14.581: International Trade
— Lecture 15—
Trade Costs and Gravity (Empirics III)

Plan for Today's Lecture

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

Neoclassical Trade Model—Begin With Recap from Lecture #10...

- $i = 1, ..., I$ 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: $q_{ji}^k = f_{ji}^k(\boldsymbol{l_{ji}^k})$
  - Non-increasing returns to scale. No joint production.
  - Extensions in paper to include (global/domestic) input-output linkages and tariffs/taxes/subsidies.
- Factor endowments: $\nu_j^n > 0$
  - 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:
$$\boldsymbol{q_i} \in \text{argmax}_{\boldsymbol{\tilde{q}_i}} u_i(\boldsymbol{\tilde{q}_i})$$
$$\sum_{j,k} p_{ji}^k \tilde{q}_{ji}^k \leq \sum_n w_i^n \nu_i^n \text{ for all } i;$$
2. Firms maximize their profits:
$$\boldsymbol{l_{ji}^k} \in \text{argmax}_{\boldsymbol{\tilde{l}_{ji}^k}} \{p_{ji}^k f_{ij}^k(\boldsymbol{\tilde{l}_{ji}^k}) - \sum_n w_j^n \tilde{l}_{ji}^{nk}\} \text{ for all } i,\ j,\ k;$$
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:

$$U_i(\boldsymbol{L_i}) \equiv \max_{\boldsymbol{\tilde{q}_i},\boldsymbol{\tilde{l}_i}} u_i(\boldsymbol{\tilde{q}_i})$$
$$\tilde{q}_{ji}^k \leq f_{ji}^k(\boldsymbol{\tilde{l}_{ji}^k}) \text{ for all } j \text{ and } k,$$
$$\sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n \text{ for all } j \text{ and } n,$$

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

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

Counterfactual Trade Flows and Factor Prices

- **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:

$$U_i(\boldsymbol{L_i}) \equiv \max_{\boldsymbol{\tilde{q}_i}, \boldsymbol{\tilde{l}_i}} u_i(\boldsymbol{\tilde{q}_i})$$
$$\tilde{q}_{ji}^k \leq \bar{f}_{ji}^k(\{\tilde{l}_{ji}^{nk}/\tau_{ji}^n\}) \text{ for all } j \text{ and } k,$$
$$\sum_k \tilde{l}_{ji}^{nk} \leq L_{ji}^n \text{ for all } j \text{ and } n.$$

- 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: $\boldsymbol{\hat{\tau}}$ 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]** $E[\boldsymbol{\eta}^n_{ji,t}|\boldsymbol{z}_t] = 0$, *with* $\boldsymbol{z}_t \equiv \{\boldsymbol{z}^\tau_{l,t}, z^y_{l,t}\}$.

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)
  - $\boldsymbol{\chi}_i(\boldsymbol{\omega}_{i,t}) = \boldsymbol{\chi}(\{\mu_{ji}\omega_{ji,t}\})$, 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:
  - κ_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:

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

- 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

	$\overline{\epsilon}$	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

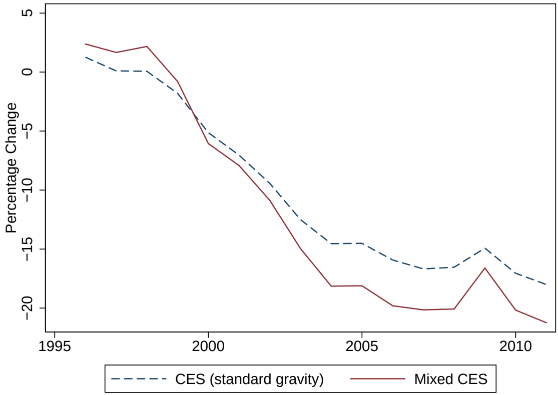

Figure 2: Average trade cost changes since 1995: China, 1996-2011.

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

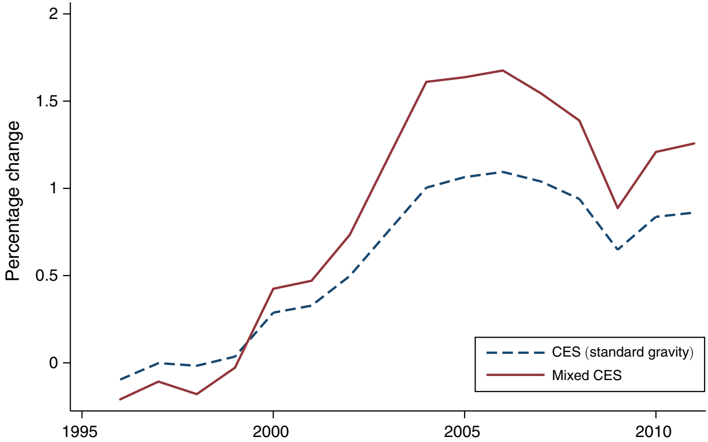

FIGURE 3. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: CHINA, 1996–2011

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

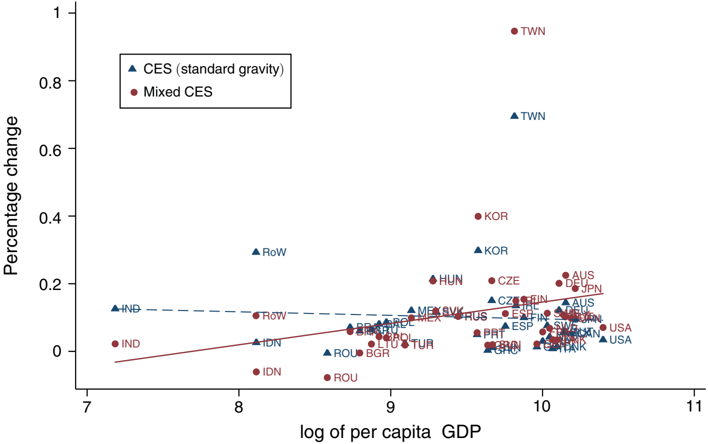

FIGURE 4. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: OTHER COUNTRIES, 2007

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.