country's stock of original or imported ideas.
- Since the actual technique that would ever be used in any country represents the best discovered to date for producing each good, it makes sense to represent technology with an extreme value distribution.
- The distribution of the maximum of a set of draws can converge to one of only three distributions:
- the Weibull
- the Gumbell
- the Frechet

Only for Frechet does the distribution of prices inherit an extreme value distribution.

Therefore it was chosen.

Frechet distribution: $F_{i}(z)=e^{-T_{i} z^{-\theta}}$, where $\mathrm{T}_{\mathrm{i}}>0$ and $\varphi>1$.

Theta=1. 2
T=100

$F_{i}(z)=e^{-T_{i} z^{-\theta}}$ where $\mathrm{T}_{\mathrm{i}}>0$ and $\phi 1$
Treat the distributions as independent across countries.

- $\mathrm{T}_{\mathrm{i}}$ is country specific parameter governing the location of the distribution. (A bigger $\mathrm{T}_{\mathrm{i}}$ implies that a high efficiency draw for any good j is more likely).

Think about $T_{i}$ as country i's state of technology reflecting country i's absolute advantage across a continuum of goods.
$F_{i}(z)=e^{-T_{i} z^{-\theta}}$ where $\mathrm{T}_{\mathrm{i}}>0$ and $\propto \perp 1$

- qparameter is common to all countries and reflects the amount of variation within distribution. (Bigger qimplies less variability.)

Think about $q$ as a parameter regulating heterogeneity across goods in countries’ relative efficiencies. It governs comparative advantage within a continuum of goods.

Resulting distribution of prices in different countries:
Country i presents country $n$ with a distribution of prices:

$$
\begin{aligned}
& G_{n i}(p)=\operatorname{Pr}\left[P_{n i} \leq p\right]=1-F_{i}\left(\frac{c_{i} \cdot d_{n i}}{p}\right) \\
& G_{n i}(p)=1-e^{-\left[T_{i}\left(c_{i} \cdot d_{i j}\right)^{-\theta}\right] \cdot p^{\theta}}
\end{aligned}
$$

How to get it:
Recall: $P_{n i}=\frac{c_{i} \cdot d_{n i}}{Z_{i}}$ and $F_{i}(z)=\operatorname{Pr}\left[Z_{i} \leq z\right]=e^{-T_{i} z^{-\theta}}$.
Define:

$$
\begin{aligned}
G_{n i}(p)=\operatorname{Pr}\left[P_{n i} \leq p\right] \\
\begin{aligned}
G_{n i}(p)=\operatorname{Pr}\left[\frac{c_{i} \cdot d_{n i}}{Z_{i}} \leq p\right] & =1-\operatorname{Pr}\left[Z_{i} \leq \frac{c_{i} \cdot d_{n i}}{p}\right] \\
& =1-F\left[\frac{\left.c_{i} \cdot d_{n i}\right]}{p}\right] \\
& =1-e^{-T_{i}\left(\frac{c_{i} \cdot d_{n i}}{p}\right)^{-\theta}}=1-e^{-T \cdot\left(c_{i} \cdot d_{n i}\right)^{-\theta} \cdot p^{o}}
\end{aligned}
\end{aligned}
$$

The lowest price for a good in country $n\left(P_{n}\right)$ will be less than $p$ unless each source's price is greater than $p$.

Therefore: the distribution $G_{n}(p)=\operatorname{Pr}\left[P_{n} \leq p\right]$ for what country n actually buys is:

$$
G_{n}(p)=1-\prod_{i=1}^{N}\left[1-G_{n i}(p)\right]
$$

Inserting $\mathrm{G}_{\mathrm{ni}}$, price distribution inherits form of $\mathrm{G}_{\mathrm{ni}}(\mathrm{p})$ :

$$
G_{n}(p)=1-e^{-\phi_{n} \cdot p^{\theta}}
$$

where $\phi_{n}=\sum_{i=1}^{N} T_{i}\left(c_{i} \cdot d_{n i}\right)^{-\theta}$

The price parameter $\phi_{n}=\sum_{i=1}^{N} T_{i}\left(c_{i} \cdot d_{n i}\right)^{-\theta}$ summarizes how:

1. states of technology around the world,
2. inputs costs around the world,
3. and geographic barriers
govern prices in each country n.
Special cases:
a) in zero-gravity world with no geographic barriers $\mathrm{d}_{\text {ni }}=1$ for all n and i
$F$ is the same everywhere and the law of one price holds for each good
b) in autarky, with prohibitive geographic barriers $\mathrm{F}_{\mathrm{n}}$ reduces to $T_{n} \cdot c_{n}^{-\theta}$

Country n's own state of technology downweighted by its input cost.

Price distribution has 3 important properties:

1. $\pi_{n i}$ (the probability that country i provides a good at the lowest price in country n)

$$
\begin{aligned}
& \pi_{n i}=\operatorname{Pr}\left[P_{n i}(j) \leq \min \left\{P_{n s}(j), s \neq i\right\}\right] \\
& \pi_{n i}=\frac{T_{i} \cdot\left(c_{i} \cdot d_{n i}\right)^{-\theta}}{\phi_{n}}
\end{aligned}
$$

Continuum of goods implies, $\pi_{n i}$ is also the fraction of goods that country n buys from country i .
2. Can be shown:

The price of a good that country n actually buys from any country i also has the distribution $\mathrm{G}_{\mathrm{n}}$.

$$
\forall i \operatorname{Pr}\left[\mathrm{P}_{\mathrm{n}}<p \mid P_{n}=P_{n i}\right]=G_{n}(p) .
$$

For goods that are purchased, conditioning on the source has no bearing on the good's price.

The prices of goods actually sold in a country have the same distribution regardless of where they come from.
Corollary:
Country n's average expenditure per good does not vary by source.
Hence the fraction of goods that country n buys from country $\mathrm{i}, \pi_{n i}$ is also the fraction of its expenditure on goods from country i:

$$
\pi_{n i}=\frac{X_{n i}}{X_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\phi_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\sum_{k=1}^{N} T_{k}\left(c_{k} d_{n k}\right)^{-\theta}}
$$

where $X_{n}$ is country $n$ 's total spending and $X_{n i}$ is spent (c.i.f.) on goods from i.
$\frac{X_{n i}}{X_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\phi_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\sum_{k=1}^{N} T_{k}\left(c_{k} d_{n k}\right)^{-\theta}}$
Notice: this already resembles gravity equation.
Bilateral trade is related to the importer's total expenditure and to geographic barriers.
3. The exact price index for the CES function is:

$$
p_{n}=\gamma \cdot \phi_{n}^{-1 / \theta}
$$

where $\gamma=\left[\Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\right]^{\frac{1}{1-\sigma}}$ and Gis the Gamma function.

Connection between trade flows and price differences:
Divide $\frac{X_{\text {ni }}}{X_{n}}$ by $\frac{X_{i i}}{X_{i}}$ and substitute for F from price index $\mathrm{p}_{\mathrm{n}}$.

$$
\frac{X_{n i} / X_{n}}{X_{i i} / X_{i}}=\frac{\phi_{i}}{\phi_{n}} d_{n i}^{-\theta}=\left(\frac{p_{i} d_{n i}}{p_{n}}\right)^{-\theta}
$$

(Notice: $p_{i}$ and $p_{n}$ above are price indices for country i and n, not prices of some single good.)

Call the left hand side "country i’s normalized import share in country n."
(Triangle inequality implies, it never exceeds one.)
$\frac{X_{n i} / X_{n}}{X_{i i} / X_{i}}=\frac{\phi_{i}}{\phi_{n}} d_{n i}^{-\theta}=\left(\frac{p_{i} d_{n i}}{p_{n}}\right)^{-\theta}$

- As overall prices in market $n$ fall relative to prices in market i or as n becomes more isolated from i (higher $\mathrm{d}_{\mathrm{ni}}$ ) i's normalized share in $n$ declines.
- As the force of comparative advantage weakens (higher q), normalized import shares become more elastic w.r.t. the average relative price and to geographic barriers.
- A higher qmeans relative efficiencies are more similar across goods. There are fewer efficiency outliers that overcome differences in average prices or geographic barriers.

Empirical exploration of the trade-price relationship:
$\frac{X_{n i} / X_{n}}{X_{i i} / X_{i}}=\frac{\phi_{i}}{\phi_{n}} d_{n i}^{-\theta}=\left(\frac{p_{i} d_{n i}}{p_{n}}\right)^{-\theta}$
A)

Measure left-hand side by data on bilateral trade in manufactures among 19 OECD countries in 1990. (normalized import shares never exceed 0.2)

Crude proxy for $\mathrm{d}_{\mathrm{ni}}$ is distance.

Normalized import shares against distance between the corresponding country-pair (logarthmic scale).

Ignoring the price indices in $\frac{X_{n i} / X_{n}}{X_{i i} / X_{i}}=\frac{\phi_{i}}{\phi_{n}} d_{n i}^{-\theta}=\left(\frac{p_{i} d_{n i}}{p_{n}}\right)^{-\theta}$.
We will see the resistance that geography imposes on trade.

Inverse correlation.

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FIGURE 1.-Trade and geography.
$\frac{X_{n i} / X_{n}}{X_{i i} / X_{i}}=\frac{\phi_{i}}{\phi_{n}} d_{n i}^{-\theta}=\left(\frac{p_{i} d_{n i}}{p_{n}}\right)^{-\theta}$
B)

Retail prices in each of 19 OECD countries of 50 selected manufactured products were used to construct price measure.

Price measure: $\ln \left(\frac{p_{i} d_{n i}}{p_{n}}\right)$
Negative relationship between normalized import shares against price measure as model predicts.

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Figure 2.-Trade and prices.

Equilibrium input costs (so far input costs $\mathrm{c}_{\mathrm{i}}$ were taken as given).

Strategy:

1. Decompose the input bundle into labor and intermediates.
2. Determinate prices of intermediates, given wages.
3. Determination of wages.

## Production

- Production combines labor and intermediate input, with labor having a constant share b.
- Intermediates comprise the full set of goods combined according to the CES aggregator.
- The overall price index in country $\mathrm{i}, \mathrm{p}_{\mathrm{i}}$, becomes appropriate index of intermediate goods prices there.
- The cost of an input bundle in country i:

$$
c_{i}=W_{i}^{\beta} \cdot p_{i}^{1-\beta},
$$

where $\mathrm{w}_{\mathrm{i}}$ is the wage in country i .
Notice: $\mathrm{c}_{\mathrm{i}}\left(\mathrm{F}_{\mathrm{i}}\right)$ through $\mathrm{p}_{\mathrm{i}}$ and $\mathrm{F}_{\mathrm{i}}\left(\sum_{i=1}^{N} T_{i}\left(c_{i}\right)^{-\theta}\right)$.

Determination of price levels around the world:
Substituting $c_{i}=W_{i}^{\beta} \cdot p_{i}^{1-\beta}$ into $\phi_{n}=\sum_{i=1}^{N} T_{i}\left(c_{i} \cdot d_{n i}\right)^{-\theta}$ and applying $p_{n}=\gamma \cdot \phi_{n}^{-1 / \theta}$,
we can get system of equations:

$$
p_{n}=\gamma \cdot\left[\sum_{i=1}^{N} T_{i}\left(d_{n i} w_{i}^{\beta} p_{i}^{1-\beta}\right)^{-\theta}\right]^{-1 / \theta}
$$

Numerical methods necessary.

Plug $C_{i}=w_{i}^{\beta} \cdot p_{i}^{1-\beta}$ into $\frac{X_{n i}}{X_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\phi_{n}}=\frac{T_{i}\left(c_{i} d_{n i}\right)^{-\theta}}{\sum_{k=1}^{N} T_{k}\left(c_{k} d_{n k}\right)^{-\theta}}$
to get expression for trade shares as functions of wages and parameters of the model:

$$
\frac{X_{n i}}{X_{n}}=\pi_{n i}=T_{i}\left(\frac{\gamma d_{n i} w_{i}^{\beta} p_{i}^{1-\beta}}{p_{n}}\right)^{-\theta}
$$

Labor market equilibrium
(They show how manufacturing fits into the larger economy.)

Denote: $\mathrm{L}_{\mathrm{i}}$ manufacturing workers $\mathrm{X}_{\mathrm{n}}$ total spending on manufactures.

$$
w_{i} L_{i}=\beta \sum_{n=1}^{N} \pi_{n i} X_{n}
$$

Manufacturing labor income in country i is labor's share of country i's manufacturing exports around the world, including sales at home.

Denote $\mathrm{Y}_{\mathrm{n}}$ aggregate final expenditures and a the fraction spent on manufactures.

Total manufacturing expenditures are:

$$
X_{n}=\underbrace{\begin{array}{l}
\text { Final } \\
\text { consumption } \\
\text { of } \\
\text { manufactures. }
\end{array}}_{\begin{array}{l}
\text { Demand for } \\
\text { manufactures } \\
\text { as } \\
\text { intermediates } \\
\text { by the } \\
\text { manufacturing } \\
\text { sector itself. }
\end{array}}
$$

Aggregate final expenditures $\mathrm{Y}_{\mathrm{n}}$ consist of value-added in manufacturing $\mathrm{w}_{\mathrm{n}} \mathrm{L}_{\mathrm{n}}$ plus income generated in nonmanufacturing $Y_{n}{ }^{0}$.

$$
Y_{n}=w_{n} L_{n}+Y_{n}^{O}
$$

Assume nonmanufacturing output can be traded costlessly (not innocuous), and use it as numeraire.

To close the model simply, consider two polar cases:

1. Labor is mobile
(Workers can move freely between manufacturing and nonmanufacturing.)
Wage $\mathrm{w}_{\mathrm{n}}$ given by productivity in nonmanufacturing and total income $\mathrm{Y}_{\mathrm{n}}$ is exogenous.

Combining equations $w_{i} L_{i}=\beta \sum_{n=1}^{N} \pi_{n i} X_{n}$ and $X_{n}=\frac{1-\beta}{\beta} w_{n} L_{n}+\alpha Y_{n}$
get $\quad w_{i} L_{i}=\sum_{n=1}^{N} \pi_{n i}\left[(1-\beta) w_{n} L_{n}+\alpha \beta Y_{n}\right]$
that determines manufacturing employment $\mathrm{L}_{\mathrm{i}}$.
2. Labor is immobile

- The number of manufacturing workers in each country is fixed at $\mathrm{L}_{\mathrm{n}}$.
- Nonmanufacturing income $Y_{n}^{o}$ is exogenous.

Combining $w_{i} L_{i}=\beta \sum_{n=1}^{N} \pi_{n i} X_{n}$ and $X_{n}=\frac{1-\beta}{\beta} w_{n} L_{n}+\alpha Y_{n}$ we get:

$$
w_{i} L_{i}=\sum_{n=1}^{N} \pi_{n i}\left[(1-\beta+\alpha \beta) w_{n} L_{n}+\alpha \beta Y_{n}^{o}\right]
$$

which determines manufacturing wages $\mathrm{w}_{\mathrm{i}}$.
The full general equilibrium is comprised by:

$$
\begin{aligned}
& p_{n}=\gamma \cdot\left[\sum_{i=1}^{N} T_{i}\left(d_{n i} w_{i}^{\beta} p_{i}^{1-\beta}\right)^{-\theta}\right]^{-1 / \theta} \\
& \frac{X_{n i}}{X_{n}}=\pi_{n i}=T_{i}\left(\frac{\gamma d_{n i} w_{i}^{\beta} p_{i}^{1-\beta}}{p_{n}}\right)^{-\theta} \\
& w_{i} L_{i}=\sum_{n=1}^{N} \pi_{n i}\left[(1-\beta) w_{n} L_{n}+\alpha \beta Y_{n}\right]
\end{aligned}
$$

(Manufacturing employment for labor mobility.)
$w_{i} L_{i}=\sum_{n=1}^{N} \pi_{n i}\left[(1-\beta+\alpha \beta) w_{n} L_{n}+\alpha \beta Y_{n}^{O}\right]$
(Manufacturing wages for immobile case.)

# Rich interaction among prices in different countries 

 makes analytic solution unattainable.Estimates
Estimates with source effects
(characteristics of trading partners and distance between them).

$$
\frac{X_{n i}}{X_{n}}=\pi_{n i}=T_{i}\left(\frac{\gamma d_{n i} w_{i}^{\beta} p_{i}^{1-\beta}}{p_{n}}\right)^{-\theta}
$$

From estimating it, we can learn about states of technology and geographic barriers.
Normalize by the importer's home sales (divide by $\mathrm{X}_{\mathrm{n}} / \mathrm{X}_{\mathrm{n}}$ )

$$
\frac{X_{n i}}{X_{n n}}=\frac{T_{i}}{T_{n}}\left(\frac{w_{i}}{w_{n}}\right)^{-\theta \beta}\left(\frac{p_{i}}{p_{n}}\right)^{-\theta(1-\beta)} d_{n i}^{-\theta}
$$

After a few other rearranging steps, finally get equation to estimate:

$$
\ln \left(\frac{X_{n i}^{\prime}}{X_{n n}^{i}}\right)=-\theta \cdot \ln d_{n i}+\frac{1}{\beta} \ln \frac{T_{i}}{T_{n}}-\theta \ln \frac{w_{i}}{w_{n}}
$$

where:
$\ln X_{n i}^{\prime}=\ln X_{n i}-\frac{1-\beta}{\beta} \ln \left(\frac{X_{i}}{X_{i i}}\right)$.
Defining $S_{i} \equiv \frac{1}{\beta} \ln T_{i}-\theta \cdot \ln w_{i}$
Think of $S_{i}$ as a measure of country i's competitiveness, its state of technology adjusted for its labor costs.

$$
\ln \left(\frac{X_{n i}^{\prime}}{X_{n n}^{\prime}}\right)=-\theta \cdot \ln d_{n i}+S_{i}-S_{n}
$$

Left-hand side is calculated:

- The same data on bilateral trade of 19 OECD countries.
(How many observations? 19*19-19=361-19=342.
- Set $\mathrm{b}=0.21$ (the average labor share in gross manufacturing production in the sample).
- $\mathrm{X}_{\mathrm{n}}$ includes imports from all countries in the world since price of intermediates reflect imports from all sources.

$$
\ln \left(\frac{X_{n i}^{\prime}}{X_{n n}^{\prime}}\right)=-\theta \cdot \ln d_{n i}+S_{i}-S_{n}
$$

Right-hand side is calculated:

- $\mathrm{S}_{\mathrm{i}}$ captured as the coefficients on source-country dummies.
- Proxies for $\mathrm{d}_{\mathrm{ni}}$ (reflecting proximity, language and treaties).

For all $n \neq i$ we have:

$$
\ln d_{n i}=d_{k}+b+l+e_{h}+m_{n}+\delta_{n i}
$$

$\ln d_{n i}=d_{k}+b+l+e_{h}+m_{n}+\delta_{n i}$
where dummies are:

- $\mathrm{d}_{\mathrm{k}}(\mathrm{k}=1, \ldots .6)$ is the effect of distance between n and i lying in the $\mathrm{k}^{\text {th }}$ interval,
- $b$ is the effect of $n$ and $i$ sharing a border,
- l is the effect of $n$ and $i$ sharing a language,
- $\mathrm{e}_{\mathrm{h}}(\mathrm{h}=1,2)$ is the effect of n and i both belonging to trading area $h$ (EFTA and EC),
- $\mathrm{m}_{\mathrm{n}}(\mathrm{n}==1, \ldots 19)$ is an overall destination effect,
- $\delta_{n i}$ is error term capturing geographic barriers arising from all other factors.
- Error term $\delta_{n i}$ is decomposed to capture potential reciprocity in geographic barriers:

$$
\delta_{n i}=\delta_{n i}^{2}+\delta_{n i}^{1}
$$

$\delta_{n i}^{2}$ the country-pair specific component affects twoway trade, such that $\delta_{n i}^{2}=\delta_{i n}^{2}$, $\delta_{n i}^{1}$ affects one-way trade.

GLS estimation of:

$$
\ln \left(\frac{X_{n i}^{\prime}}{X_{m n}^{\prime}}\right)=S_{i}-S_{n}-\theta m_{n}-\theta d_{k}-\theta b-\theta l-\theta e_{h}+\delta_{n i}^{2}+\delta_{n i}^{1}
$$

- Results: estimates of $\mathrm{S}_{\mathrm{i}}$ indicate Japan is the most competitive country in 1990, Belgium and Greece the least competitive.
- Distance inhibits trade a lot.
- The EC and EFTA do not play a major role.

TABIE III
BILATERAE TRADE EOUATION

| Variablic |  |  |  | cas. |  | s.e. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Distance [0,375) | $-6 d_{1}$ |  |  | -3.10 |  | (0.16) |
| Distance $\{375,750)$ | $-\theta d t_{2}$ |  |  | -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] | $-\theta d^{\circ}$ |  |  | -6.56 |  | (0.10) |
| Shared borcter | $-9 b$ |  |  | 0.30 |  | (0.14) |
| Shared languazge | $-\theta I$ |  |  | 0.51 |  | (0.15) |
| European Community | $-\theta e_{2}$ |  |  | 0.04 |  | (0.13) |
| EFTA | $-\theta e_{2}$ |  |  | 0.54 |  | (0.19) |
| Coumtry | Sinuree Coumtry |  |  | Destimation Country |  |  |
|  |  | con. | s.e. |  | ent. | 5.e. |
| Australia | $S_{1}$ | 0.19 | (0.15) | $-8 m r_{1}$ | 0.24 | (0.27) |
| Austria | $S_{2}$ | $-1.16$ | (0.12) | $-8 m m_{2}$ | $-1.68$ | (0.21) |
| Belgium | $S_{3}$ | -3.3.4 | (0.11) | $-8 m_{3}$ | 1.12 | (0.19) |
| Canada | $S_{2}$ | 0.41 | (0.14) | $-8 m m_{4}$ | 0.69 | (0.25) |
| Denmark | $S_{5}$ | $-1.75$ | (0.12) | $-8 \mathrm{~mm}$ | $-0.51$ | (0.19) |
| Finland | $S_{6}$ | $-0.52$ | (0.12) | $-\theta m{ }^{\text {c }}$ | $-1.33$ | (0.22) |
| France | $S_{7}$ | 1.28 | (0.11) | - 8 mm | 0.22 | (0.19) |
| Germany | $S_{8}$ | 2.35 | (0.12) | $-\theta m m_{n}$ | 1.00 | (0.19) |
| Greece | $S_{9}$ | $-2.81$ | (0.12) | $-8 m z$ | $-2.36$ | (0.20) |
| Italy | $S_{3 n}$ | 1.78 | (0.11) | $-\theta m m_{10}$ | 0.07 | (0.19) |
| Japan | $S_{12}$ | 4.20 | (0.13) | $-\theta m r_{11}$ | 1.59 | (0.22) |
| Netherlands | $5_{12}$ | $-2.19$ | (0.11) | $-\theta m_{12}$ | 1.00 | (0.19) |
| New Zealand | $S_{33}$ | $-1.20$ | (0.15) | $-\theta m r_{3}$ | 0.07 | (0.27) |
| Norway | $S_{16}$ | $-1.35$ | (0.12) | $-\theta \pi m r_{\text {a }}$ | $-1.00$ | (0.21) |
| Portugal | $S_{15}$ | $-1.57$ | (0.12) | $-\theta m m_{15}$ | $-1.21$ | (0.21) |
| Spain | $S_{56}$ | 0.30 | (0.12) | $-9 \mathrm{mrs}$ | $-1.16$ | (0.19) |
| Sweden | $S_{17}$ | 0.01 | (0.12) | $-9 m \mathrm{~m}$ | $-0.02$ | (0.22) |
| United Kingdom | $S_{18}$ | 1.37 | (0.12) | $-\theta m r_{\text {1x }}$ | 0.81 | (0.19) |
| United States | $5_{19}$ | 3.98 | (0.14) | $-8 \mathrm{~mm}$ | 2.46 | (0.25) |
| Total Sum of squanes | 2937 |  | Error | iance: |  |  |
| Sum of squared residuals | 71 |  | Two-w | $\left(\theta^{2} \omega_{2}^{2}\right)$ |  | 0.05 |
| Number of observations | 3.42 |  | One-w | $\left(\theta^{2} \sigma_{3}^{2}\right)$ - |  | 0.16 |




Counterfactuals:
Highly stylized model (suppressed heterogeneity in geographic barriers across manufacturing goods)

- The Gains From Trade
- The Benefits of Foreign Technology
- Eliminating Tariffs
- Trade diversion in the EC
- US Unilateral Tariff Elimination If US remove tariffs on its own, everyone benefits except the USA. Biggest winner is Canada if labor is mobile.
- General Multilateral Tariff Elimination
- Technology vs. Geography

For smaller countries manufacturing shrinks as geographic barriers diminish from their autarky level. Production shifts to larger countries where inputs are cheaper. As geographic barriers continue to fall, however, the forces of technology take over and the fraction of the labor force in manufacturing grows, often exceeding its autarky level.

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Figure 3.-Specialization, technology, and geography.

## Conclusion

- Ricardian model capturing the importance of geographic barriers in curtailing trade flows.
- The model delivers equations relating bilateral trade around the world to parameters of technology and geography.

