14.581: International Trade
— Lecture 19—
Counterfactuals and Welfare (Empirics)

Plan for Today's Lecture

1. Gravity estimation basics
2. Goodness of fit of gravity equations
3. Beyond gravity

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1. **Gravity estimation basics**
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Estimating the Gravity Model

- Using the notation in Anderson and van Wincoop (2004, JEL), but study imports (M) into i from j rather than exports:

$$M_{ij}^k = \frac{E_i^k Y_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{P_i^k \Pi_j^k} \right)^{1-\epsilon^k}$$

    - Where E_i^k is the importing country's total expenditure on sector k, and Y_j^k is the exporting country's total output in sector k
    - P_i^k and Π_j^k are price indices (that of course depend on E, M and τ, as well as ϵ^k).
    - Y^k is total world income/expenditure
    - τ_{ij}^k here refers to tariffs

- Goal is to estimate ϵ^k
- Write it in logs and in general as:

$$\ln M_{ij}^k(\boldsymbol{\tau}, \mathbf{E}) = A_i^k(\boldsymbol{\tau}, \mathbf{E}) + B_j^k(\boldsymbol{\tau}, \mathbf{E}) + \varepsilon^k \ln \tau_{ij}^k.$$

Identification

- Let's model total trade costs as:

$$\ln \tau_{ij}^k = \ln t_{ij}^k + \ln f_{ij}^k + \sum_m \rho_m^k \ln D_{ij,m}^k + \nu_{ij}^k$$

- Where:
  - t_{ij}^k: tariffs
  - f_{ij}^k: freight/shipping costs
  - $D_{ij,m}^k, \forall m$: bilateral potential shifters of trade costs (eg distance)
  - ν_{ij}^k: unobserved determinants
- Notes:
  - The (log-) additively separable form here is not innocuous
  - The fact that t_{ij}^k and f_{ij}^k have coefficients of one in front of them (perfect proportional pass-through into trade costs) is what allows identification of ϵ^k

Identification

- Let's model total trade costs as:

$$\ln \tau_{ij}^k = \ln t_{ij}^k + \ln f_{ij}^k + \sum_m \rho_m^k \ln D_{ij,m}^k + \nu_{ij}^k$$

- Papers have proceeded with different approaches:
  - Tariffs: e.g. Caliendo and Parro (RESTUD, 2015)
  - Freight rates (from customs bills of lading): e.g. Shapiro (AEJMa, 2015), ACD (2017)
  - Shipping rates from a shipping company: e.g. Limao and Venables (WBER, 2001)
  - Price gaps: e.g Eaton and Kortum (2002) and Simonovska and Waugh (JIE 2013)

Anderson and van Wincoop (AER, 2003)

- AvW (2003) offered an important lesson about how one actually estimates the gravity equation
- Suppose we are estimating the general gravity model:

$$\ln M_{ij}^k(\boldsymbol{\tau}, \mathbf{E}) = A_i^k(\boldsymbol{\tau}, \mathbf{E}) + B_j^k(\boldsymbol{\tau}, \mathbf{E}) + \varepsilon^k \ln \tau_{ij}^k + \nu_{ij}^k. \qquad (1)$$

  - Note how A_i^k and B_j^k (which are equal to $Y_i^k(\Pi_i^k)^{\varepsilon^k-1}$ and $E_j^k(P_j^k)^{\varepsilon^k-1}$ respectively in the AvW, 2004 system) depend on τ_{ij}^k too.
  - Obviously the Y_i^k and E_j^k terms, as well as the P_j^k and Π_i^k terms, are all endogenous. Also very hard to get data on.
  - So a naive regression of X_{ij}^k on E_j^k, Y_i^k and τ_{ij}^k had typically been performed (this is AvW's 'traditional gravity') instead.
  - AvW (2003) pointed out that this is wrong. The estimates of ϵ^k and ρ_m^k will be biased by OVB (we've omitted the P_j^k and Π_i^k terms and they are correlated with τ_{ij}^k).

Anderson and van Wincoop (AER, 2003)

- How to solve this problem?
  - AvW (2003) propose non-linear least squares:
    - The functions $(\Pi_i^k)^{1-\varepsilon^k} \equiv \sum_j \left(\frac{\tau_{ij}^k}{P_j^k}\right)^{1-\varepsilon^k} \frac{E_j^k}{Y^k}$ and $(P_j^k)^{1-\varepsilon^k} \equiv \sum_i \left(\frac{\tau_{ij}^k}{\Pi_i^k}\right)^{1-\varepsilon^k} \frac{Y_i^k}{Y^k}$ are known.
    - These are non-linear functions of the parameter of interest (ρ), but NLS can solve that.
  - A simpler approach (first in Harrigan, 1996) is usually pursued instead though:
    - The terms $A_i^k(\boldsymbol{\tau}, \mathbf{E})$ and $B_j^k(\boldsymbol{\tau}, \mathbf{E})$ can be partialled out using α_i^k and α_j^k fixed effects.
    - Note that (i.e. avoid what Baldwin and Taglioni call the 'gold medal mistake') if you're doing this regression on panel data, you need separate fixed effects α_{it}^k and α_{jt}^k in each year t.

Anderson and van Wincoop (AER, 2003)

- This was an important general point about estimating gravity equations
  - And it is a nice example of general equilibrium empirical thinking.
- But AvW (2003) applied their method to revisit McCallum (AER, 1995)'s famous argument that there was a huge 'border' effect within North America:
  - This is an additional premium on crossing the border, controlling for distance.
  - Ontario appears to want to trade far more with Alberta (miles away) than New York (close, but over a border).
- The problem is that, as AvW (2003) showed, McCallum (1995) didn't control for the endogenous terms $A_i^k(\boldsymbol{\tau}, \mathbf{E})$ and $B_j^k(\boldsymbol{\tau}, \mathbf{E})$.

Anderson and van Wincoop (AER, 2003): Results

Re-running McCallum (1995)'s specification. Canadian border effect much larger than US border effect. It is also enormous.

TABLE 1—MCCALLUM REGRESSIONS

	McCallum regressions			Unitary income elasticities		
Data	(i) CA–CA CA–US	(ii) US–US CA–US	(iii) US–US CA–CA CA–US	(iv) CA–CA CA–US	(v) US–US CA–US	(vi) US–US CA–CA CA–US
Independent variable						
$\ln y_i$	1.22	1.13	1.13	1	1	1
	(0.04)	(0.03)	(0.03)			
$\ln y_j$	0.98	0.98	0.97	1	1	1
	(0.03)	(0.02)	(0.02)			
$\ln d_{ij}$	−1.35	−1.08	−1.11	−1.35	−1.09	−1.12
	(0.07)	(0.04)	(0.04)	(0.07)	(0.04)	(0.03)
Dummy–Canada	2.80		2.75	2.63		2.66
	(0.12)		(0.12)	(0.11)		(0.12)
Dummy–U.S.		0.41	0.40		0.49	0.48
		(0.05)	(0.05)		(0.06)	(0.06)
Border–Canada	16.4		15.7	13.8		14.2
	(2.0)		(1.9)	(1.6)		(1.6)
Border–U.S.		1.50	1.49		1.63	1.62
		(0.08)	(0.08)		(0.09)	(0.09)
$\bar{R}^2$	0.76	0.85	0.85	0.53	0.47	0.55
Remoteness variables added						
Border–Canada	16.3		15.6	14.7		15.0
	(2.0)		(1.9)	(1.7)		(1.8)
Border–U.S.		1.38	1.38		1.42	1.42
		(0.07)	(0.07)		(0.08)	(0.08)
$\bar{R}^2$	0.77	0.86	0.86	0.55	0.50	0.57

Notes: The table reports the results of estimating a McCallum gravity equation for the year 1993 for 30 U.S. states and 10 Canadian provinces. In all regressions the dependent variable is the log of exports from region i to region j. The independent variables are defined as follows: y_i and y_j are gross domestic production in regions i and j; d_{ij} is the distance between regions i and j; *Dummy–Canada* and *Dummy–U.S.* are dummy variables that are one when both regions are located in respectively Canada and the United States, and zero otherwise. The first three columns report results based on nonunitary income elasticities (as in the original McCallum regressions), while the last three columns assume unitary income elasticities. Results are reported for three different sets of data: (i) state–province and interprovincial trade, (ii) state–province and interstate trade, (iii) state–province, interprovincial, and interstate trade. The border coefficients *Border–U.S.* and *Border–Canada* are the exponentials of the coefficients on the respective dummy variables. The final three rows report the border coefficients and $\bar{R}^2$ when the remoteness indices (3) are added. Robust standard errors are in parentheses.

Anderson and van Wincoop (AER, 2003): Results

Using theory-consistent (NLS) specification. All countries now have similar (and reasonable) border effects.

TABLE 2—ESTIMATION RESULTS

		Two-country model	Multicountry model
Parameters	$(1-\sigma)\rho$	-0.79	-0.82
		(0.03)	(0.03)
	$(1-\sigma)\ln b_{US,CA}$	-1.65	-1.59
		(0.08)	(0.08)
	$(1-\sigma)\ln b_{US,ROW}$		-1.68
			(0.07)
	$(1-\sigma)\ln b_{CA,ROW}$		-2.31
			(0.08)
	$(1-\sigma)\ln b_{ROW,ROW}$		-1.66
			(0.06)
Average error terms:	US–US	0.06	0.06
	CA–CA	-0.17	-0.02
	US–CA	-0.05	-0.04

Notes: The table reports parameter estimates from the two-country model and the multicountry model. Robust standard errors are in parentheses. The table also reports average error terms for interstate, interprovincial, and state–province trade.

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2. **Goodness of fit of gravity equations**
3. Beyond gravity

Goodness of Fit of Gravity Equations

- Lai and Trefler (2002, unpublished) discuss (among other things) the fit of the gravity equation.
- Using the notation in Anderson and van Wincoop (2004, JEL), but study imports (M) into i from j rather than exports:

$$M_{ij}^k = \frac{E_i^k Y_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{P_i^k \Pi_j^k} \right)^{1-\epsilon^k}$$

  - Where P_i^k and Π_j^k are price indices (that of course depend on E, M and τ).
  - Y^k is total world income/expenditure
  - τ_{ij}^k here refers to tariffs

Goodness of Fit of Gravity Equations

$$M_{ij}^k = \frac{E_i^k Y_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{P_i^k \Pi_j^k} \right)^{1-\epsilon^k}$$

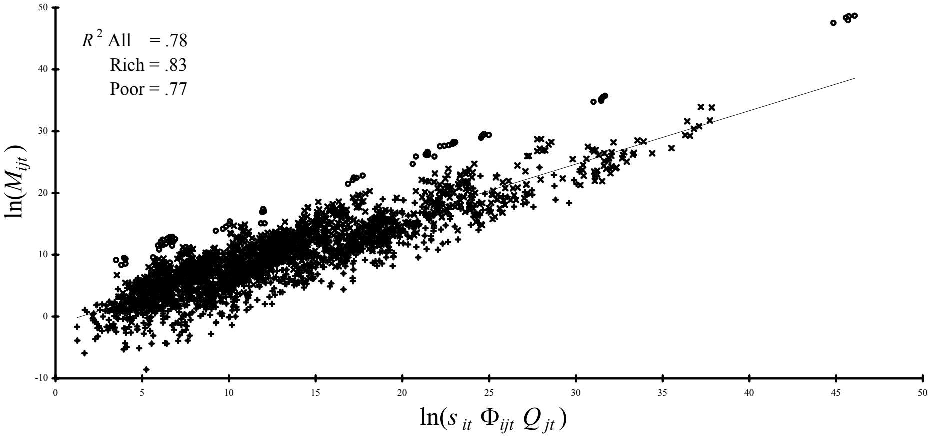
- Lai and Trefler (2002) discuss the fit of this equation, and then divide up the fit into 3 parts (mapping to their notation):
  1. $Q_j^k \equiv Y_j^k$. Fit from this, they argue, is uninteresting due to the "data identity" that $\sum_i M_{ij}^k = Y_j^k$.
  2. $s_i^k \equiv E_i^k$. Fit from this, they argue, is somewhat interesting as it's due to homothetic preferences. But not *that* interesting.
  3. $\Phi_{ij}^k \equiv \left(\frac{\tau_{ij}^k}{P_i^k \Pi_j^k} \right)^{1-\epsilon^k}$. This, they argue, is the interesting bit of the gravity equation. It includes the partial-equilibrium effect of trade costs τ_{ij}^k, as well as the general equilibrium effects in P_i^k and Π_j^k.

Lai and Trefler (2002): Other Notes

- Other notes on their estimation procedure:
  - They use 3-digit manufacturing industries (28 industries), every 5 years from 1972-1992, 14 importers (OECD) and 36 exporters. (Big constraint is data on tariffs.)
  - They assume that trade costs τ_{ij}^k (which could, in principle, include transport costs, etc) is just equal to tariffs.
  - They estimate one parameter ϵ^k per industry k.
  - They also allow for unrestricted taste-shifters by country (fixed over time).
  - Note that the term Φ_{ij}^k is highly non-linear in parameters. So this is done via NLS. But that isn't strictly necessary because one could instead use the normal gravity method of regressing $\ln M_{ij}^k$ on $\ln \tau_{ij}^k$ using OLS with ik and jk fixed-effects

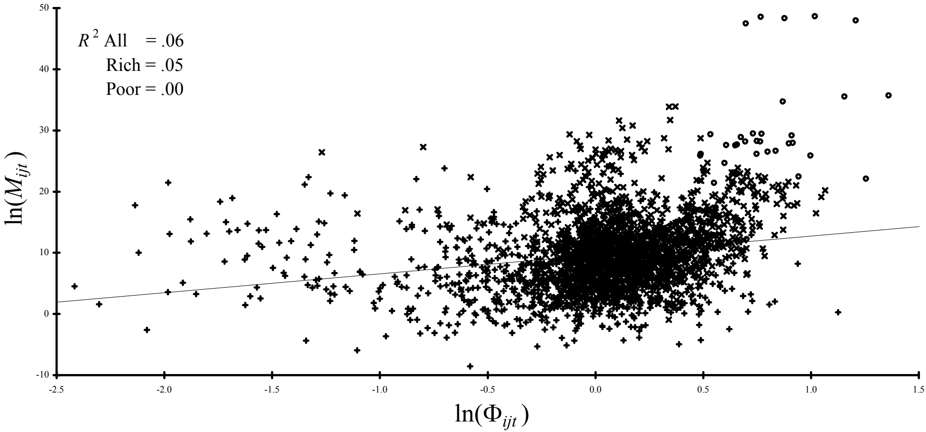
Lai and Trefler (2002): Results

Overall fit, pooled cross-sections



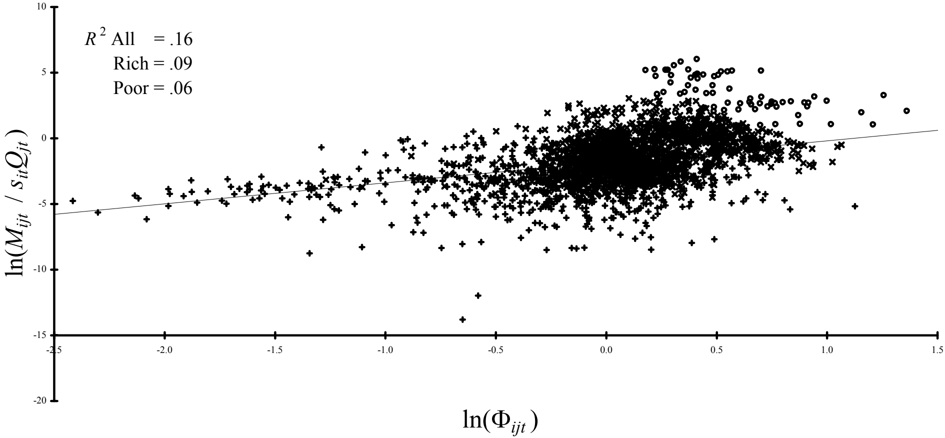
Lai and Trefler (2002): Results

Fit from just Φ_{ijt}^{k}, pooled cross-sections



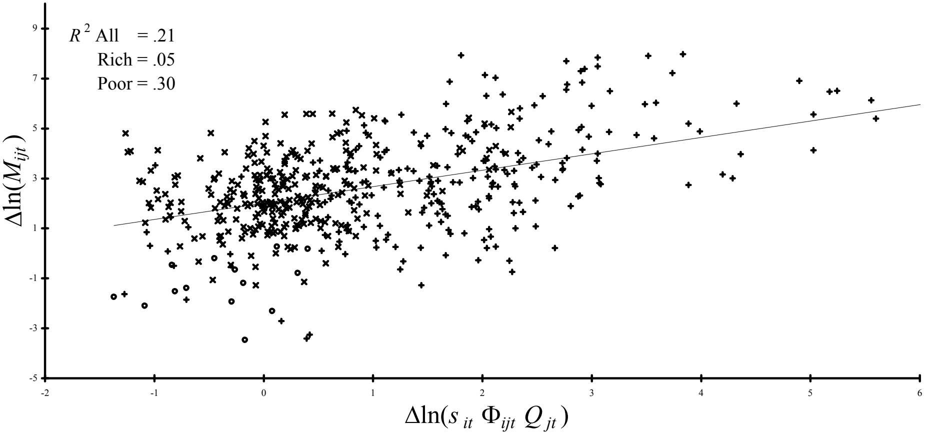
Lai and Trefler (2002): Results

Fit from just Φ_{ijt}^k, but controlling for s_{it}^k and Q_{jt}^k, pooled cross-sections



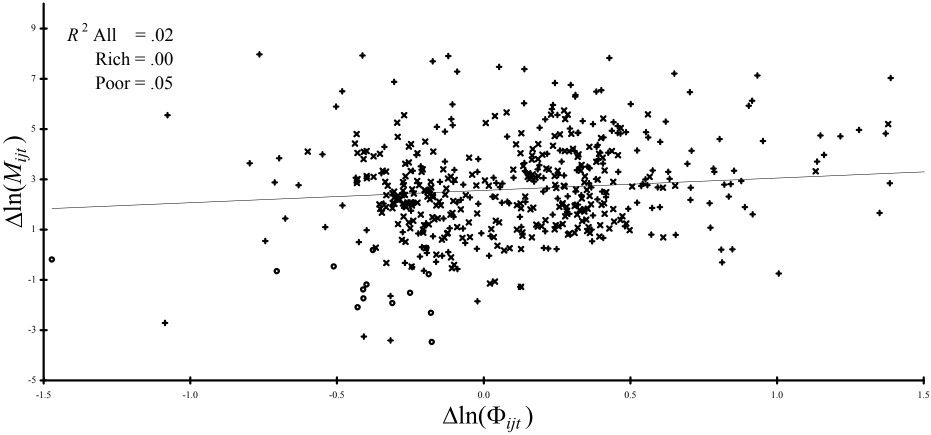
Lai and Trefler (2002): Results

Overall fit, long differences



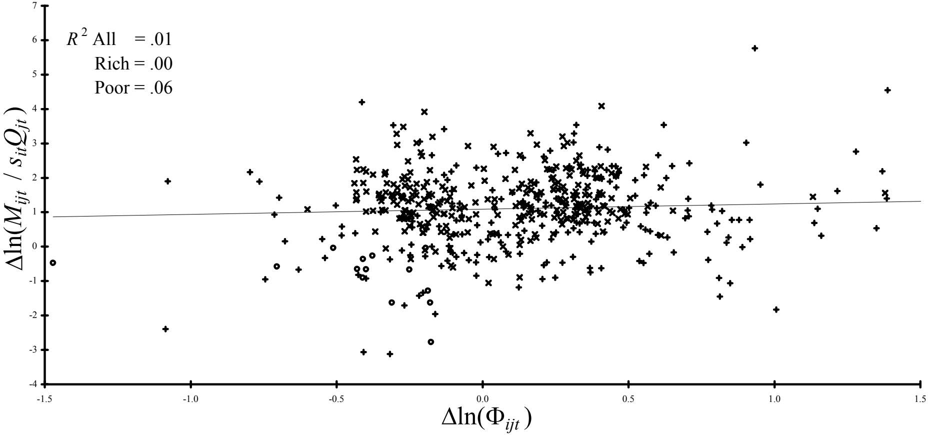
Lai and Trefler (2002): Results

Fit from just Φ_{ijt}^{k}, long differences



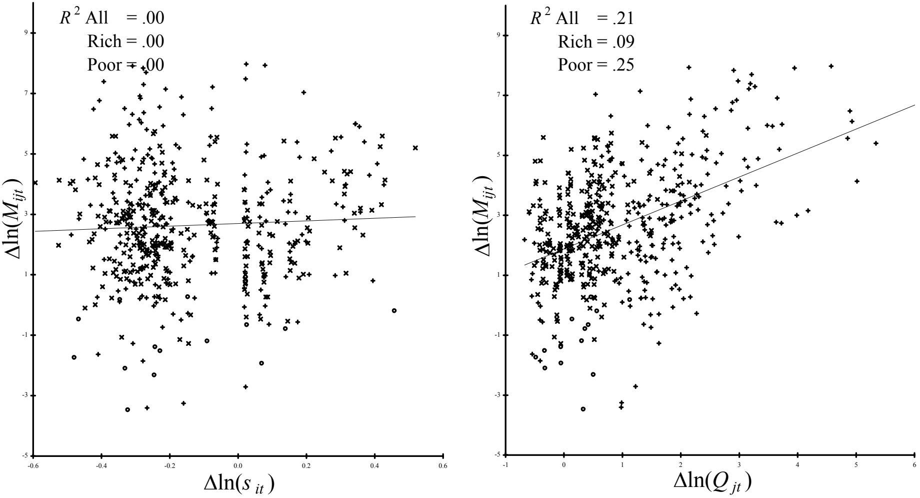
Lai and Trefler (2002): Results

Fit from just Φ_{ijt}^{k}, but controlling for s_{it}^{k} and Q_{jt}^{k}, long differences



Lai and Trefler (2002): Results

Is fit over long diffs driven by s_{it}^k or Q_{jt}^k?



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Plan for Today's Lecture

1. Estimating trade costs and trade demand functions beyond gravity: Adao, Costinot and Donaldson (2016)

Adao, Costinot and Donaldson (2016)—Begin with recap from lecture #18...

- $i = 1, ..., I$ countries
- $k = 1, ..., K$ goods
- $n = 1, ..., N$ factors
- Goods consumed in country i:

$$\boldsymbol{q_i} \equiv \{q_{ji}^k\}$$

- Factors used in country i to produce good k for country j:

$$\boldsymbol{l_{ij}^k} \equiv \{l_{ij}^{nk}\}$$

Neoclassical Trade Model

- Preferences: $u_i = u_i(\boldsymbol{q_i})$
  - Representative consumer (driven by data from "country" i)
- Technology: $q^k_{ji} = f^k_{ji}(\boldsymbol{l^k_{ji}})$
  - Non-increasing returns to scale. No joint production.
  - Extensions in paper to include (global/domestic) input-output linkages and tariffs/taxes/subsidies.
- Factor endowments: $\nu^n_j > 0$
  - Defined as the (set of imperfectly substitutable) inputs to production that are in fixed supply.

Competitive Equilibrium

A $\boldsymbol{q} \equiv \{\boldsymbol{q_i}\}$, $\boldsymbol{l} \equiv \{\boldsymbol{l_i}\}$, $\boldsymbol{p} \equiv \{\boldsymbol{p_i}\}$, and $\boldsymbol{w} \equiv \{\boldsymbol{w_i}\}$ such that:

1. Consumers maximize their utility:

$$\boldsymbol{q_i} \in \operatorname{argmax}_{\boldsymbol{\tilde{q}_i}} u_i(\boldsymbol{\tilde{q}_i})$$
$$\sum_{j,k} p_{ji}^k \tilde{q}_{ji}^k \leq \sum_n w_i^n \nu_i^n \text{ for all } i;$$

2. Firms maximize their profits:

$$\boldsymbol{l_{ji}^k} \in \operatorname{argmax}_{\boldsymbol{\tilde{l}_{ji}^k}} \{p_{ji}^k f_{ij}^k(\boldsymbol{\tilde{l}_{ji}^k}) - \sum_n w_j^n \tilde{l}_{ji}^{nk}\} \text{ for all } i, j, k;$$

3. Goods markets clear:

$$q_{ji}^k = f_{ji}^k(\boldsymbol{l_{ji}^k}) \text{ for all } i, j, \text{ and } k;$$

4. Factors markets clear:

$$\sum_{i,k} l_{ji}^{nk} = \nu_j^n \text{ for all } j \text{ and } n.$$

Reduced Exchange Model

- Fictitious endowment economy in which consumers directly exchange factor services
  - Taylor (1938), Rader (1972), Wilson (1980), Mas-Colell (1991)

- *Reduced preferences* over primary factors of production defined by:

$$U_i(\boldsymbol{L_i}) \equiv \max_{\tilde{\boldsymbol{q}}_{\boldsymbol{i}}, \tilde{\boldsymbol{l}}_{\boldsymbol{i}}} u_i(\tilde{\boldsymbol{q}}_{\boldsymbol{i}})$$

$$\tilde{q}_{ji}^k \leq f_{ji}^k(\tilde{\boldsymbol{l}}_{\boldsymbol{ji}}^{\boldsymbol{k}}) \text{ for all } j \text{ and } k,$$

$$\sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n \text{ for all } j \text{ and } n,$$

Reduced Equilibrium

Corresponds to $\boldsymbol{L} \equiv \{\boldsymbol{L_i}\}$ and $\boldsymbol{w} \equiv \{\boldsymbol{w_i}\}$ such that:

1. Consumers maximize their reduced utility:

$$\boldsymbol{L_i} \in \operatorname{argmax}_{\tilde{\boldsymbol{L}}_{\boldsymbol{i}}} U_i(\tilde{\boldsymbol{L}}_{\boldsymbol{i}})$$

$$\sum_{j,n} w_j^n \tilde{L}_{ji}^n \leq \sum_n w_i^n \nu_i^n \text{ for all } i;$$

2. Factor markets clear:

$$\sum_j L_{ij}^n = \nu_i^n \text{ for all } i \text{ and } n.$$

Equivalence

- **Proposition 1**: *For any competitive equilibrium,* $(\boldsymbol{q}, \boldsymbol{l}, \boldsymbol{p}, \boldsymbol{w})$*, there exists a reduced equilibrium,* $(\boldsymbol{L}, \boldsymbol{w})$*, with:*
  1. *the same factor prices,* $\boldsymbol{w}$*;*
  2. *the same factor content of trade,* $L_{ji}^n = \sum_k l_{ji}^{nk}$ *for all* i*,* j*, and* n*;*
  3. *the same welfare levels,* $U_i(\boldsymbol{L_i}) = u_i(\boldsymbol{q_i})$ *for all* i*.*

  Conversely, for any reduced equilibrium, $(\boldsymbol{L}, \boldsymbol{w})$*, there exists a competitive equilibrium,* $(\boldsymbol{q}, \boldsymbol{l}, \boldsymbol{p}, \boldsymbol{w})$*, such that 1-3 hold.*

Reduced Counterfactuals

- Suppose that the reduced utility function over primary factors in this economy can be parametrized as

$$U_i(\boldsymbol{L_i}) \equiv \bar{U}_i(\{L_{ji}^n/\tau_{ji}^n\}),$$

where $\tau_{ji}^n > 0$ are exogenous preference shocks

- **Counterfactual question:** *What are the effects of a change from* $(\boldsymbol{\tau}, \boldsymbol{\nu})$ *to* $(\boldsymbol{\tau}', \boldsymbol{\nu}')$ *on trade flows, factor prices, and welfare?*

Reduced Factor Demand System

- Start from factor demand = solution of reduced UMP:

$$\boldsymbol{L_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i})$$

- Compute associated expenditure shares:

$$\boldsymbol{\chi_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i}) \equiv \{\{x_{ji}^n\}|x_{ji}^n = w_j^n L_{ji}^n / y_i \text{ for } \boldsymbol{L_i} \in \boldsymbol{L_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i})\}$$

- Rearrange in terms of *effective factor prices*, $\boldsymbol{\omega_i} \equiv \{w_j^n \tau_{ji}^n\}$:

$$\boldsymbol{\chi_i}(\boldsymbol{w}, y_i|\boldsymbol{\tau_i}) \equiv \boldsymbol{\chi_i}(\boldsymbol{\omega_i}, y_i)$$

Reduced Equilibrium

- In this notation, RE is:

$$\boldsymbol{x_i} \in \boldsymbol{\chi_i}(\boldsymbol{\omega_i}, y_i), \text{ for all } i,$$
$$\sum_j x_{ij}^n y_j = y_i^n, \text{ for all } i \text{ and } n$$

- **Gravity model (i.e. ACR):** Reduced factor demand system is CES

$$\chi_{ji}(\boldsymbol{\omega_i}, y_i) = \frac{\mu_{ji}(\omega_{ji})^{\epsilon}}{\sum_l \mu_{li}(\omega_{li})^{\epsilon}}, \text{ for all } j \text{ and } i$$

- **Proposition 2:** *Proportional changes in expenditure shares and factor prices,* $\hat{\boldsymbol{x}}$ *and* $\hat{\boldsymbol{w}}$*, caused by proportional changes in preferences and endowments,* $\hat{\boldsymbol{\tau}}$ *and* $\hat{\boldsymbol{\nu}}$*, solve*

$$\{\hat{x}_{ji}^n x_{ji}^n\} \in \boldsymbol{\chi_i}(\{\hat{w}_j^n \hat{\tau}_{ji}^n\}, \sum_n \hat{w}_i^n \hat{\nu}_i^n y_i^n) \ \forall \ i,$$

$$\sum_j \hat{x}_{ij}^n x_{ij}^n (\sum_n \hat{w}_j^n \hat{\nu}_j^n y_j^n) = \hat{w}_i^n \hat{\nu}_i^n y_i^n \ \forall \ i \text{ and } n.$$

Counterfactual Welfare Changes

- **Proposition 3:** *Equivalent variation associated with change from $(\boldsymbol{\tau}, \boldsymbol{\nu})$ to $(\boldsymbol{\tau}', \boldsymbol{\nu}')$, expressed as fraction of initial income, is*

$$\Delta W_i = (e(\boldsymbol{\omega}_i, U_i') - y_i)/y_i,$$

where $\boldsymbol{\omega}_i = 1$ for all i, j and n, and $e(\cdot, U_i')$ is the unique solution of ODE

$$\frac{d \ln e_i(\boldsymbol{\omega}, U_i')}{d \ln \omega_j^n} = x_{ji}^n(\boldsymbol{\omega}, e_i(\boldsymbol{\omega}, U_i')) \text{ for all } j \text{ and } n.$$

with boundary condition $e(\boldsymbol{\omega}_i', U_i') = y_i'$.

Application to Neoclassical Trade Models

- Suppose that technology in neoclassical model satisfies:

$$f_{ij}^k(\boldsymbol{l_{ij}^k}) \equiv \bar{f}_{ij}^k(\{l_{ij}^{nk}/\tau_{ij}^n\}), \text{ for all } i, j, \text{ and } k,$$

- Reduced utility function over primary factors:

$$\begin{aligned} U_i(\boldsymbol{L_i}) \equiv \max\nolimits_{\tilde{\boldsymbol{q}}_{\boldsymbol{i}}, \tilde{\boldsymbol{l}}_{\boldsymbol{i}}} u_i(\tilde{\boldsymbol{q}}_{\boldsymbol{i}}) & \\ \tilde{q}_{ji}^k \leq \bar{f}_{ji}^k(\{\tilde{l}_{ji}^{nk}/\tau_{ji}^n\}) & \text{ for all } j \text{ and } k, \\ \sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n & \text{ for all } j \text{ and } n. \end{aligned}$$

- Change of variable: $U_i(L_i) \equiv \bar{U}_i(\{L_{ji}^n/\tau_{ji}^n\}) \Rightarrow$ factor-augmenting productivity shocks in CE = preference shocks in RE
  - NB: $\hat{\boldsymbol{\tau}}$ cannot depend on k. But $\boldsymbol{\tau}$ can do so freely.
  - And can always allow for $\hat{\tau}_{ji}^{nk} \neq 1$ by defining a new factor that is specific to sector k (plus arbitrage).

Econometric Model

- Data generated by neoclassical trade model at different dates t
- At each date, preferences and technology such that:

$$u_{i,t}(\boldsymbol{q_{i,t}}) = \bar{u}_i(\{q^k_{ji,t}\}), \text{ for all } i,$$
$$f^k_{ij,t}(\boldsymbol{l^k_{ij,t}}) = \bar{f}^k_{ji}(\{l^{nk}_{ij,t}/\tau^n_{ij,t}\}), \text{ for all } i, j, \text{ and } k.$$

- Observables:
  1. $x^n_{ji,t}$: factor expenditure shares (normal FCT data in principle; but non-trivial aggregation bias issues in practice)
  2. $y^n_{i,t}$: factor payments
  3. $(z^\tau)^n_{ji,t}$: factor price shifters (e.g. observable shifter of trade costs)
  4. $(z^y)_{i,t}$: income shifter

Identification Assumptions: Exogeneity

- Effective factor prices, $\omega^n_{ji,t}$, unobservable, but assume related to $(z^\tau)^n_{ji,t}$ via:

$$\ln\omega^n_{ji,t} = \ln(z^\tau)^n_{ji,t} + \varphi^n_{ji} + \xi^n_{j,t} + \eta^n_{ji,t}, \text{ for all } i,\, j,\, n, \text{ and } t$$

- **A1. [Exogeneity]** $E[\eta^n_{ji,t}|\mathbf{z}_t] = 0$, *with* $\mathbf{z}_t \equiv \{\mathbf{z}^\tau_{l,t}, z^y_{l,t}\}$.

Identification Assumptions: Completeness

- Following Newey and Powell (Ecta, 2003), we impose the following completeness condition.
- **A2. [Completeness]** *For any importer pair* (i_1, i_2)*, and any function* $g(\boldsymbol{x_{i_1,t}}, y_{i_1,t}, \boldsymbol{x_{i_2,t}}, y_{i_2,t})$ *with finite expectation,* $E[g(\boldsymbol{x_{i_1,t}}, y_{i_1,t}, \boldsymbol{x_{i_2,t}}, y_{i_2,t})|\boldsymbol{z}_t] = 0$ *implies* $g(\boldsymbol{x_{i_1,t}}, y_{i_1,t}, \boldsymbol{x_{i_2,t}}, y_{i_2,t}) = 0$*.*
- (This is the analog of the rank condition in parametric models.)

Identification of Factor Demand

- Argument follows Berry and Haile (Ecta, 2014)
- **A3. [Invertibility]** *In any country i, for any observed expenditure shares, $\boldsymbol{x} > 0$, and any observed income level, $y > 0$, there exists a unique vector of relative effective factor prices, $(\boldsymbol{\chi}_i)^{-1}(\boldsymbol{x}, y)$, such that all $\boldsymbol{\omega}_i$ satisfying $\boldsymbol{x} \in \boldsymbol{\chi}_i(\boldsymbol{\omega}_i, y)$ also satisfy $\omega_{ji}^n / \omega_{1i}^1 = (\chi_{ji}^n)^{-1}(\boldsymbol{x}, y)$.*
- **Proposition 4** *Suppose that A1-A3 hold. Then relative effective factor prices $\{\boldsymbol{\omega_{i,t}}\}$ and the factor demand system $\bar{\boldsymbol{\chi}}$ are identified.*
- Paper discusses sufficient conditions for invertibility of some trade models—e.g. Ricardian model when goods preferences satisfy connected substitutes (Berry, Gandhi and Haile, Ecta, 2013).

Estimation

- **Some simplifications:**
  - Homothetic preferences
  - Within any country, all goods have same factor intensities (i.e. Ricardian model)
  - $\chi_i(\boldsymbol{\omega}_{i,t}) = \chi(\{\mu_{ji}\omega_{ji,t}\})$, for all i.
- **Our data:**
  - $x^n_{ji,t}$ and $y^n_{i,t}$ from WIOD
  - $z^{\tau}_{ji,t}$ = freight costs (Hummels and Lugovsky 2006, Shapiro 2014)
  - i = Australia and USA
  - t = 1995-2010
  - j = 36 large exporters + ROW

Parametric Demand System

- Inspired by Berry (1994) and BLP's (1995) on mixed logit, we consider the following "Mixed CES" system:

$$\chi_{ji}(\boldsymbol{\omega}_{i,t}) = \int \frac{(\kappa_j)^{\sigma_\alpha \alpha}(\mu_{ji}\omega_{ji,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}}{\sum_{l=1}^{N}(\kappa_l)^{\sigma_\alpha \alpha}(\mu_{li}\omega_{li,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}} dF(\alpha, \epsilon)$$

- Where:
  - $\kappa_j =$ "characteristic" of exporter j (per-capita GDP in 1995);
  - $F(\alpha, \epsilon)$ is a bivariate distribution of parameter heterogeneity: α has mean zero, $\ln \epsilon$ mean zero, and covariance matrix is identity
  - $\boldsymbol{\mu}_i \equiv \{\mu_{ji}\}$ is a vector of unobserved importer-exporter-specific shifters;

- Departures from gravity (IIA) governed by $\sigma_\alpha \neq 0$ or $\sigma_\epsilon \neq 0$

Comments

$$\chi_{ji}(\boldsymbol{\omega}_{i,t}) = \int \frac{(\kappa_j)^{\sigma_\alpha \alpha} (\mu_{ji}\omega_{ji,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}}{\sum_{l=1}^{N} (\kappa_l)^{\sigma_\alpha \alpha} (\mu_{li}\omega_{li,t})^{-(\bar{\epsilon}\cdot\epsilon^{\sigma_\epsilon})}} dF(\alpha, \epsilon)$$

- **Costs**:
  - Ricardian $\Rightarrow$ Only cross-country price elasticities
  - Homothetic preferences $\Rightarrow$ Factor shares independent of income
- **Benefits**:
  - $\sigma_\alpha = \sigma_\epsilon = 0 \Rightarrow$ CES demand system is nested
  - $\sigma_\alpha \neq 0 \Rightarrow$ Departure from IIA: more similar exporters in terms of $|\kappa_j - \kappa_l|$ are closer substitutes
  - $\sigma_\epsilon \neq 0 \Rightarrow$ Departure from IIA: more similar exporters in terms of $|\omega_j - \omega_l|$ are closer substitutes

reduced-form results

GMM Estimation

- Start by inverting mixed CES demand system:

$$\Delta\eta_{ji,t} - \Delta\eta_{j1,t} = \ln\chi_j^{-1}(\boldsymbol{x}_{i,t}) - \ln\chi_j^{-1}(\boldsymbol{x}_{1,t})$$
$$-(\Delta\ln(z^\tau)_{ji,t} - \Delta\ln(z^\tau)_{j1,t}) + \zeta_{ji}$$

- Construct structural error term $e_{ji,t}(\boldsymbol{\theta})$ and solve for:

$$\hat{\boldsymbol{\theta}} = \mathrm{argmin}_{\boldsymbol{\theta}}\ \boldsymbol{e(\theta)'Z\Phi Ze(\theta)}$$

- Parameters:
  - $\boldsymbol{\theta} \equiv (\sigma_\alpha, \sigma_\epsilon, \bar{\epsilon}, \{\zeta_{ji}\})$
- Instruments (by A1):
  - $\Delta\ln(z^\tau)_{ji,t} - \Delta\ln(z^\tau)_{j1,t}$, $\{|\kappa_j - \kappa_l|(\ln z^\tau_{li,t} - \ln z^\tau_{l1,t})\}$, $\boldsymbol{d}_{ji,t}$

Departures from IIA in Standard Gravity

TABLE 1—REDUCED-FORM ESTIMATES AND VIOLATION OF IIA IN GRAVITY ESTIMATION

Dependent var.: $\Delta\Delta$ log(exports)	(1)	(2)	(3)	(4)
$\Delta\Delta$ log(freight cost)	-5.955	-6.239	-1.471	-1.369
	(0.995)	(1.100)	(0.408)	(0.357)
Test for joint significance of interacted competitors' freight costs ($H_0 : \gamma_l = 0$ *for all* l)				
F-stat		110.34		768.63
p-value		< 0.001		< 0.001
Disaggregation level	exporter		exporter-industry	
Observations	576		8,880	

Notes: Sample of exports from 37 countries to Australia and United States between 1995 and 2010 (aggregate and 2-digit industry-level). The notation $\Delta\Delta$ refers to the double-difference (first with respect to one exporting country, the United States, and second across the two importing countries). All models include a full set of dummy variables for exporter(-industry). Standard errors clustered by exporter are reported in parentheses.

Demand System Parameter Estimates

TABLE 2—GMM ESTIMATES OF MIXED CES DEMAND

	$\bar{\epsilon}$	σ_{α}	σ_{ϵ}
Panel A. CES			
	−5.955		
	(0.950)		
Panel B. Mixed CES (restricted heterogeneity)			
	−6.115	2.075	
	(0.918)	(0.817)	
Panel C. Mixed CES (unrestricted heterogeneity)			
	−6.116	2.063	0.003
	(0.948)	(0.916)	(0.248)

Notes: Sample of exports from 37 countries to Australia and United States between 1995 and 2010. All models include 36 exporter dummies. One-step GMM estimator described in Appendix B. Standard errors clustered by exporter are reported in parentheses.

Estimates of Chinese Trade Costs

- Non-parametric generalization of Head and Ries (2001) index:

$$\frac{(\tau_{ji,t}/\tau_{ii,t})}{(\tau_{jj,t}/\tau_{ij,t})} = \frac{(\bar{\chi}_j^{-1}(\boldsymbol{x}_{i,t})/\bar{\chi}_i^{-1}(\boldsymbol{x}_{i,t}))}{(\bar{\chi}_j^{-1}(\boldsymbol{x}_{j,t})/\bar{\chi}_i^{-1}(\boldsymbol{x}_{j,t}))}, \text{ for all } i,\ j, \text{ and } t.$$

- To go from (log-)difference-in-differences to levels of trade costs:

$$\begin{aligned} \tau_{ii,t}/\tau_{ii,95} &= 1 \text{ for all } i \text{ and } t, \\ \tau_{ij,t}/\tau_{ij,95} &= \tau_{ji,t}/\tau_{ji,95} \text{ for all } t \text{ if } i \text{ or } j \text{ is China.} \end{aligned}$$

Estimates of Chinese Trade Costs

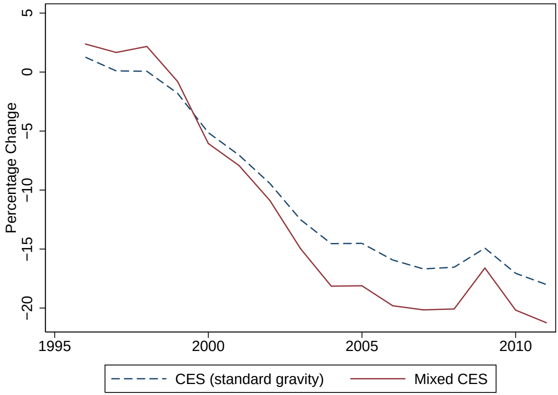

Figure 2: Average trade cost changes since 1995: China, 1996-2011.

Notes: Arithmetic average across all trading partners in the percentage reduction in Chinese trade costs between 1995 and each year $t = 1996, \ldots, 2011$. "CES (standard gravity)" and "Mixed CES" plot the estimates of trade costs obtained using the factor demand system in Panels A and C, respectively, of Table 2.

Counterfactual Shock: Chinese Integration

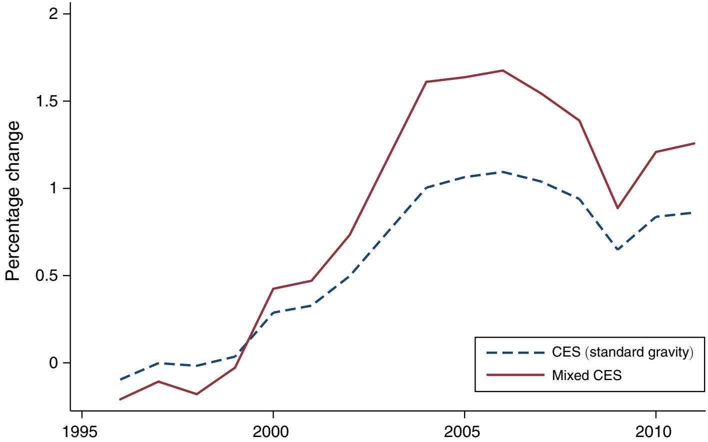

FIGURE 3. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: CHINA, 1996–2011

Notes: Welfare gains in China from reduction in Chinese trade costs relative to 1995 in each year $t = 1996, \ldots, 2011$. CES (standard gravity) and mixed CES plot the estimates of welfare changes obtained using the factor demand system in panels A and C, respectively, of Table 2.

Counterfactual Shock: Chinese Integration

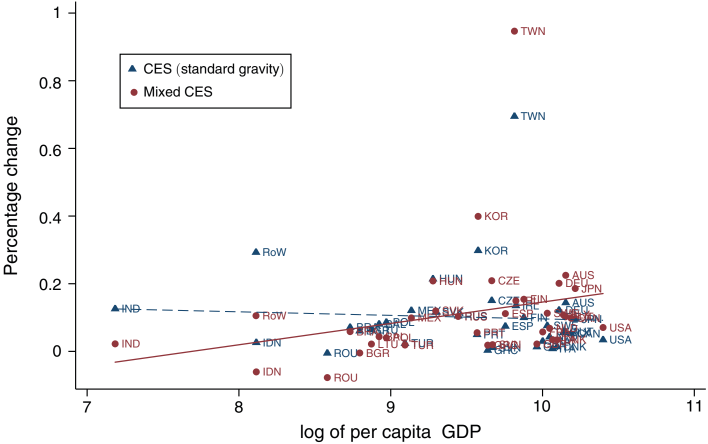

FIGURE 4. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: OTHER COUNTRIES, 2007

Notes: Welfare gains in other countries from reduction in Chinese trade costs relative to 1995 in year $t = 2007$. CES (standard gravity) and mixed CES plot the estimates of welfare changes obtained using the factor demand system in panels A and C, respectively, of Table 2. The solid line shows the line of best fit through the mixed CES points, and the dashed line the equivalent for the CES case. Bootstrapped 95 percent confidence intervals for these estimates are reported in Table A2.