CEMMAP Masterclass: Empirical Models of Comparative Advantage and the Gains from Trade[1] — Lecture 2: Ricardian Models (II)—

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[1] All material based on earlier courses taught jointly with Arnaud Costinot (MIT).

“Putting Ricardo to Work” (EK, JEP, 2012)

- Ricardian model has long been perceived has useful pedagogic tool, with little empirical content:
  - Great to explain undergrads why there are gains from trade
  - But grad students should study richer models (e.g. Feenstra’s graduate textbook has a total of 3 pages on the Ricardian model!)
- Eaton and Kortum (2002) have lead to “Ricardian revival”
  - Same basic idea as in Wilson (1980): Who cares about the pattern of trade for counterfactual analysis?
  - But more structure: Small number of parameters, so well-suited for quantitative work
- **Goals of this lecture:**
  1. Present EK model
  2. Discuss estimation of its key parameter
  3. Introduce tools for welfare and counterfactual analysis
  4. Implications for testing Ricardian model (Costinot, Donaldson and Komunjer, 2012)

Basic Assumptions

- N countries, $i = 1, ..., N$
- Continuum of goods $u \in [0, 1]$
- Preferences are CES with elasticity of substitution σ (this is actually way stronger than needed):

$$U_i = \left(\int_0^1 q_i(u)^{(\sigma-1)/\sigma} du \right)^{\sigma/(\sigma-1)},$$

- One factor of production ("labor")
- There may also be intermediate goods (more on that later)
- $c_i \equiv$ unit cost of the "common input" used in production of all goods
  - Without intermediate goods, c_i is equal to wage w_i in country i

Basic Assumptions (Cont.)

- Constant returns to scale:
  - $Z_i(u)$ denotes productivity of (any) firm producing u in country i
  - $Z_i(u)$ is drawn independently (across goods and countries) from a **Fréchet distribution**:

$$\Pr(Z_i \leq z) = F_i(z) = e^{-T_i z^{-\theta}},$$

  with $\theta > \sigma - 1$ (important restriction, see below)
  - Since goods are symmetric except for productivity, we can forget about index u and keep track of goods through $\boldsymbol{Z} \equiv (Z_1, ..., Z_N)$.
- Trade is subject to iceberg costs $d_{ni} \geq 1$
  - d_{ni} units need to be shipped from i so that 1 unit makes it to n
- All markets are perfectly competitive

Four Key Results

A - The Price Distribution

- Let $P_{ni}(\boldsymbol{Z}) \equiv c_i d_{ni} / Z_i$ be the unit cost at which country i can serve a good $\boldsymbol{Z}$ to country n and let $G_{ni}(p) \equiv \Pr(P_{ni}(\boldsymbol{Z}) \leq p)$. Then:

$$G_{ni}(p) = \Pr\left(Z_i \geq c_i d_{ni} / p\right) = 1 - F_i(c_i d_{ni} / p)$$

- Let $P_n(\boldsymbol{Z}) \equiv \min\{P_{n1}(\boldsymbol{Z}), ..., P_{nN}(\boldsymbol{Z})\}$ and let $G_n(p) \equiv \Pr(P_n(\boldsymbol{Z}) \leq p)$ be the price distribution in country n. Then:

$$G_n(p) = 1 - \exp[-\Phi_n p^{\theta}]$$

where

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

- To show this, note that (suppressing notation $\boldsymbol{Z}$ from here onwards)

$$\begin{aligned} \Pr(P_n \leq p) &= 1 - \Pi_i \Pr(P_{ni} \geq p) \\ &= 1 - \Pi_i \left[1 - G_{ni}(p)\right] \end{aligned}$$

- Using

$$G_{ni}(p) = 1 - F_i(c_i d_{ni}/p)$$

then

$$\begin{aligned} 1 - \Pi_i \left[1 - G_{ni}(p)\right] &= 1 - \Pi_i F_i(c_i d_{ni}/p) \\ &= 1 - \Pi_i e^{-T_i (c_i d_{ni})^{-\theta} p^{\theta}} \\ &= 1 - e^{-\Phi_n p^{\theta}} \end{aligned}$$

- Consider a particular good. Country n buys the good from country i if $i = \arg\min\{p_{n1}, ..., p_{nN}\}$. The probability of this event is simply country i's contribution to country n's price parameter Φ_n,

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

- To show this, note that

$$\pi_{ni} = \Pr\left(P_{ni} \leq \min_{s \neq i} P_{ns}\right)$$

- If $P_{ni} = p$, then the probability that country i is the least cost supplier to country n is equal to the probability that $P_{ns} \geq p$ for all $s \neq i$

- The previous probability is equal to

$$\Pi_{s\neq i}\Pr(P_{ns}\geq p)=\Pi_{s\neq i}\left[1-G_{ns}(p)\right]=e^{-\Phi_n^{-i}p^{\theta}}$$

where

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

- Now we integrate over this for all possible p's times the density $dG_{ni}(p)$ to obtain

$$\int_0^{\infty}e^{-\Phi_n^{-i}p^{\theta}}T_i\left(c_i d_{ni}\right)^{-\theta}\theta p^{\theta-1}e^{-T_i\left(c_i d_{ni}\right)^{-\theta}p^{\theta}}dp$$

$$=\left(\frac{T_i\left(c_i d_{ni}\right)^{-\theta}}{\Phi_n}\right)\int_0^{\infty}\theta\Phi_n e^{-\Phi_n p^{\theta}}p^{\theta-1}dp$$

$$=\pi_{ni}\int_0^{\infty}dG_n(p)dp=\pi_{ni}$$

- Close connection between EK and McFadden's logit model
- Take heteorogeneous consumers, indexed by u, with utility $U_n(u)$ from consuming good i:

$$U_i(u) = U_i - p_i + \varepsilon_i(u)$$

with $\varepsilon_i(u)$ i.i.d from **Gumbel distribution:**

$$\Pr(\varepsilon_i(u) \leq \varepsilon) = \exp(-\exp(-\theta\varepsilon))$$

- **Logit:** for each *consumer* u, choose *good* i that maximizes $U_i(u) \Rightarrow$

$$\pi_i = \frac{\exp[\theta(U_i - p_i)]}{\sum_j \exp[\theta(U_j - p_j)]}$$

- **EK:** for each *good* u, choose *source country* i that minimizes $\ln p_i(u) = \ln c_i - \ln Z_i(u)$. Then ln(**Fréchet**) =**Gumbel** $\Rightarrow$

$$\pi_i = \frac{\exp[\theta(-\ln c_i)]}{\sum_j \exp[\theta(-\ln c_j)]} = \frac{c_i^{-\theta}}{\sum_j c_j^{-\theta}}$$

- The price of a good that country n actually buys from any country i also has the distribution $G_n(p)$.
- To show this, note that if country n buys a good from country i it means that i is the least cost supplier. If the price at which country i sells this good in country n is q, then the probability that i is the least cost supplier is

$$\Pi_{s\neq i}\Pr(P_{ni} \geq q) = \Pi_{s\neq i}\left[1 - G_{ns}(q)\right] = e^{-\Phi_n^{-i} q^\theta}$$

- The joint probability that country i has a unit cost q of delivering the good to country n **and** is the the least cost supplier of that good in country n is then

$$e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q)$$

Four Key Results

C - The Conditional Price Distribution (Cont.)

- Integrating this probability $e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q)$ over all prices $q \leq p$ and using $G_{ni}(q) = 1 - e^{-T_i (c_i d_{ni})^{-\theta} p^\theta}$ then

$$\int_0^p e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q)$$

$$= \int_0^p e^{-\Phi_n^{-i} q^\theta} \theta T_i (c_i d_{ni})^{-\theta} q^{\theta-1} e^{-T_i (c_i d_{ni})^{-\theta} p^\theta} dq$$

$$= \left(\frac{T_i (c_i d_{ni})^{-\theta}}{\Phi_n} \right) \int_0^p e^{-\Phi_n q^\theta} \theta \Phi_n q^{\theta-1} dq$$

$$= \pi_{ni} G_n(p)$$

- 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

$$\frac{1}{\pi_{ni}} \int_0^p e^{-\Phi_n^{-i} q^\theta} dG_{ni}(q) = G_n(p)$$

- In Eaton and Kortum (2002):
  1. All the adjustment is at the extensive margin: countries that are more distant, have higher costs, or lower $T's$, simply sell a smaller range of goods, but the average price charged is the same.
  2. The share of spending by country n on goods from country i is the same as the probability π_{ni} calculated above.
- We will see in the next lecture a similar property in models of monopolistic competition with Pareto distributions of firm-level productivity

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

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

is given by

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

where

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

where Γ is the Gamma function, *i.e.* $\Gamma(a) \equiv \int_0^\infty x^{a-1} e^{-x} dx$.

- To show this, note that

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

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

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

- This implies $p_n = \gamma \Phi_n^{-1/\theta}$ with $\frac{1-\sigma}{\theta} + 1 > 0$ or $\sigma - 1 < \theta$ for gamma function to be well defined

Equilibrium

- Let X_{ni} be total spending in country n on goods from country i
- Let $X_n \equiv \sum_i X_{ni}$ be country n's total spending
- We know that $X_{ni}/X_n = \pi_{ni}$, so

$$X_{ni} = \frac{T_i(c_i d_{ni})^{-\theta}}{\sum_j T_j(w_j d_{nj})^{-\theta}} X_n \qquad (*)$$

- Suppose that there are no intermediate goods so that $c_i = w_i$.
- In equilibrium, total income in country i must be equal to total spending on goods from country i so

$$w_i L_i = \sum_n X_{ni}$$

- Trade balance further requires $X_n = w_n L_n$ so that

$$w_i L_i = \sum_n \frac{T_i(w_i d_{ni})^{-\theta}}{\sum_j T_j(w_j d_{nj})^{-\theta}} w_n L_n$$

Equilibrium (Cont.)

- This provides system of $N - 1$ independent equations (Walras' Law) that can be solved for wages $(w_1, ..., w_N)$ up to a choice of numeraire
- Everything is as if countries were exchanging labor
  - Fréchet distributions imply that labor demands are iso-elastic
  - Armington model leads to similar eq. conditions under assumption that each country is exogenously specialized in a differentiated good
  - In the Armington model, the labor demand elasticity simply coincides with elasticity of substitution σ.
    - See Anderson and van Wincoop (2003)
- Iso-elastic case is what trade economists refer to as a ''gravity model" with (*)=''gravity equation"
  - We'll come back to gravity models in next lecture

How to Estimate the Trade Elasticity?

- As we will see, trade elasticity $\theta =$ key structural parameter for welfare and counterfactual analysis in EK model (and other gravity models)
- From (*) we also get that country i's share in country n's expenditures normalized by its own share is

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

- This shows the importance of trade costs in determining trade volumes. Note that if there are no trade barriers (i.e, frictionless trade), then $S_{ni} = 1$.
- If we had data on d_{ni}, we could run a regression of $\ln S_{ni}$ on $\ln d_{ni}$ with importer and exporter dummies to recover θ
  - But how do we get d_{ni}?

How to Estimate the Trade Elasticity?

- EK use price data to measure $p_i d_{ni} / p_n$:
- They use retail prices in 19 OECD countries for 50 manufactured products from the UNICP 1990 benchmark study.
- They interpret these data as a sample of the prices $p_i(j)$ of individual goods in the model.
- They note that for goods that n imports from i we should have $p_n(j) / p_i(j) = d_{ni}$, whereas goods that n doesn't import from i can have $p_n(j) / p_i(j) \leq d_{ni}$.
- Since every country in the sample does import manufactured goods from every other, then $\max_j \{ p_n(j) / p_i(j) \}$ should be equal to d_{ni}.
- To deal with measurement error, they actually use the second highest $p_n(j) / p_i(j)$ as a measure of d_{ni}.

How to Estimate the Trade Elasticity?

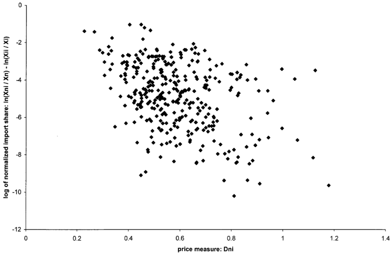

FIGURE 2.—Trade and prices.

- Let $r_{ni}(j) \equiv \ln p_n(j) - \ln p_i(j)$. They calculate $\ln(p_n/p_i)$ as the mean across j of $r_{ni}(j)$. Then they measure $\ln(p_i d_{ni}/p_n)$ by

$$D_{ni} = \frac{\max 2_j \{r_{ni}(j)\}}{\sum_j r_{ni}(j)/50}$$

- Given $S_{ni} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta}$ they estimate θ from $\ln(S_{ni}) = -\theta D_{ni}$. Method of moments: $\theta = 8.28$. OLS with zero intercept: $\theta = 8.03$.

Alternative Strategies for Estimating θ

- Simonovska and Waugh (2014, JIE) argue that EK's procedure suffers from upward bias:
  - Since EK are only considering 50 goods, maximum price gap may still be strictly lower than trade cost
  - If we underestimate trade costs, we overestimate trade elasticity
  - Simulation based method of moments leads to a θ closer to 4.
- An alternative approach is to use tariffs (Caliendo and Parro, 2015, REStud). If $d_{ni} = t_{ni}\tau_{ni}$ where t_{ni} is one plus the ad-valorem tariff (they actually do this for each 2 digit industry) and τ_{ni} is assumed to be symmetric, then

$$\frac{X_{ni}X_{ij}X_{jn}}{X_{nj}X_{ji}X_{in}} = \left(\frac{d_{ni}d_{ij}d_{jn}}{d_{nj}d_{ji}d_{in}}\right)^{-\theta} = \left(\frac{t_{ni}t_{ij}t_{jn}}{t_{nj}t_{ji}t_{in}}\right)^{-\theta}$$

- They can then run an OLS regression and recover θ. Their preferred specification leads to an estimate of 8.22

Alternative Strategies for Estimating θ

- Shapiro (2014) uses time-variation in freight costs (again for each 2 digit industry):

$$\ln X_{ni}^{t} = \alpha_{ni} + \beta_{nt} + \gamma_{it} - \theta \ln(1 + s_{ni}^{t}) + \varepsilon_{ni}^{t}$$

  - $s_{ni}^{t} \equiv$ total shipping costs between i and n in (Q1 and Q4 of) year t
  - $\alpha_{ni} \equiv$ importer-exporter fixed effect; $\beta_{nt} \equiv$ importer-year fixed effect; $\gamma_{it} \equiv$ exporter-year fixed-effect
  - To deal with measurement error in freight costs, he instruments shipping costs from Q1 and Q4 with shipping costs from Q2 and Q3
  - IV estimate of trade elasticity $\equiv$ 7.91.

- Head and Mayer (2015) offer a review of trade elasticity estimates:
  - Typical value is around 5
  - But should we expect aggregate = sector-level elasticities?

Gains from Trade

- Consider again the case where $c_i = w_i$
- From (*), we know that

$$\pi_{nn} = \frac{X_{nn}}{X_n} = \frac{T_n w_n^{-\theta}}{\Phi_n}$$

- We also know that $p_n = \gamma \Phi_n^{-1/\theta}$, so

$$\omega_n \equiv w_n / p_n = \gamma^{-1} T_n^{1/\theta} \pi_{nn}^{-1/\theta}.$$

- Under autarky we have $\omega_n^A = \gamma^{-1} T_n^{1/\theta}$, hence the **gains from trade** are given by

$$GT_n \equiv \omega_n / \omega_n^A = \pi_{nn}^{-1/\theta}$$

- Trade elasticity θ and share of expenditure on domestic goods π_{nn} are sufficient statistics to compute GT. We will see this again in the next lecture.

Gains from Trade (Cont.)

- A typical value for π_{nn} (manufacturing) is 0.7. With $\theta = 5$ this implies $GT_n = 0.7^{-1/5} = 1.074$ or 7.4% gains. Belgium has $\pi_{nn} = 0.2$, so its gains are $GT_n = 0.2^{-1/5} = 1.38$ or 38%.
- One can also use the previous approach to measure the welfare gains associated with any foreign shock, not just moving to autarky:

$$\omega_n'/\omega_n = \left(\pi_{nn}'/\pi_{nn}\right)^{-1/\theta}$$

- For more general counterfactual scenarios, however, one needs to know both π_{nn}' and π_{nn}.

Adding an Input-Output Loop

- Imagine that intermediate goods are used to produce a composite good with a CES production function with elasticity $\sigma > 1$. This composite good can be either consumed or used to produce intermediate goods (input-output loop).

- Each intermediate good is produced from labor and the composite good with a Cobb-Douglas technology with labor share β. We can then write $c_i = w_i^{\beta} p_i^{1-\beta}$.

Adding an Input-Output Loop (Cont.)

- The analysis above implies

$$\pi_{nn} = \gamma^{-\theta} T_n \left(\frac{c_n}{p_n} \right)^{-\theta}$$

  and hence

$$c_n = \gamma^{-1} T_n^{-1/\theta} \pi_{nn}^{-1/\theta} p_n$$

- Using $c_n = w_n^{\beta} p_n^{1-\beta}$ this implies

$$w_n^{\beta} p_n^{1-\beta} = \gamma^{-1} T_n^{-1/\theta} \pi_{nn}^{-1/\theta} p_n$$

  so

$$w_n / p_n = \gamma^{-1/\beta} T_n^{-1/\theta\beta} \pi_{nn}^{-1/\theta\beta}$$

- The gains from trade are now

$$\omega_n / \omega_n^A = \pi_{nn}^{-1/\theta\beta}$$

- Standard value for β is 1/2 (Alvarez and Lucas, 2007). For $\pi_{nn} = 0.7$ and $\theta = 5$ this implies $GT_n = 0.7^{-2/5} = 1.15$ or 15% gains.

Adding Non-Tradables

- Assume now that the composite good cannot be consumed directly.
- Instead, it can either be used to produce intermediates (as above) or to produce a consumption good (together with labor).
- The production function for the consumption good is Cobb-Douglas with labor share α.
- This consumption good is assumed to be non-tradable.

Adding Non-Tradables (Cont.)

- The price index computed above is now p_{gn}, but we care about $\omega_n \equiv w_n / p_{fn}$, where
$$p_{fn} = w_n^{\alpha} p_{gn}^{1-\alpha}$$
- This implies that
$$\omega_n = \frac{w_n}{w_n^{\alpha} p_{gn}^{1-\alpha}} = (w_n / p_{gn})^{1-\alpha}$$
- Thus, the gains from trade are now
$$\omega_n / \omega_n^A = \pi_{nn}^{-\eta/\theta}$$
where
$$\eta \equiv \frac{1-\alpha}{\beta}$$
- Alvarez and Lucas argue that $\alpha = 0.75$ (share of labor in services). Thus, for $\pi_{nn} = 0.7$, $\theta = 5$ and $\beta = 0.5$, this implies $GT_n = 0.7^{-1/10} = 1.036$ or 3.6% gains

Comparative statics (Dekle, Eaton and Kortum, 2008)

- Go back to the simple EK model above ($\alpha = 0$, $\beta = 1$). We have

$$\begin{aligned} X_{ni} &= \frac{T_i (w_i d_{ni})^{-\theta} X_n}{\sum_{i=1}^N T_i (w_i d_{ni})^{-\theta}} \\ \sum_n X_{ni} &= w_i L_i \end{aligned}$$

- As we have already established, this leads to a system of non-linear equations to solve for wages,

$$w_i L_i = \sum_n \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_k T_k (w_k d_{nk})^{-\theta}} w_n L_n .$$

Comparative statics (Dekle, Eaton and Kortum, 2008)

- Consider a shock to labor endowments, trade costs, or productivity. One could compute the original equilibrium, the new equilibrium and compute the changes in endogenous variables.
- But there is a simpler way that uses only information for observables in the initial equilibrium, trade shares and GDP; the trade elasticity, θ; and the exogenous shocks. First solve for changes in wages by solving

$$\hat{w}_i \hat{L}_i Y_i = \sum_n \frac{\pi_{ni} \hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}} \hat{w}_n \hat{L}_n Y_n$$

  and then get changes in trade shares from

$$\hat{\pi}_{ni} = \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.$$

- From here, one can compute welfare changes by using the formula above, namely $\hat{\omega}_n = \left(\hat{\pi}_{nn}\right)^{-1/\theta}$.

Comparative statics (Dekle, Eaton and Kortum, 2008)

- To show this, note that trade shares are

$$\pi_{ni} = \frac{T_i \left(w_i d_{ni}\right)^{-\theta}}{\sum_k T_k \left(w_k d_{nk}\right)^{-\theta}} \text{ and } \pi'_{ni} = \frac{T'_i \left(w'_i d'_{ni}\right)^{-\theta}}{\sum_k T'_k \left(w'_k d'_{nk}\right)^{-\theta}}.$$

- Letting $\hat{x} \equiv x'/x$, then we have

$$\begin{aligned}
\hat{\pi}_{ni} &= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k T'_k \left(w'_k d'_{nk}\right)^{-\theta} / \sum_j T_j \left(w_j d_{nj}\right)^{-\theta}} \\
&= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta} T_k \left(w_k d_{nk}\right)^{-\theta} / \sum_j T_j \left(w_j d_{nj}\right)^{-\theta}} \\
&= \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.
\end{aligned}$$

Comparative statics (Dekle, Eaton and Kortum, 2008)

- On the other hand, for equilibrium we have

$$w_i' L_i' = \sum_n \pi_{ni}' w_n' L_n' = \sum_n \hat{\pi}_{ni} \pi_{ni} w_n' L_n'$$

- Letting $Y_n \equiv w_n L_n$ and using the result above for $\hat{\pi}_{ni}$ we get

$$\hat{w}_i \hat{L}_i Y_i = \sum_n \frac{\pi_{ni} \hat{T}_i \left(\hat{w}_i \hat{d}_{ni} \right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk} \right)^{-\theta}} \hat{w}_n \hat{L}_n Y_n$$

- This forms a system of N equations in N unknowns, $\hat{w}_i$, from which we can get $\hat{w}_i$ as a function of shocks and initial observables (establishing some numeraire). Here π_{ni} and Y_i are data and we know $\hat{d}_{ni}$, $\hat{T}_i$, $\hat{L}_i$, as well as θ.

Comparative statics (Dekle, Eaton and Kortum, 2008)

- To compute the implications for welfare of a foreign shock, simply impose that $\hat{L}_n = \hat{T}_n = 1$, solve the system above to get $\hat{w}_i$ and get the implied $\hat{\pi}_{nn}$ through

$$\hat{\pi}_{ni} = \frac{\hat{T}_i \left(\hat{w}_i \hat{d}_{ni}\right)^{-\theta}}{\sum_k \pi_{nk} \hat{T}_k \left(\hat{w}_k \hat{d}_{nk}\right)^{-\theta}}.$$

  and use the formula to get

$$\hat{\omega}_n = \hat{\pi}_{nn}^{-1/\theta}$$

- Of course, if it is not the case that $\hat{L}_n = \hat{T}_n = 1$, then one can still use this approach, since it is easy to show that in autarky one has $w_n / p_n = \gamma^{-1} T_n^{1/\theta}$, hence in general

$$\hat{\omega}_n = \left(\hat{T}_n\right)^{1/\theta} \hat{\pi}_{nn}^{-1/\theta}$$

Extensions of EK

- **Bertrand Competition**: Bernard, Eaton, Jensen, and Kortum (2003)
  - Bertrand competition $\Rightarrow$ variable markups at the firm-level
  - Measured productivity varies across firms $\Rightarrow$ one can use firm-level data to calibrate model
  - Still tractable because everything in Bertrand depends on max and 2nd-max prices, both of which are relatively easy to work with when using EV distribution.
- **Multiple Sectors**: Costinot, Donaldson, and Komunjer (2012)
  - $T_i^k \equiv$ fundamental productivity in country i and sector k
  - One can use EK's machinery to study pattern of trade, not just volumes
- **Non-homothetic preferences:** Fieler (2011)
  - Rich and poor countries have different expenditure shares
  - Combined with differences in θ^k across sectors k, one can explain pattern of North-North, North-South, and South-South trade

Testing the Ricardian Model

- Given that Ricardo's model of trade is the first and simplest model of international trade it's surprising to learn that very little has been done to confront its predictions with the data
- As Deardorff (*Handbook of Int'l Econ*, 1984) points out, this is actually doubly puzzling:
  - As he puts it, a major challenge in empirical trade is to go from the Deardorff (1980) correlation ($p^A . T \leq 0$) based on unobservable autarky prices p^A to some relationship based on observables (since actually observing p^A is nearly impossible).
  - So the name of the game is modeling p^A as a function of primitives (technology and tastes).
  - Doing so is (or so it might seem...) relatively trivial in a Ricardian model: relative prices are equal to relative labor costs, both in autarky and when trading.

Early Tests of the Ricardian Model

- MacDougall (1951) made use of newly available comparative productivity measures (for the UK and the USA in 1937) to "test" the intuitive prediction of Ricardian (aka: "comparative costs") theory:
    - If there are 2 countries in the world (e.g. UK an USA) then each country will "export those goods for which the ratio of its output per worker to that of the other country exceeds the ratio of its money wage rate to that of the other country."
- This statement is not necessarily true in a Ricardian model with more than 2 countries (and even in 1937, 95% of US exports went to places other than the UK). But that didn't deter early testers of the Ricardian model.
- MacDougall (1951) plots relative labor productivities (US:UK) against relative exports to the entire world (US:UK).
    - 2×2 Ricardian intuition suggests (if we're prepared to be very charitable) that this should be upward-sloping.
    - But note that even this simple intuition says nothing about *how much* a country will export.

MacDougall (1951) Results

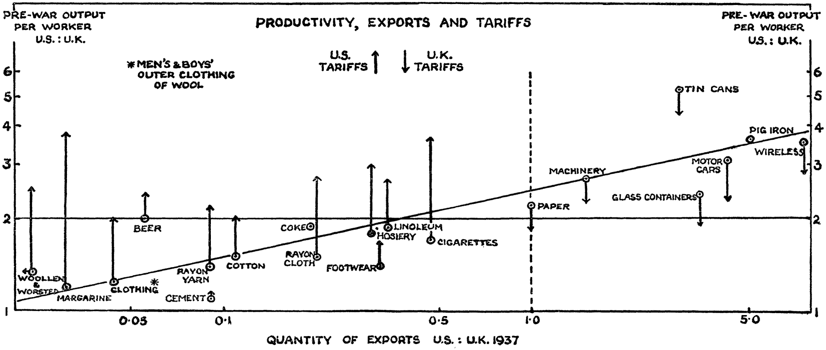

Fig. 1.

This plot was then replicated many times....

Stern (1962): 1950 data

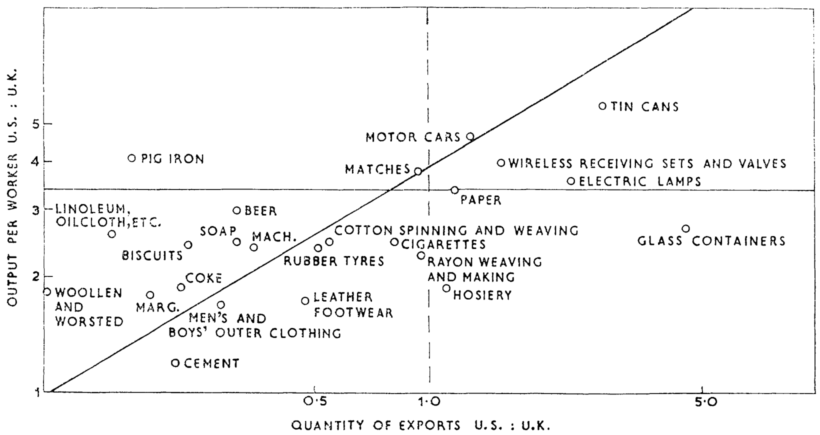

FIG. 1. Scatter diagram of American and British ratios of output per worker and quantity of exports, 1950.

This plot was then replicated many times....

MacDougall et al (1962): 1950 data

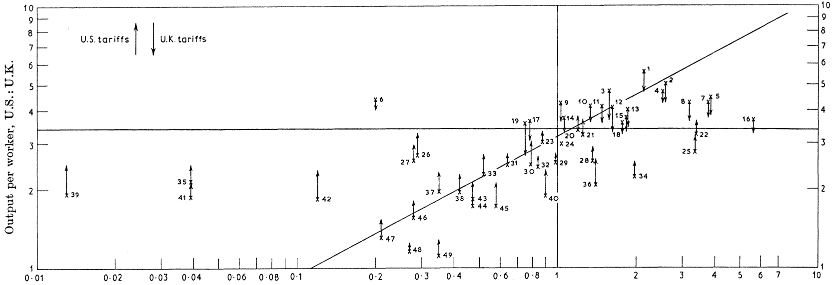

FIG. 1. Quantity of exports, U.S.: U.K. Productivity, exports, and tariffs, 1950.

For key to numbers,
see Table I.

This plot was then replicated many times....

Balassa (1963): 1950 data

Chart 2. — U.S./U.K. Export and Productivity Ratios 1950 and 1951 (Logarithmic scale)

Costinot, Donaldson and Komunjer (REStud, 2012)
Basic Idea

- As we saw above, EK (2002) leads to closed-form predictions about the total volume of trade, but it remains silent about central Ricardian question: Who produces/exports what to whom? (Or, what is the pattern of trade?)
- CDK extend EK (2002) in order to bring the Ricardian model closer to the data:
    - Multiple industries:
        - Now the model says nothing about which varieties within an industry get traded: fundamental EK-style indeterminacy moves 'down' a level.
        - But the model does predict *aggregate* industry trade flows.
        - These industry-level aggregate trade flow predictions can take a very Ricardian form. These predictions are the core of the paper.
    - Also, an extension that weakens the Frechet distributional assumption in EK 2002.

- The result goes beyond the preceding Ricardian literature (e.g. MacDougall (1951)) and other recent work (e.g. Golub and Hseih (2000), and Nunn (2007)):
    - Provides theoretical justification for the regression being run. This not only relaxes the minds of the critics, but also adds clarity: it turns out that (according to the Ricardian model) no one was running the right regression before.
    - Model helps us to discuss what might be in the error term and hence whether orthogonality restrictions sound plausible.
    - Empirical approach explicitly allows (and attempts to correct) for Deardorff (1984)'s selection problem of unobserved productivities.
    - Explicit GE model allows full quantification: How important is Ricardian CA for welfare (given the state of the productivity differences and trade costs in the world we live in)?

- Essentially just a multi-industry Eaton and Kortum (2002) model.
- Many countries indexed by i.
- Many goods (here, "good" = "industry") indexed by k.
  - Each comprised of infinite number of varieties, ω.
- One factor ('labor'):
  - Freely mobile across industries but not countries.
  - In fixed supply L_i.
  - Paid wage w_i.

Costinot, Donaldson and Komunjer (2012)

Assumption 1: Technology

- Productivity $z_i^k(\omega)$ is a random variable drawn independently for each triplet (i, k, ω)
- Drawn from a Fréchet distribution $F_i^k(\cdot)$:

$$F_i^k(z) = \exp[-\left(z/z_i^k\right)^{-\theta}]$$

- Where:
  - $z_i^k > 0$ is location parameter CDK refer to as "fundamental productivity". Heterogeneity in relative z_i^k's generates scope for cross-industry Ricardian comparative advantage. This "layer" of CA is the focus of CDK (2012).
  - $\theta > 1$ is intra-industry heteroegeneity. Generates scope for intra-industry Ricardian comparative advantage. This "layer" of CA is the focus of EK (2002).

Costinot, Donaldson and Komunjer (2012)

Assumption 2: Trade Costs

- Standard iceberg formulation:
  - For each unit of good k shipped from country i to country j, only $1/d_{ij}^k \leq 1$ units arrive.
  - Normalize $d_{ii}^k = 1$
  - Assume (log) triangle inequality: $d_{il}^k \leq d_{ij}^k \cdot d_{jl}^k$

- Perfect competition:
  - In any country j price $p_j^k(\omega)$ paid by buyers of variety ω of good k is:

$$p_j^k(\omega) = \min_i \left[c_{ij}^k(\omega) \right]$$

  - Where $c_{ij}^k(\omega) = \frac{d_{ij}^k w_i}{z_i^k(\omega)}$ is the cost of producing and delivering one unit of this variety from country i to country j.
- Paper also develops case of Bertrand competition.
  - This builds on the work of Bernard, Eaton, Jensen and Kortum (2003)
  - Here, the price paid is the *second*-lowest price (but the identity of the seller is the seller with the lowest price).
  - This alteration doesn't change any of the results that follow, because the distribution of markups turns out to be fixed in BEJK (2003). Still get gravity at industry level.

- Cobb-Douglas upper-tier (across goods), CES lower-tier (across varieties within goods):
    - Expenditure given by:

$$x_j^k(\omega) = \left[p_j^k(\omega) \Big/ p_j^k \right]^{1-\sigma_j^k} \cdot \alpha_j^k w_j L_j$$

    - Where $0 \leq \alpha_j^k \leq 1$, $\sigma_j^k < 1 + \theta$
    - And $p_j^k \equiv \left[\sum_{\omega' \in \Omega} p_j^k(\omega')^{1-\sigma_j^k} \right]^{1/(1-\sigma_j^k)}$ is the typical CES price index.
- Assumption on upper-tier is not necessary for main Ricardian prediction (Theorem 3 below); can have any upper-tier utility function.

- For any country i, trade is balanced:

$$\sum_{j=1}^{I}\sum_{k=1}^{K}\pi_{ij}^{k}\alpha_{j}^{k}\gamma_{j}=\gamma_{i}$$

  - where $\gamma_i \equiv \frac{w_i L_i}{\sum_{i'=1}^{I} w_{i'} L_{i'}}$ is the share of country i in world income.

- As with most of the models we have seen (and will see), the key thing is just that any trade imbalance is exogenous, not that it's exogenous and equal to zero.

Theoretical Predictions: 2 Types

1. Cross-sectional predictions:
   - How productivity (z_i^k) affects trade flows (x_{ij}^k) within any given equilibrium.
   - These relate to previous Ricardian literature that we've seen above (e.g. Golub and Hsieh, 2000).
   - Testable in any cross-section of data.

2. Counterfactual predictions:
   - How productivity changes affect trade flows and welfare across equilibria.
   - Used to inform GE response of economy to a counterfactual scenario.
   - CDK's scenario of interest: a world without cross-industry Ricardian trade, which they explore in order to shed light on the "importance" (e.g. for welfare) of Ricardian forces for trade.

Cross-Sectional Predictions: Lemma 1

Lemma 1

Suppose that Assumptions A1-A4 hold. Let x_{ij}^k be the value of trade from i to j in industry k. Then for any importer, j, any pair of exporters, i and i', and any pair of goods, k and k',

$$\ln\left(\frac{x_{ij}^k x_{i'j}^{k'}}{x_{ij}^{k'} x_{i'j}^k}\right) = \theta \ln\left(\frac{z_i^k z_{i'}^{k'}}{z_i^{k'} z_{i'}^k}\right) - \theta \ln\left(\frac{d_{ij}^k d_{i'j}^{k'}}{d_{ij}^{k'} d_{i'j}^k}\right).$$

where $\theta > 0$.

- Proof: model delivers a 'gravity equation' for trade flows and pair of countries i and j in each industry k. Then just take differences twice.

$$x_{ij}^k = \frac{\left(w_i d_{ij}^k / z_i^k\right)^{-\theta}}{\sum_{i'} \left(w_{i'} d_{i'j}^k / z_{i'}^k\right)^{-\theta}} \cdot \alpha_j^k w_j L_j$$

Cross-Sectional Predictions: Theorem 3

- Difficulty of taking Lemma 1 to data:
  - 'Fundamental Productivity' (z_i^k) is not observed (except in autarky). This is $z_i^k = E\left[z_i^k(\omega)\right]$.
  - Instead one can only hope to observe 'Observed Productivity', $\widetilde{z}_i^k \equiv E\left[z_i^k(\omega) | \Omega_i^k\right]$, where Ω_i^k is set of varieties of k that i actually produces.
  - This is Deardorff's (1984) selection problem working at the level of varieties, ω.
- CDK show that:

$$\frac{\widetilde{z}_i^k}{\widetilde{z}_{i'}^k} = \left(\frac{z_i^k}{z_{i'}^k}\right) \cdot \left(\frac{\pi_{ii}^k}{\pi_{i'i'}^k}\right)^{-1/\theta}$$

  - Intuition: more open economies (lower π_{ii}^k's) are able to avoid using their low productivity draws by importing these varieties.
  - This solves the selection problem, but only by extrapolation due to a functional form assumption.

Cross-Sectional Predictions: Theorem 3

Theorem 3

Suppose that Assumptions A1-A4 hold. Then for any importer, j, any pair of exporters, i and i', and any pair of goods, k and k',

$$\ln\left(\frac{\widetilde{x}_{ij}^{k}\widetilde{x}_{i'j}^{k'}}{\widetilde{x}_{ij}^{k'}\widetilde{x}_{i'j}^{k}}\right)=\theta\ln\left(\frac{\widetilde{z}_{i}^{k}\widetilde{z}_{i'}^{k'}}{\widetilde{z}_{i}^{k'}\widetilde{z}_{i'}^{k}}\right)-\theta\ln\left(\frac{d_{ij}^{k}d_{i'j}^{k'}}{d_{ij}^{k'}d_{i'j}^{k}}\right),$$

where $\widetilde{x}_{ij}^{k}\equiv x_{ij}^{k}\Big/\pi_{ii}^{k}$.

- Note that (if trade costs take the form $d_{ij}^{k}=d_{ij}d_{j}^{k}$) then this has a very similar feel to the standard 2×2 Ricardian intuition.
  - But standard 2×2 Ricardian model doesn't usually specify trade quantities like Theorem 3 does.
  - And the Ricardian model here makes this same 2×2 prediction for each export destination j.

Cross-Sectional Predictions: Theorem 3

- Can also write this in (industry-level) 'gravity equation' form:

$$\ln \widetilde{x}_{ij}^k = \gamma_{ij} + \gamma_j^k + \theta \ln \widetilde{z}_i^k - \theta \ln d_{ij}^k$$

- This derivation answers a lot of questions implicitly left unanswered in the previous Ricardian literature:
  - Should the dependent variable be x_i^k or something else?
  - How do we average over multiple country-pair comparisons (ie what to do with the j's)?
  - How do we interpret the regression structurally (ie, What parameter is being estimated)?
  - What fixed effects should be included?
  - Should we estimate the relationship in levels, logs, semi-log?
  - What is in the error term? (Answer here: the error term is $\ln d_{ij}^k$ plus measurement error in trade flows.)

Cross-Sectional Predictions: Theorem 3

$\ln \widetilde{x}_{ij}^k = \delta_{ij} + \delta_j^k + \theta \ln \widetilde{z}_i^k - \theta \ln d_{ij}^k$

- In the above specification, note that δ_{ij} and δ_j^k are fixed-effects. Comments about these:
  - These absorb a bunch of economic variables that are important to the model (e.g. e_j^k is in δ_j^k) but which are unknown. This is good and bad.
  - The good: CDK don't have to collect data on the e_j^k variables—they are perfectly controlled for by δ_j^k. (And similarly for other variables like wages and the price indices.) Even if CDK did have data on these variables such that they could control for them, these variables would be endogenous and their presence in the regression would bias the results. The fixed effects correct for this endogeneity as well.
  - The bad: The usual problem with fixed-effect regressions is that the types of counterfactual statements you can make are much more limited. However, in this instance, because of the particular structure of this model, there are a surprising number of counterfactual statements that *can* be made with fixed effects estimates only.

Finally, an Extension

- A1 (Fréchet distributed technologies) is restrictive. However, consider the following alternative environment:
  (i) Productivites are drawn from <u>any</u> distribution that has a single location parameter (z_i^k).
  (ii) Production and trade cost differences are small: $c_{1j}^k \simeq \ldots \simeq c_{Ij}^k$.
  (iii) CES parameters are identical: $\sigma_j^k = \sigma$.

- In this environment, Theorems 3 and 5 hold approximately.
  - Furthermore: Fréchet is the <u>only</u> such distribution in which Theorems 3 and 5 hold exactly, and in which the CES parameter can vary arbitrarily across countries and industries.

Data: Productivity

- Well-known challenge of finding productivity data that is comparable across countries and industries
  - Problem lies in converting nominal revenues into measures of physical output.
  - Need internationally comparable producer price deflators, across countries and sectors (Bernard and Jones, 2001).

- CDK use what they see to be the best available data for this purpose:
  - 'International Comparisions of Output and Productivity (ICOP) Industry Database' from GGDC (Groningen).

Data: Productivity

- ICOP data:
  - Single cross-section in 1997.
  - Data are available from 1970-2007, but only fit for CDK's purposes in 1997, the one year in which ICOP collected comparable producer price data.
  - Careful attention to matching producer prices in thousands of product lines.
  - 21 OECD countries: 17 Europe plus Japan, Korea, USA.
  - 13 (2-digit) manufacturing industries.

Data: Productivity

- As Bernard, Eaton, Jensen and Kortum (2003) point out, in Ricardian world relative productivity is entirely reflected in relative (inverse) producer prices.
  - That is, $\frac{\widetilde{z}_i^k \widetilde{z}_{i'}^{k'}}{\widetilde{z}_{i'}^k \widetilde{z}_i^{k'}} = \left[\frac{E\left[p_i^k(\omega)|\Omega_i^k\right] E\left[p_{i'}^{k'}(\omega)|\Omega_{i'}^{k'}\right]}{E\left[p_{i'}^k(\omega)|\Omega_{i'}^k\right] E\left[p_i^{k'}(\omega)|\Omega_i^{k'}\right]} \right]^{-1}$.
  - This is always true in a Ricardian model (since wages cancel).
- But further impetus here:
  - It might be tempting to use measures of "real output per worker" instead as a measure of productivity.
  - But statistical agencies rarely observe physical output. Instead they observe revenues ($R_i^k \equiv Q_i^k P_i^k$) and deflate them by some price index (P_i^k) to try to construct "real output" ($\equiv \frac{R_i^k}{P_i^k}$).
  - In a Ricardian world, then, "real output per worker" $= \frac{R_i^k / P_i^k}{L_i^k} = \frac{w_i L_i^k}{P_i^k L_i^k} = \frac{w_i}{P_i^k}$.
  - So again wages cancel. In a Ricardian world, statistical agencies' measures of relative "real output per worker" are just relative inverse producer prices.

Final Specification

- With all of the above comments included the final specification used by CDK (2012) is:

$$\ln(x_{ij}^k / \pi_{ii}^k) = \delta_{ij} + \delta_j^k + \theta \ln \widetilde{z}_i^k + \varepsilon_{ij}^k$$

- Where, given the fixed effects (δ_{ij}, δ_j^k), log producer price ($\ln p_i^k$) is a measure of $-\ln \widetilde{z}_i^k$.
- OLS requires the orthogonality restriction that $E[\ln p_i^k | d_{ij}^k, \delta_{ij}, \delta_j^k] = 0$.
  - CDK can't just control for trade costs, because the full measure of trade costs d_{ij}^k is not observable (trade costs are hard to observe—see, e.g. Anderson and van Wincoop (JEL, 2004)).
  - Recall that ε_{ij}^k includes the component of trade costs that is not country-pair or importer-industry specific.
- This orthogonality restriction is probably not believable. So CDK also present IV specifications (more on that shortly).

Table 3: OLS Results

- OLS estimates of θ in $\ln(x^k_{ij}/\pi^k_{ii}) = \delta_{ij} + \delta^k_j + \theta \ln \tilde{z}^k_i + \varepsilon^k_{ij}$ in columns (1) and (2)

TABLE 3
Cross-sectional results—baseline

Dependent variable	log (corrected exports)	log (exports)	log (corrected exports)	log (exports)
	(1)	(2)	(3)	(4)
log (productivity based on producer prices)	1·123***	1·361***	6·534***	11·10***
	(0·0994)	(0·103)	(0·708)	(0·981)
Estimation method	OLS	OLS	IV	IV
Exporter × importer fixed effects	YES	YES	YES	YES
Industry × importer fixed effects	YES	YES	YES	YES
Observations	5652	5652	5576	5576
R^2	0·856	0·844	0·747	0·460

Notes: Regressions estimating equation (18) using data from 21 countries and 13 manufacturing sectors (listed in Table 1) in 1997. "Exports" is the value of bilateral exports from the exporting country to the importing country in a given industry. "Corrected exports" is "exports" divided by the share of the exporting country's total expenditure in the given industry that is sourced domestically (equal to one minus the country and industry's IPR). "Productivity based on producer prices" is the inverse of the average producer price in an exporter–industry. Columns (3) and (4) use the log of 1997 R&D expenditure as an instrument for productivity. Data sources and construction are described in full in Section 4.1. Heteroskedasticity-robust standard errors are reported in parentheses. ***Statistically significantly different from zero at the 1% level.

Endogeneity Concerns

- Concerns about OLS results:
  1. Measurement error in relative observed productivity levels: attenuation bias.
  2. Simultaneity: act of exporting raises fundamental productivity.
  3. OVB: eg endogenous protection (relative trade costs are a function of relative productivity)
- Move to IV analysis:
  - Use 1997 R&D expenditure as instrument for productivity (inverse producer prices).
  - This follows Eaton and Kortum (2002), and Griffith, Redding and van Reenen (2004).
- Also cut sample: pairs for which $d_{ij}^k = d_{ij} \cdot d_j^k$ is more likely.

Table 3: IV Results

- IV estimates of θ in $\ln(x_{ij}^k / \pi_{ii}^k) = \delta_{ij} + \delta_j^k + \theta \ln \widetilde{z}_i^k + \varepsilon_{ij}^k$ in columns (3) and (4)

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Counterfactual Predictions

- Remainder of paper does something different: exploring the model's response to counterfactual scenarios.
- CDK's scenarios aim to answer: How "important" is (cross-industry) Ricardian comparative advantage for driving trade flows and gains from trade?
  - More precisely: suppose that, for any pair of exporters, there were no fundamental relative productivity differences across industries. What would be the consequences of this for aggregate trade flows and welfare?

Counterfactual Predictions

- More formally:
  1. Fix a reference country i_0.
  2. For all other countries $i \neq i_0$, assign a new fundamental productivity $(z_i^k)' \equiv Z_i \cdot z_{i_0}^k$.
  3. Choose Z_i such that terms-of-trade effects on i_0 are neutralized: $(w_i / w_{i_0})' = (w_i / w_{i_0})$.
  4. Let $Z_{i_0} = 1$ (normalization).
  5. Refer to all of this as 'removing country i_0's Ricardian comparative advantage.'
- Questions:
  (a) How to compute Z_i? (Lemma 4)
  (b) How to solve for endogenous GE responses under counterfactual scenario? (Theorem 5)
  (c) What model parameters and ingredients (eg trade costs) are needed to answer (a) and (b)?

Counterfactual Predictions: Computing Z_i

Lemma 4

Suppose that Assumptions A1-A5 hold. For all countries $i \neq i_0$, adjustments in absolute productivity, Z_i, can be computed as the implicit solution of

$$\sum_{j=1}^{I} \sum_{k=1}^{K} \frac{\pi_{ij}^k \left(z_i^k / Z_i\right)^{-\theta} \alpha_j^k \gamma_j}{\sum_{i'=1}^{I} \pi_{i'j}^k \left(z_{i'}^k / Z_{i'}\right)^{-\theta}} = \gamma_i$$

(So only need data (π_{ij}^k, z_i^k) and θ. Same idea as we saw above when discussing Dekle, Eaton and Kortum (2008).)

Counterfactual Predictions: Trade Flows

Theorem 5 (a)

Suppose that Assumptions A1-A5 hold. If we remove country i_0's Ricardian comparative advantage, then counterfactual (proportional) changes in bilateral trade flows, x_{ij}^k, satisfy

$$\widehat{x}_{ij}^k = \frac{\left(z_i^k / Z_i\right)^{-\theta}}{\sum_{i'=1}^{I} \pi_{i'j}^k \left(z_{i'}^k / Z_{i'}\right)^{-\theta}}$$

(Again, only need data (π_{ij}^k, z_i^k) and θ.)

Counterfactual Predictions: Welfare

Theorem 5 (b)

And counterfactual (proportional) changes in country i_0's welfare, $W_{i_0} \equiv w_{i_0} \cdot \prod_k (p_{i_0}^k)^{-\alpha_{i_0}^k}$, satisfy

$$\widehat{W}_{i_0} = \prod_{k=1}^{K} \left[\sum_{i=1}^{I} \pi_{ii_0}^k \left(\frac{z_i^k}{z_{i_0}^k Z_i} \right)^{-\theta} \right]^{\alpha_{i_0}^k / \theta}$$

CDK normalize this by the total gains from trade ($\equiv$ welfare loss of going to autarky):

$$\text{GFT}_{i_0} \equiv \prod_{k=1}^{K} (\pi_{i_0 i_0}^k)^{-\alpha_{i_0}^k / \theta}$$

Revealed Productivity Levels

- Counterfactual method requires data on relative z_i^k.
  - Could use data on z_i^k from ICOP, but empirics suggest measurement error is a problem.
  - Instead use trade flows to obtain 'revealed' productivity:
  - Estimate fixed effect $\delta_i^k = \theta \ln z_i^k$ from:

$$\ln x_{ij}^k = \delta_{ij} + \delta_j^k + \delta_i^k + \varepsilon_{ij}^k$$

- This is a theoretically-justified analogue of Balassa's (1965) 'revealed comparative advantage' measure.

Results: Gains from Trade (Baseline)

Welfare change as fraction of total gains from trade, for each possible choice of the reference country

TABLE 7
Counterfactual results—baseline

	Outcome variable of interest			
	% change in in total exports	Change in index of interindustry trade	% change in welfare	% change in welfare relative to the total gains from trade
Reference country	(1)	(2)	(3)	(4)
Australia	18·52	24·57	−2·90	−39·11
Belgium and Luxembourg	−1·76	4·12	0·71	2·64
Czech Republic	3·91	5·62	−0·12	−1·26
Denmark	0·60	−2·64	−0·40	−2·18
Spain	3·68	−3·89	−0·46	−7·08
Finland	−5·62	3·44	0·14	1·65
France	0·80	−0·49	−0·20	−3·09
Germany	−2·10	−8·46	0·14	2·22
Greece	26·35	−11·23	−4·37	−40·47
Hungary	1·70	−5·28	−0·25	−1·62
Ireland	−5·48	−4·31	0·20	0·74
Italy	−4·76	−9·85	0·14	2·78
Japan	−6·12	−24·75	0·35	24·48
Korea	2·68	−10·15	−0·44	−9·60
Netherlands	1·95	−0·94	−0·64	−2·81
Poland	12·33	−22·35	−1·68	−23·09
Portugal	8·44	−13·62	−0·92	−9·12
Slovakia	2·33	14·11	0·82	4·64
Sweden	−2·98	3·03	0·34	3·30
U.K.	3·45	−4·04	−0·26	−2·94
U.S.	3·82	−3·83	−0·42	−11·71
World average	2·94	−5·72	−0·49	−5·32

Gains from Removing Ricardian CA?

- Some countries (e.g. Japan) appear to gain from removing Ricardian CA.
- How is this possible?
- In both model and in calibration, nothing restricts CA from coming about as purely a supply-side (conventional Ricardian) phenomenon.
  - Upper-tier utility function's Cobb-Douglas shares could vary by country and industry (demand-driven CA). Recall that CDK didn't need to estimate these, so didn't restrict them in any way.
  - And trade costs were unrestricted (so they can in principle vary in such a way as to create CA). Again, recall that these were not estimated and hence not restricted (a common approach is to make TCs a function of distance, which doesn't vary by industry and so would not create CA directly).

Gains from Removing Ricardian CA?

- With this much generality, it is possible that when you remove a country's supply-side (i.e. Ricardian, here) CA then it is actually better off.
  - Put loosely, this requires that, prior to this change, supply-side and demand/TC-driven CA were offsetting one another. That is, countries prefer (ceteris paribus) the goods that they're better at producing. See Atkin (AER, 2014) for a microfoundation for this, based on habit formation.
  - This 'offsetting' sources of CA will mean that autarky prices are actually similar to realized trading equilibrium prices.
- The paper discusses some calibration exercises that confirm this intuition:
  - If restrict things, such that either tastes are homogeneous across countries (taking the Cobb-Douglas weights of world expenditure shares), or TCs do not create CA, then fewer countries lose from removing Ricardian CA.
  - If impose both of these two restrictions then no countries lose