Technology, Geography, and Trade

By Jonathan Eaton and Samuel Kortum, *Econometrica, 2002.*

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Putting Ricardo to Work

Jonathan Eaton and Samuel Kortum, *Journal of Economic Perspectives, 2012.*

- basic model: two countries with two goods
- two countries with more goods(countable)
  a chain of comparative advantage[stairway]

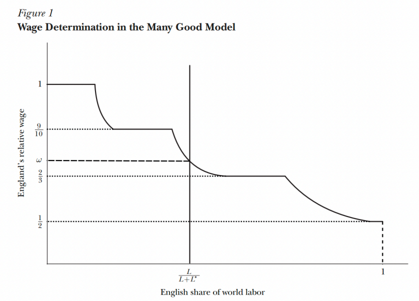

图: Two countries with n discrete goods

Putting Ricardo to Work

Jonathan Eaton and Samuel Kortum, *Journal of Economic Perspectives, 2012.*

- two countries with more goods(countless)
  Dornbusch,Fisher,and Samuelson(1977)
  A continuum of goods from 0 to 1:the set of goods correspond to all the points on an interval between 0 and 1.
  a chain of comparative advantage[ramp]

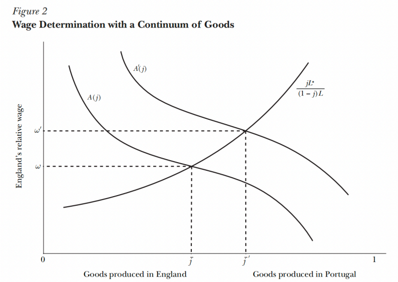

图: Two countries with a continuum of goods

Putting Ricardo to Work

Jonathan Eaton and Samuel Kortum,*Journal of Economic Perspectives,2012.*

- Many countries with many goods(countless)
  Problem: In this setting, chains no longer work.
  –**Where DFS stops and EK starts**

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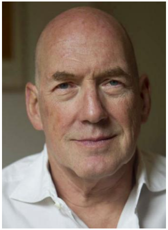
1 About Authors:Jonathan Eaton



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1 About Authors:Samuel Kortum

图: Samuel Kortum

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2 The Model

$z_i(j)$: country i's efficiency in producing good j$\in [0,1]$
c_i : input cost in country i
$\frac{c_i}{z_i(j)}$: the cost of a unit of good j in country i

Geographic barriers: Samuelson's standard and convenient "iceberg" assumption–delivering a unit from country i to country n requires producing d_{ni} units in i, which satisfies

$$d_{ni} \leq d_{nk} d_{ki} (\text{triangle inequation}), d_{ii} = 1.$$

2 The Model

Delivering a unit of good j produced in country i to country n costs:

$$p_{ni}(j) = \left(\frac{c_i}{z_i(j)} \right) d_{ni} \tag{1}$$

perfect competition assumption

$$p_n(j) = \min \{ p_{ni}(j); i = 1, \ldots, N \} \tag{2}$$

where N is the number of countries

$$U = \left[\int_0^1 Q(j)^{(\sigma-1)/\sigma} dj \right]^{\sigma/(\sigma-1)} \tag{3}$$

the elasticity of substitution is $\delta > 0$

2.1 Technology

A probabilistic representation of technologies $F_i(z) = Pr[Z_i \leq z]$
We assume that country i's efficiency distribution is Fréchet(the Type II extreme value distribution) Go

$$F_i(z) = e^{-T_i z^{-\theta}} \tag{4}$$

where $T_i > 0$ and $\theta > 1$
T_i :reflects country i' s state of technology(absolute advantage)
θ : regulates heterogeneity across goods in countries' relative efficiencies(comparative advantage)

2.2 Prices

Distribution of prices $G_{ni}(p) = Pr[P_{ni} \leq p] = 1 - F_i(c_i d_{ni}/p)$

$$G_{ni}(p) = 1 - e^{-\left[T_i (c_i d_{ni})^{-\theta}\right] p^{\theta}} \tag{5}$$

The distribution for what country n actually buys Go

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

$$G_n(p) = 1 - e^{-\Phi_n p^{\theta}} \tag{6}$$

the price parameter Go

$$\Phi_n = \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta} \tag{7}$$

2.2 Prices

Three useful properties of the price distributions:

(a)The probability that country i provides a good at the lowest price in country n Go

$$\pi_{ni} = \frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n} \tag{8}$$

(b)The price of a good that country n actually buys from any country i also has the distribution $G_n(p)$ Go

(c)The exact price index for the CES objective function,assuming $\delta < 1 + \theta$ Go

$$\pi_n = \gamma \Phi_n^{-1/\theta} \tag{9}$$

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

2.3 Trade Flows

To link the model to data on trade shares , we focus on the fraction of goods that country n buys from country i:

$$\frac{X_{ni}}{X_n} = \pi_{ni} = \frac{T_i(c_i d_{ni})^{-\theta}}{\Phi_n} = \frac{T_i(c_i d_{ni})^{-\theta}}{\sum_{k=1}^{N} T_k(c_k d_{nk})^{-\theta}} \tag{10}$$

X_n is country n's total spending X_{ni} is spent on goods from i

Note that π_{ni}, till now, has three implications:

- the probability that country i provides a good at the lowest price
- the fraction of goods that country n buys form country i
- the proportion of country i in the price parameter Φ_n

*In *Section:The Gravity Equation*, we will discuss how equation (10) relates to the existing literature on bilateral trade.

Before: taking c_i as given
Now: to conduct later counterfactual experiment, adjustment of input costs to a new equilibrium is crucial

Then, to close this adjusted model, we will decompose the input bundle into labor + intermediates.

And finally, how wages are defined.

Assume: Production combines labor and intermediate inputs, with labor having a constant share β.
The cost of an input bundle in country *i* is thus:

$$c_i = w_i^{\beta} p_i^{1-\beta} \tag{14}$$

Then, through equation (7) (9) (10) (14), we deliver an expression relating the *real wage* to the state of technology parameter T_i and share of purchases from home π_i: Go

$$\frac{w_i}{p_i} = \gamma^{-1/\beta} \left(\frac{T_i}{\pi_{ii}} \right)^{1/\beta\theta} \tag{15}$$

To see how price levels are mutually determined, substitute (14) into (7), applying (9):

$$p_n = \gamma \left[\sum_{i=1}^{N} T_i \big(d_{ni} w_i^{\beta} p_i^{1-\beta} \big)^{-\theta} \right]^{-1/\theta} \tag{16}$$

which is the price parameter of country n.

Similarly, expanding equation (10) using (14):

$$\frac{X_{ni}}{X_n} = \pi_{ni} = T_i \left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n} \right)^{-\theta} \tag{17}$$

where p_i is obtained from the equation above.

Till now, we have made preparations for the equilibrium.

To build the model, we now divide the society into manufacturing sector and non-manufacturing sector.

* Note that in this section X_i means spending on manufactures rather than the whole goods market.

First, we have

$$w_i L_i = \beta \sum_{n=1}^{N} \pi_{ni} X_n \tag{18}$$

where β is the fraction of labor as before.

With cost minimization, we expands X_n Go

$$X_n = \frac{1-\beta}{\beta} w_n L_n + \alpha Y_n \tag{19}$$

where Y_n is aggregate final expenditures , with α the fraction spent on manufactures.

To close the model, we consider two polar cases.

1) When labor is mobile between manu and non-manu:
See w_n and Y_n as exogenous, combine (18)(19):

$$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \big[(1-\beta) w_n L_n + \alpha\beta Y_n \big] \tag{20}$$

In this case, given w_n and Y_n, we can use (16) (17) to find p_n and π_{ni} , which can determine manufacturing employment L_i in (20).

2) When labor is immobile:
The number of manufacturing workers in each country is fixed at L_n.
Non-manufacturing income Y_n^O is exogenous.
Combine (18) (19):

$$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \Big[(1 - \beta + \alpha\beta) w_n L_n + \alpha\beta Y_n^O \Big] \tag{21}$$

In this case, given L_n and Y_n^O, we can use (16) (17) (21) to find p_n, π_{ni} and w_n.

In this section, we will consider two special cases and see the gains from trade tentatively.

- Zero-Gravity

$d_{ni} = 1$, from (7) (8) (14) we get:

$$\frac{w_i}{w_N} = \left(\frac{T_i/L_i}{T_N/L_N} \right)^{1/(1+\theta\beta)} \tag{22}$$

which means:

· When labor is mobile the relative amounts of manufacturing labor in each country are determined by $T_i/w_i^{1+\theta\beta}$.

· When labor is immobile the expression gives relative wages, which depend on the state of technology in per worker terms.

Suppose manufacturing is the only activity so that $\alpha = 1$ and $Y_i = w_i Li$. From (16) and (22), measure welfare by Real GDP per worker:

$$W_i = \gamma^{-1/\beta} T_i^{1/(1+\theta\beta)} \left[\sum_{k=1}^{N} T_k^{1/(1+\theta\beta)} (L_k/L_i)^{\theta\beta/(1+\theta\beta)} \right]^{1/\theta\beta} \tag{23}$$

- Autarky

See the world as a whole country , referring back to (15) setting $\pi_{ii} = 1$:

$$W_i = \gamma^{-1/\beta} T_i^{1/\theta\beta} \tag{24}$$

- Comparison

Compare W in (23) and (24), there are gains from trade for everyone.

2.5 The Gravity Equation

The exporter's total sales $Q_i = \sum_{m=1}^{N} X_{mi} = T_i c_i^{-\theta} \sum_{m=1}^{N} \frac{d_{mi}^{-\theta} X_m}{\Phi_m}$
Solving for $T_i c_i^{-\theta}$, and substituting it into(10), incorporating(9), we get

$$X_{ni} = \frac{\left(\frac{d_{ni}}{p_n}\right)^{-\theta} X_n}{\sum_{m=1}^{N} \left(\frac{d_{mi}}{p_m}\right)^{-\theta} X_m} Q_i \quad (11)$$

Go

- traditional Armington case
  a_i:the weight on goods from country i in CES preferences

$$\frac{X_{ni}}{X_n} = \frac{a_i^{\delta-1} (c_i d_{ni})^{-(\delta-1)}}{\sum_{k=1}^{N} a_k^{\delta-1} (c_k d_{nk})^{-(\delta-1)}}$$

- monopolistic competition case
  m_i:the number of goods produced by country i

$$\frac{X_{ni}}{X_n} = \frac{m_i (c_i d_{ni})^{-(\delta-1)}}{\sum_{k=1}^{N} m_k (c_k d_{nk})^{-(\delta-1)}}$$

2.5 The Gravity Equation

	traditional Armington & monopolistic competition model	EK model
the heterogenity of goods	in consumption	in production
the sensitivity of trade to costs and geographic barriers depends on	preference parameter δ	technological parameter θ
trade shares respond to costs and geographic barriers	at the intensive margin (fixed set of goods)	at the extensive margin (changable set of goods)

图: Comparison

3.1 Estimates with Source Effects

Normalizing (17) by the importer's home sales delivers

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i}{T_n} \left(\frac{W_i}{W_n} \right)^{-\theta\beta} \left(\frac{P_i}{P_n} \right)^{-\theta(1-\beta)} d_{ni}^{-\theta} \tag{25}$$

We can use equation (17) as it applies to home sales, for both country i and country n, to obtain

$$\frac{P_i}{P_n} = \frac{W_i}{W_n} \left(\frac{T_i}{T_n} \right)^{-1/(\theta\beta)} \left(\frac{\frac{X_i}{X_{ii}}}{\frac{X_n}{X_{nn}}} \right)^{-1/(\theta\beta)}$$

Plugging this expression for the relative price of intermediates into (25) and rearranging gives, in logarithms (setting $\beta = 0.21$):

$$\ln \left(\frac{X'_{ni}}{X'_{nn}} \right) = -\theta \ln(d_{ni}) + \frac{1}{\beta} \ln \left(\frac{T_i}{T_n} \right) - \theta \ln \left(\frac{W_i}{W_n} \right) \tag{26}$$

3.1 Estimates with Source Effects

where $\ln(X'_{ni}) \equiv \ln(X_{ni}) - [(1-\beta)/\beta]\ln(X_i/X_{ii})$. By defining

$$S_i \equiv \frac{1}{\beta}\ln(T_i) - \theta\ln(W_i) \tag{27}$$

This equation simplifies to

$$\ln\left(\frac{X'_{ni}}{X'_{nn}}\right) = -\theta\ln(d_{ni}) + S_i - S_n \tag{28}$$

Equation (28) forms the basis of our estimation.

3.1 Estimates with Source Effects

We use proxies for geographic barriers suggested by the gravity literature.

$$\ln(d_{ni}) = d_k + b + l + e_h + m_n + \delta_{ni} \tag{29}$$

Imposing this specification of geographic barriers, equation (28) becomes

$$\ln\left(\frac{X'_{ni}}{X'_{nn}}\right) = -S_i + S_n - \theta m_n - \theta d_k - \theta b - \theta e_n - \theta l + \theta^2_{ni} + \theta^1_{ni} \tag{30}$$

3.1 Estimates with Source Effects

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)

Country	Source Country			Destination 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.

3.2 Estimates with Wage Data

Based on Kortum (1997) and Eaton and Kortum (1996), we relate technology to national stocks of R&D and to human capital as measured by years of schooling. We can translate equation(27) into

$$S_i \equiv \frac{1}{\beta} \ln(T_i) - \theta \ln(W_i)$$

$$S_i = \alpha_0 + \alpha_R \ln(R_i) - \alpha_H(\frac{1}{H_i}) - \theta \ln(W_i) + \tau_i \tag{31}$$

3.2 Estimates with Wage Data

TABLE IV

DATA FOR ALTERNATIVE PARAMETERS

Country	Research Stock (U.S. = 1)	Years of Schooling (years/person)	Labor Force (HK adjusted) (U.S. = 1)	Density (pop/area) (U.S. = 1)
Australia	0.0087	8.7	0.054	0.08
Austria	0.0063	8.6	0.024	3.43
Belgium	0.0151	9.4	0.029	12.02
Canada	0.0299	10.0	0.094	0.10
Denmark	0.0051	6.9	0.017	4.47
Finland	0.0053	10.8	0.019	0.55
France	0.1108	9.5	0.181	3.88
Germany	0.1683	10.3	0.225	9.50
Greece	0.0005	8.4	0.025	2.87
Italy	0.0445	9.1	0.159	7.16
Japan	0.2492	9.5	0.544	12.42
Netherlands	0.0278	9.5	0.043	13.64
New Zealand	0.0010	9.3	0.010	0.47
Norway	0.0057	9.2	0.015	0.49
Portugal	0.0007	6.5	0.026	4.01
Spain	0.0084	9.7	0.100	2.88
Sweden	0.0206	9.6	0.031	0.71
United Kingdom	0.1423	8.5	0.186	8.76
United States	1.0000	12.1	1.000	1.00

Notes: Research stocks, in 1990, are from Coe and Helpman (1995). Average years of schooling H_i, in 1985, are from Kyriacou (1991). Labor forces, in 1990, are from Summers and Heston (1991). They are adjusted for human capital by multiplying the country i figure by $e^{0.06H_i}$. See the Appendix for complete definitions.

3.2 Estimates with Wage Data

TABLE V

COMPETITIVENESS EQUATION

		Ordinary Least Squares		Two-Stage Least Squares	
		est.	s.e.	est.	s.e.
Constant		3.75	(1.89)	3.82	(1.92)
Research stock, $\ln R_i$	α_R	1.04	(0.17)	1.09	(0.18)
Human capital, $1/H_i$	$-\alpha_H$	−18.0	(20.6)	−22.7	(21.3)
Wage, $\ln w_i$	$-\theta$	−2.84	(1.02)	−3.60	(1.21)
Total Sum of squares		80.3		80.3	
Sum of squared residuals		18.5		19.1	
Number of observations		19		19	

Notes: Estimated using 1990 data. The dependent variable is the estimate $\widehat{S}_i$ of source-country competitiveness shown in Table III. Standard errors are in parentheses.

3.3 Estimates using Price Data

According to equation (12),

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta} \tag{32}$$

we measure $\ln(p_i d_{ni}/p_n)$ by the term D_{ni} defined as

$$D_{ni} = \frac{\max(2_j[r_{ni}(j)])}{\sum_{j=1}^{50}[r_{ni}(j)]/50} \tag{33}$$

with data on bilateral trade in manufactures among 19 OECD countries in 1990, the implied θ is 8.28.

3.3 Estimates using Price Data

A potential objection is the errors-in-variables problem with our D_{ni} measure discussed in Section 3. We address this problem by using the observable geography terms in (29) as instruments for D_{ni}.

$$\ln(d_{ni}) = d_k + b + l + e_h + m_n + \delta_{ni}$$

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

$$\ln\left(\frac{X'_{ni}}{X'_{nn}}\right) = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta l - \theta e_n + \theta^2_{ni} + \theta^1_{ni} \tag{34}$$

Doing so, we obtain a 2SLS estimate of $\theta = 12.86$ (with a standard error of 1.64).

Following equation (27), we strip the estimates of S_i in Table III down to T_i using data on wages (adjusted for education) and an estimate of θ:

$$S_i \equiv \frac{1}{\beta}\ln(T_i) - \theta \ln(W_i)$$

$$T_i = \left(\exp^{\hat{S}_i} W_i^{\theta}\right)^{\beta}$$

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 relative to the U.S. value.

Consider equation (29):

$$\ln(d_{ni}) = d_k + b + l + e_h + m_n + \delta_{ni}$$

3.4 States of Technology and Geographic Barriers

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 $100(e^{-\hat{d}/\theta} - 1)$.

4.1 Logic

- Construct the model theoretically
- Estimate the parameters so that to quantify the model

TABLE VIII
SUMMARY OF PARAMETERS

Parameter	Definition	Value	Source
θ	comparative advantage	8.28 (3.60, 12.86)	Section 3 (Section 5.2, Section 5.3)
α	manufacturing share	0.13	production and trade data
β	labor share in costs	0.21	wage costs in gross output
T_i	states of technology	Table VI	source effects stripped of wages
d_{ni}	geographic barriers	Table VII	geographic proxies adjusted for θ

- **Counterfactual analysis**
    - Preparation: create baselines, define criteria
    - Explore counterfactuals: trade gains, foreign tech, and tariffs

- **Create a baseline world**
  actual manufacturing employment L_n, GDP Y_n, and price level p_n and p_n^{α}
  calculated wages w_n
- **Define criteria: Welfare**

$$W_n = \frac{Y_n}{P_n^{\alpha}} \tag{35}$$

Go

$$\ln \frac{W_n'}{W_n} = \ln \frac{Y_n'}{Y_n} - \alpha \ln \frac{p_n'}{p_n} \approx (\frac{w_n' - w_n}{w_n}) \frac{w_n L_n}{Y_n} - \alpha \ln \frac{p_n'}{p_n} \tag{36}$$

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.

4.4 The benefits of foreign technology

- Increase T_i(the state of technology) by 20 percent for the US and Germany respectively, what will happen in this world?

4.4 The benefits of foreign technology

TABLE XI
THE BENEFITS OF FOREIGN TECHNOLOGY

Country	Welfare Consequences of Improved Technology: Higher U.S. State of Technology — Mobile Labor	Higher U.S. State of Technology — Immobile Labor	Higher German State of Technology — Mobile Labor	Higher German State of Technology — 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 or Germany.

4.5 Eliminating tariffs

- **Incorporate tariffs**

$$d_{ni} = (1 + t_{ni}) d^*_{ni} \tag{37}$$

$$TR_n = \sum_{i \neq n} \frac{t_{ni}}{1 + t_{ni}} X_{ni} \tag{38}$$

- **Create a baseline world**
  5 percent tariff on all imports
- **What happens if:**
  - All tariffs removed
  - US removes its tariffs on its own
  - Eliminating tariffs within European Community

5 Conclusion

- **Counterfactuals**
  Trade gains, foreign technology, tariffs......
- **Comparative advantages and geographic barriers**
  "Comparative advantage creates potential gains from trade. The extent to which these gains are realized, however, is attenuated by the resistance imposed bygeographic barriers."

6 Extensions

- **Bertrand Competition**: Bernard, Eaton, Jensen, and Kortum (2003)
- **Non-homothetic preferences**: Fieler (2011)
- **Multisectors**:Costinot, Donaldson, and Komunjer (2012); Caliendo L , Parro F . Estimates of the Trade and Welfare Effects of NAFTA[J]. NBER Working Papers, 2012, 82(1):1-44.
- **Country-specific Assumptions**
  盖庆恩、方聪龙、程名望、朱喜:《贸易成本、劳动力市场扭曲与中国的劳动生产率》,《管理世界》,2019 年第 3 期,第 64~80 页。
- **Factor Endowment Differences**
  Heckscher-Ohlin Model

Appendix I:The Frechet distribution

Research, Patenting, and Technological Change,By Samuel Kortum,*Econometrica*,1997.

If the stationary search distribution is Pareto, then the distribution of the technological frontier is Frechet (type 2 extreme value) and average efficiency is

$$A_K = c_1 K^{\lambda(1+\gamma)} + \epsilon(K).$$

If the stationary search distribution is exponential, then the distribution of the technological frontier is Gumbel (type 1 extreme value) and average efficiency is

$$A_K = c_0 + c_1 \ln K + \epsilon(K).$$

If the stationary search distribution is uniform, then the distribution of the technological frontier is Weibull (type 3 extreme value) and average efficiency is

$$A_K = c_0 - c_1 K^{-(1+\gamma)} + \epsilon(K).$$

Appendix I:The Frechet distribution

Research, Patenting, and Technological Change,By Samuel Kortum,*Econometrica*,1997.

Only the Pareto case is consistent with the trend of constant productivity growth associated with constant growth in research and with the standard econometric equation used to quantify the impact of research on productivity growth (Griliches (1979)).

$$F_i(z) = e^{-T_i z^{-\theta}}$$

The expection and variation of the Frechet Distribution can be written as:

$$E[\ln(Z_i)] = \frac{\gamma + log_i(T_i)}{\theta}$$

$$D[ln(Z_i)] = \frac{\pi^2}{6\theta^2}$$

Appendix I:The Frechet distribution

Research, Patenting, and Technological Change,By Samuel Kortum,*Econometrica*,1997.

$$F_i(z) = e^{-T_i z^{-\theta}}, E[\ln(Z_i)] = \frac{\gamma + log_i(T_i)}{\theta}, D[ln(Z_i)] = \frac{\pi^2}{6\theta^2}.$$

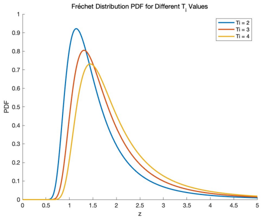

图: Different Frechet Distribution Given $\theta = 3$

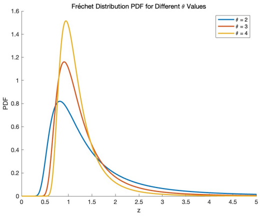

图: Different Frechet Distribution Given $T_i = 1$

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Appendix II:Dixit-Stigliz Framework

Monopolistic Competition and Optimal Product Diversity, *AER*,1997.

Consumer's Problem:

$$\max_{[c_i]_{=0}^{N},y} U\left([c_i]_{=0}^{N}, y\right) \equiv u(C, y)$$

$$\text{s.t.} \int_0^N p_i c_i di + y \leq m$$

$$\text{where } C \equiv \left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} di\right)^{\epsilon/(\epsilon-1)}$$

m: income of the consumer;
$[c_i]_{=0}^{N}$:consumption bundle;
y: other goods, which are provided at a fixed price.
C: CES utility function of the consumer.

Since the goods y are provided at the fixed price, the consumer only needs to solve the following cost-minimization subquestion:

$$p(C) = \min_{[c_i]_{=0}^{N}} \int_0^N p_i c_i di$$

$$\text{s.t.} \quad \left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} di \right)^{\epsilon/(\epsilon-1)} \geq C$$

Using Lagrangian method to solve this subproblem:

$$\mathcal{L} = \int_0^N p_i c_i \, di - \lambda \left[\left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}} - C \right]$$

Taking the derivative with respect to c_i:

$$\frac{\partial \mathcal{L}}{\partial c_i} = p_i - \lambda \left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{1}{\epsilon-1}} c_i^{-\frac{1}{\epsilon}} = 0$$

Taking the derivative with respect to λ:

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}} - C = 0 \Rightarrow \left(\int_0^N c_i^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{1}{\epsilon-1}} = C^{\frac{1}{\epsilon}}$$

Therefore,

$$\frac{\partial \mathcal{L}}{\partial c_i} = p_i - \lambda C^{\frac{1}{\epsilon}} c_i^{-\frac{1}{\epsilon}} = 0 \Rightarrow p_i = \lambda C^{\frac{1}{\epsilon}} c_i^{\frac{1}{\epsilon}}. \tag{39}$$

Solving for λ: taking integration of both sides of (39)

$$\int_0^N p_i^{1-\epsilon} di = \int_0^N (\lambda C^{\frac{1}{\epsilon}} c_i^{\frac{1}{\epsilon}})^{1-\epsilon} di = \lambda^{1-\epsilon}$$

where we can define the **ideal price index** P:

$$\lambda = [\int_0^N p_i^{1-\epsilon}]^{\frac{1}{1-\epsilon}} = P.$$

Taking the price index P back to (39) and it gives

$$c_i = C(\frac{p_i}{P})^{-\epsilon}.$$

The the cost of bundle can be rewritten as:

$$\int_0^N p_i c_i di = \frac{C}{P^{-\epsilon}} \int_0^N p_i^{1-\epsilon} di = CP.$$

Therefore, we can show the connection between price index, welfare and expenditure:

$$C = \frac{m-y}{P}.$$ Back

Appendix III: The price parameter Φ_n

$$
\begin{aligned}
G_n(p) &= \Pr\left(P_n \leq p\right) \\
&= 1 - \prod_i \Pr\left(P_{ni} \geq p\right) \\
&= 1 - \prod_i \left[1 - G_{ni}(p)\right] \\
&= 1 - \prod_i \left[1 - G_{ni}(p)\right] \\
&= 1 - \prod_i F_i\left(\frac{c_i d_{ni}}{p}\right) \\
&= 1 - \prod_i e^{-T_i (c_i d_{ni})^{-\theta} p^{\theta}}
\end{aligned}
$$

Back

Therefore, we define the price parameter $\Phi_n = -T_i \left(c_i d_{ni}\right)^{-\theta}$ Back

Appendix III: The price distribution π_{ni}

$$
\begin{aligned}
\pi_{ni} &= \Pr\left(P_{ni} = p \leq \min_{s \neq i} P_{ns}\right) \\
&= \int_0^\infty [1 - G_n^{-i}(p)] dG_n^i(p) \\
&= \int_0^\infty [1 - (1 - e^{-\Phi_n^{-i} p^\theta})] d\{1 - e^{-[T_i(c_i d_{ni}]^{-\theta} p^\theta]}\} \\
&= \int_0^\infty e^{-\Phi_n^{-i} p^\theta} T_i \left(c_i d_{ni}\right)^{-\theta} \theta p^{\theta-1} e^{-T_i(c_i d_{ni})^{-\theta} p^\theta} dp \\
&= \left(\frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n}\right) \int_0^\infty \theta \Phi_n e^{-\Phi_n p^\theta} p^{\theta-1} dp \\
&= \left(\frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n}\right) \int_0^\infty dG_n(p) dp = \frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n}.
\end{aligned}
$$

Back

Appendix III: The conditional price distribution $G_n p$

Given that $\pi_{ni} \equiv$ probability that for any particular good country i is the least cost supplier in n, then conditional distribution of the price charged by i in n for the goods that i actually sells in n is

$$\begin{aligned}
&\frac{1}{\pi_{ni}} \int_0^p e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q) \\
&= \frac{1}{\pi_{ni}} \int_0^p e^{-\Phi_n^{-i} q^\theta} \theta T_i \left(c_i d_{ni}\right)^{-\theta} q^{\theta-1} e^{-T_i (c_i d_{ni})^{-\theta} p^\theta} dq \\
&= \frac{1}{\pi_{ni}} \left(\frac{T_i \left(c_i d_{ni}\right)^{-\theta}}{\Phi_n} \right) \int_0^p e^{-\Phi_n q^\theta} \theta \Phi_n q^{\theta-1} dq \\
&= \frac{1}{\pi_{ni}} \pi_{ni} G_n(p) \\
&= G_n(p)
\end{aligned}$$

Back

Appendix III: The price index p_n

The price index for a CES utility with elasticity of substitution $\sigma < 1+\theta$, defined as

$$p_n \equiv \left(\int_0^1 p_n(u)^{1-\sigma} du \right)^{1/(1-\sigma)}$$

Then we can derive the equation as

$$\begin{aligned} p_n^{1-\sigma} &= \int_0^1 p_n(u)^{1-\sigma} du \\ &= \int_0^\infty p^{1-\sigma} dG_n(p) \\ &= \int_0^\infty p^{1-\sigma} \Phi_n \theta p^{\theta-1} e^{-\Phi_n p^\theta} dp \end{aligned}$$

Appendix III: The price index p_n

- Defining

$$x = \Phi_n p^{\theta}$$

then $p^{1-\sigma} = (x/\Phi_n)^{\frac{1-\sigma}{\theta}}$, $dx = \Phi_n \theta p^{\theta-1}$, and

$$\begin{aligned} p_n^{1-\sigma} &= \int_0^{\infty} (x/\Phi_n)^{\frac{1-\sigma}{\theta}} e^{-x} dx \\ &= \Phi_n^{-\frac{1-\sigma}{\theta}} \int_0^{\infty} x^{\frac{1-\sigma}{\theta}} e^{-x} dx \\ &= \Phi_n^{-\frac{1-\sigma}{\theta}} \Gamma\left(\frac{1-\sigma}{\theta} + 1\right) \end{aligned}$$

Given $\gamma = \left[\Gamma\left(\frac{1-\sigma}{\theta} + 1\right)\right]^{1/(1-\sigma)}$ Then the price index p_n can be formulated as:

$$p_n = \gamma \Phi_n^{-1/\theta}.$$ Back

Appendix III: Gravity Equation

Let $Y_i = Q_i = \sum_m X_{mi}$ be country $i's$ total sales, then

$$Y_i = Q_i = \sum_m \frac{T_i \left(c_i d_{mi}\right)^{-\theta} X_n}{\Phi_m} = T_i c_i^{-\theta} \Omega_i^{-\theta}$$

where

$$\Omega_i^{-\theta} \equiv \sum_m \frac{d_{mi}^{-\theta} X_m}{\Phi_m}$$

Plugging the equation into (11) and it gives

$$X_{ni} = \frac{\left(\frac{d_{ni}^{\theta}}{\Phi_n}\right) X_n}{\Omega_i^{-\theta}} Q_i \tag{40}$$

Note that

$$p_n = \Phi_n^{-\frac{1}{\theta}} \gamma \Rightarrow \Phi_n = \left(\frac{p_n}{\gamma} \right)^{-\theta}$$

Equation (40) can be rewritten as

$$X_{ni} = \frac{d_{ni}^{-\theta}}{\left(\frac{p_n}{\gamma} \right)^{-\theta}} X_n Y_i \frac{1}{\Omega_i^{-\theta}}$$
$$= \left(\frac{p_n \Omega_i}{\gamma} \right)^{\theta} \frac{X_n Y_i}{d_{ni}^{\theta}}$$

which is in the form of standard gravity equation. Back

Appendix III: Equilibrium–Production

Note that $c_i = (\frac{w_i}{p_i})^\beta p_i$, real wage can be formulated accordingly:

$$
\begin{aligned}
(\frac{w_i}{p_i})^\beta &= \frac{c_i}{p_i} \\
&= \frac{c_i}{\gamma(\Phi_n)^{-\frac{1}{\theta}}} \\
&= \frac{c_i}{\gamma}(\sum_i T_i(c_i d_{ni})^{-\theta})^{\frac{1}{\theta}}
\end{aligned}
$$

Substituting (8) into the equation and it gives

$$
\begin{aligned}
(\frac{w_i}{p_i})^\beta &= \frac{c_i}{\gamma}(\frac{T_i(c_i d_{ii})^{-\theta}}{\pi_{ii}})^{\frac{1}{\theta}} \\
&= \frac{1}{\gamma}(\frac{T_i}{\pi_{ii}})^{\frac{1}{\theta}}
\end{aligned}
$$

Therefore, (15) can be derived

$$
\frac{w_i}{p_i} = \gamma^{-\frac{1}{\beta}}(\frac{T_i}{\pi_{ii}})^{\frac{1}{\beta}}
$$

Back

Appendix III: Equilibrium–Price Levels

(9) gives that

$$p_n = \gamma(\Phi_n)^{-\frac{1}{\theta}}$$

Plugging (7) into (9):

$$p_n = \gamma(\sum_i T_i(c_i d_{ni})^{-\theta})^{-\frac{1}{\theta}}$$

Plugging (14) into (7) and it gives (16)

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

Appendix III: Equilibrium–Price Levels

(10) gives that

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

Substituting (7) into (10)

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

Plugging (9) and (14) in the equation above and it gives

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

Therefore, we can derive (17) as

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

Appendix III: Equilibrium–Working Market Equilibrium

Given Cobb-Douglas Production Function, the total cost C can be written as:

$$C = \frac{w_n L_n}{\beta} = \frac{C_{intermediate}}{1-\beta}.$$

Therefore, the cost of intermediate goods can be formulated as

$$C_{intermediate} = \frac{w_n L_n}{\beta}(1-\beta).$$

The manufacture goods brought can be decomposed as intermediate goods and final goods/expenditures, so the spending on manufactures can be rewritten as (19):

$$X_n = \frac{1-\beta}{\beta} w_n L_n + \alpha Y_n$$

where Y_n is aggregate final expenditures , with α the fraction spent on manufactures. Back