CEMMAP Masterclass: Empirical Models of Comparative Advantage and the Gains from Trade[1] — Lecture 4: General Neoclassical Models—

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

General Neoclassical Models

- Models seen so far were extremely restrictive:
  1. One factor of production (Ricardian model)
  2. Even within Ricardian: simplistic gravity-model structure (either on aggregate, or within nests)
  3. And even then: some of the most important parameters aren't even estimated (e.g. unitary elasticity in upper-tier preferences)

- Traditional approach to generalizing these models ("CGE tradition", eg GTAP project) has been to model everything: demand-side, supply-side, market structure, trade costs

- That leads to an enormous model (e.g. GTAP has perhaps 13,000 structural parameters), which are extremely difficult to estimate credibly.

- Question: How can we relax EK's strong functional form assumptions without circling back to GTAP's 13,000 parameters?

This Lecture: Adao, Costinot and Donaldson (AER, 2017)

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3. Reduced factor demand system is nonparametrically identified using standard data and orthogonality restrictions
4. Empirical application: What was the impact of China's integration into the world economy in the past two decades?
    - Departures from CES modeled in the spirit of BLP (1995)

Neoclassical Trade Model: Notation

- $i = 1, ..., I$ 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:

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

Neoclassical Trade Model: Primitives

- Preferences (rep. consumer in "country i": whatever is finest level of data at which consumption is observed):

$$u_i = u_i(\boldsymbol{q_i})$$

- Technology (so restriction in previous lectures was that $f_{ij}^k(\cdot)$ is additive, meaning that all factors are perfect substitutes in production):

$$q_{ij}^k = f_{ij}^k(\boldsymbol{l_{ij}^k})$$

- Factor endowments (could be "time"):

$$\nu_i^n > 0$$

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:

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

2. Firms maximize their profits:

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

3. Goods markets clear:

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

4. Factors markets clear:

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

Reduced Exchange Model

- Fictitious endowment economy in which consumers directly exchange factor services
  - Common proof "trick" in GE literature: e.g. Taylor (1938), Rader (1972), Mas-Colell (1991)
  - Used heavily in Wilson's (1980) Ricardian model

- *Reduced preferences* over primary factors of production:

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

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

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

- Easy to check that $U_i(\cdot)$ is strictly increasing and quasiconcave.
  - Not necessarily strictly quasiconcave, even if $u_i(\cdot)$ is.
  - Example: H-O model inside FPE set.

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:

$$\boldsymbol{L_i} \in \text{argmax}_{\tilde{\boldsymbol{L}}_{\boldsymbol{i}}} U_i(\tilde{\boldsymbol{L}}_{\boldsymbol{i}})$$
$$\sum_{j,n} w_j^n \tilde{L}_{ji}^n \leq \sum_n w_i^n \nu_i^n \text{ for all } i;$$

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,* $L^n_{ji} = \sum_k l^{nk}_{ji}$ *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.*

Equivalence

- **Comments:**
  - Proof is similar to First and Second Welfare Theorems. Key distinction is that standard Welfare Theorems go from CE to *global* planner's problem, whereas RE remains a decentralized equilibrium (but one in which countries fictitiously trade factor services and budget is balanced country by country).
  - Key implication of Prop. 1: If one is interested in the factor content of trade, factor prices and/or welfare, then one can always study a RE instead of a CE. One doesn't need *direct* knowledge of primitives u and f but only of how these *indirectly* shape U.

Reduced Counterfactuals

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

$$U_i(\boldsymbol{L_i}) \equiv \bar{U}_i(\{L^n_{ji}/\tau^n_{ji}\}),$$

  where $\tau^n_{ji} > 0$ 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:

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

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

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

Reduced Equilibrium

- RE:

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

- **Gravity model:** Reduced factor demand system is CES (the simplest possible factor demand system you could imagine?)

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

"Exact Hat Algebra" (like DEK, 2008)

- Start from the counterfactual equilibrium:

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

- Rearrange in terms of proportional changes:

$$\{\hat{x}_{ji}^n x_{ji}^n\} \in \boldsymbol{\chi_i}(\{\hat{w}_j^n \hat{\tau}_{ji}^n \omega_{ji}^n\}, \sum_n \hat{w}_i^n \hat{v}_i^n y_i^n) \text{ for all } i,$$
$$\sum_j \hat{x}_{ij}^n x_{ij}^n (\sum_n \hat{w}_j^n \hat{v}_j^n y_j^n) = \hat{w}_i^n \hat{v}_i^n y_i^n, \text{ for all } i \text{ and } n.$$

Counterfactual Trade Flows and Factor Prices

- Wlog, pick location of preference shocks so that effective factor prices in the initial equilibrium are equal to one in all countries,

$$\omega_{ji}^{n} = 1, \text{ for all } i, j, \text{ and } n.$$

- **Proposition 2** *Under A1, 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* $\hat{\boldsymbol{\upsilon}}$*, solve (with* $\omega_{ji}^{n} = 1$*, for all* i*,* j*, and* n*.):*

$$\{\hat{x}_{ji}^{n} x_{ji}^{n}\} \in \boldsymbol{\chi_i}(\{\hat{w}_{j}^{n} \hat{\tau}_{ji}^{n} \omega_{ji}^{n}\}, \sum_{n} \hat{w}_{i}^{n} \hat{\upsilon}_{i}^{n} y_{i}^{n}) \ \forall \ i,$$

$$\sum_{j} \hat{x}_{ij}^{n} x_{ij}^{n} (\sum_{n} \hat{w}_{j}^{n} \hat{\upsilon}_{j}^{n} y_{j}^{n}) = \hat{w}_{i}^{n} \hat{\upsilon}_{i}^{n} y_{i}^{n} \ \forall \ i \text{ and } n.$$

Welfare

- Equivalent variation for country i associated with change from $(\boldsymbol{\tau}, \boldsymbol{\nu})$ to $(\boldsymbol{\tau'}, \boldsymbol{\nu'})$, expressed as fraction of initial income:

$$\Delta W_i = (e_i(\boldsymbol{\omega_i}, U_i')) - y_i) / y_i,$$

with U_i' = counterfactual utility and e_i = expenditure function,

$$e_i(\boldsymbol{\omega_i}, U_i') \equiv \min_{\tilde{\boldsymbol{L}}_i} \sum \omega_{ji}^n L_{ji}^n$$
$$\bar{U}_i(\tilde{\boldsymbol{L}}_i) \geq U_i'.$$

Integrating Below Factor Demand Curves

- To go from $\boldsymbol{\chi_i}$ to ΔW_i, solve system of ODEs
- For any selection $\{x_{ji}^n(\boldsymbol{\omega}, y)\} \in \boldsymbol{\chi_i}(\boldsymbol{\omega}, y)$, Envelope Theorem:

$$\frac{d \ln e_i(\boldsymbol{\omega}, U_i')}{d \ln \omega_j^n} = x_{ji}^n(\boldsymbol{\omega}, e_i(\boldsymbol{\omega}, U_i')) \text{ for all } j \text{ and } n. \tag{1}$$

- Budget balance in the counterfactual equilibrium

$$e_i(\boldsymbol{\omega_i'}, U_i') = y_i'. \tag{2}$$

Counterfactual Welfare Changes

- **Proposition 3** *Under A1, equivalent variation associated with change from* $(\boldsymbol{\tau}, \boldsymbol{\nu})$ *to* $(\boldsymbol{\tau}', \boldsymbol{\nu}')$ *is*

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

where $e(\cdot, U_i')$ *is the unique solution of (1) and (2).*

Application to Neoclassical Trade Models

- Suppose that technology in neoclassical trade 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 of production:

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

- 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

Taking Stock

- Propositions 2 and 3 provide a system of equations that can be used for counterfactual and welfare analysis in RF economy.
  - Proposition 1 $\Rightarrow$ same system can be used in neoclassical economy.
- Gravity tools—developed for CES factor demands—extends nonparametrically to any factor demand system
- Given data on expenditure shares and factor payments, $\{x_{ji}^n, y_i^n\}$, if one knows factor demand system, $\boldsymbol{\chi_i}$, then one can compute counterfactual factor prices, aggregate trade flows, and welfare.

Other Implications

1. Efficiency plus gravity $\Rightarrow$ gains from trade are pretty small (e.g. cost of autarky for US would be 1.8%)
   - If want to get larger gains from trade than in ACR, need either inefficiencies or non-gravity at aggregate level (so fact that aggregate gravity thought to fit pretty well is sobering).

2. All one-factor models are Armington models (and for multi-factor models: just think of each factor as a country)

3. Terms-of-trade motive for tariff protection might be larger than you'd expect, even for small countries—every country is a monopolist in its own "good" (its factor services).

Estimating Factor Demand Systems: Shocks

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

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

- This implies the existence of a vector of effective factor prices, $\boldsymbol{\omega}_{i,t} \equiv \{w^n_{j,t}\tau^n_{ji,t}\}$, such that factor demand in any country i and at any date t can be expressed as $\chi_i(\boldsymbol{\omega}_{i,t}, y_{i,t})$.

Estimating Factor Demand Systems: Exogeneity

- Observables:
  1. $x^n_{ji,t}$: factor expenditure shares
  2. $y^n_{i,t}$: factor payments
  3. $(z^\tau)^n_{ji,t}$: trade cost shifters
  4. $(z^y)^n_{ji,t}$: income shifters
- Effective factor prices, $\omega_{ji,t}$, unobservable, but related to $(z^\tau)^n_{ji,t}$:

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

- **A1. [Exogeneity]** $E[\eta^n_{ji,t}|\boldsymbol{z_t}] = 0$.

Estimating Factor Demand Systems: Completeness

- Following Newey and Powell (2003, ECMA), need to 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* $g(\boldsymbol{x}_{i_1,t}, y_{i_1,t}, \boldsymbol{x}_{i_2,t}, y_{i_2,t}) = 0$.

- A2 = rank condition in estimation of parametric models.

Estimating Factor Demand Systems: Identification

- Argument follows the same steps as in Berry and Haile (2014)
- **A3 [Invertibility].** *In any country i, for any $\boldsymbol{x} > 0$ and $y > 0$, there exists a unique vector of relative factor prices, ${\boldsymbol{\chi_i}}^{-1}(\boldsymbol{x}, y)$, such that all $\boldsymbol{\omega}_i$ satisfying $\boldsymbol{x} \in \boldsymbol{\chi_i}(\boldsymbol{\omega}_i, y_i)$ also satisfy $\omega^n_{ji}/\omega^1_{1i} = (\chi^n_{ji})^{-1}(\boldsymbol{x}, y)$.*
- Sufficient conditions:
  - A3 holds if $\boldsymbol{\chi_i}$ satisfies connected substitutes property (Arrow and Hahn 1971, Howitt 1980, and Berry, Gandhi and Haile 2013)
  - $\boldsymbol{\chi_i}$ satisfies connected substitutes property in a Ricardian economy if preferences satisfy connected substitutes property

Estimating Factor Demand Systems: Identification

- A3 $\Rightarrow$

$$\omega^{n}_{ji,t}/\omega^{1}_{1i,t} = (\chi^{n}_{ji})^{-1}(\boldsymbol{x}_{i,t}, y_{i,t}).$$

- Taking logs and using definition of $\eta^{n}_{ji,t}$:

$$\Delta\eta^{n}_{ji,t} = \ln(\chi^{n}_{ji})^{-1}(\boldsymbol{x}_{i,t}, y_{i,t}) - \Delta\ln(z^{\tau})^{n}_{ji,t} - \Delta\varphi^{n}_{ji} - \Delta\xi^{n}_{j,t}.$$

- Taking a second difference $\Rightarrow$

$$\begin{aligned}\Delta\eta^{n}_{ji_1,t} - \Delta\eta^{n}_{ji_2,t} = &\ln(\chi^{n}_{ji_1})^{-1}(\boldsymbol{x}_{i_1,t}, y_{i_1,t}) - \ln(\chi^{n}_{ji_2})^{-1}(\boldsymbol{x}_{i_2,t}, y_{i_2,t})\\ &- (\Delta\ln(z^{\tau})^{n}_{ji_1,t} - \Delta\ln(z^{\tau})^{n}_{ji_2,t}) - (\Delta\varphi^{n}_{ji_1} - \Delta\varphi^{n}_{ji_2}).\end{aligned}$$

- Using A1, we obtain the following moment condition

$$\begin{aligned}E[\ln(\chi^{n}_{ji_1})^{-1}(\boldsymbol{x}_{i_1,t}, y_{i_1,t}) - \ln(\chi^{n}_{ji_2})^{-1}(\boldsymbol{x}_{i_2,t}, y_{i_2,t}) - \zeta^{n}_{ji_1 i_2}|\boldsymbol{z}_t]\\ = \Delta\ln(z^{\tau})^{n}_{ji_1,t} - \Delta\ln(z^{\tau})^{n}_{ji_2,t}.\end{aligned}$$

- A2 $\Rightarrow$ unique solution $(\bar{\chi}^{n}_{j})^{-1}$ to (3) (up to a normalization)

Estimating Factor Demand Systems: Identification

- Once the inverse factor demand is known, both factor demand and effective factor prices are known as well, with prices being uniquely pinned down by normalization in the initial equilibrium.
- **Proposition 4** *Suppose that A1-A3 hold. Then factor demand and relative effective factor prices are identified.*

From Asymptopia...

- **ACD's counterfactual question:** *What would have happened if China had not integrated into the world economy?*
- **Available data:**
  - $x_{ji,t}$ and $y_{i,t}$ 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
- With this little data, even though model is non-parametrically identified, estimation needs to proceed parametrically (or need some other means of dimensionality-reduction)

... to Mixed CES

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

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

- Where:
  - $\omega_{ji,t}$ = effective price for exporter j in importer i at year t;
  - 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

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 (independence of irrelevant alternatives): 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:

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

- 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

	$\bar{\epsilon}$	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

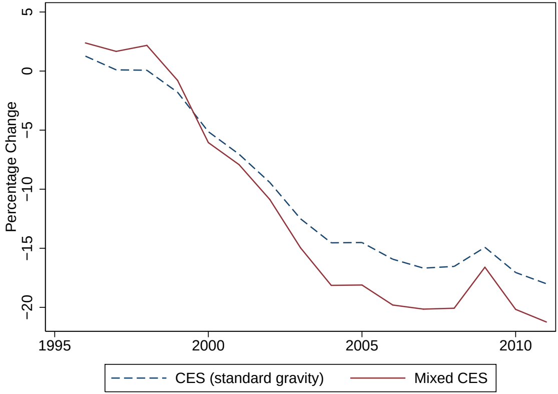

Figure 2: Average trade cost changes since 1995: China, 1996-2011.

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

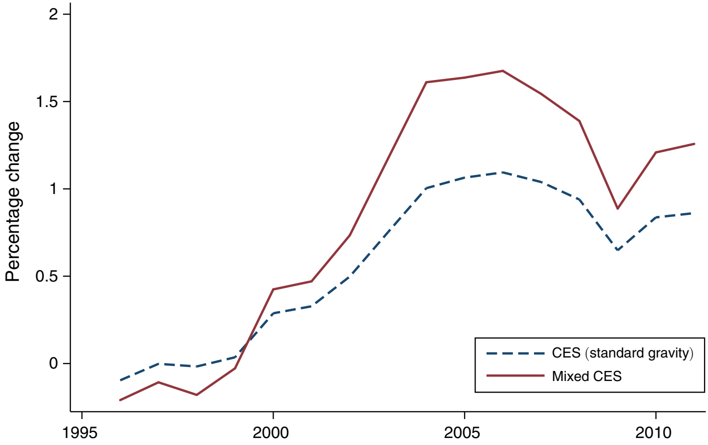

FIGURE 3. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: CHINA, 1996–2011

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

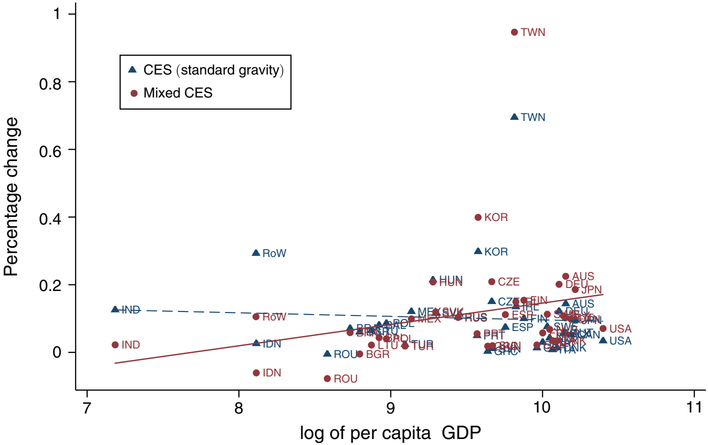

FIGURE 4. WELFARE GAINS FROM CHINESE INTEGRATION SINCE 1995: OTHER COUNTRIES, 2007

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.

Summary

- Knowledge of *reduced factor demand system* is sufficient for answering many counterfactual questions
- Away from CES, we obtain:
  - Nonparametric generalizations of standard gravity tools
  - Nonparametric identification from standard data
- This approach to counterfactual analysis allows us to:
  - Think about complex GE trading environments using simple economics of (factor) supply and demand
  - Use standard tools from IO to estimate (factor) demand
- Other applications:
  - Distributional consequences of trade
  - Revealed comparative advantage

Reduced-Form Estimates

Table 1: Reduced-Form Estimates: Violation of IIA in Gravity Estimation

Dependent variable: log(exports)	(1)	(2)	(3)	(4)
log(freight cost)	-6.103**	-6.347**	-1.301**	-1.277**
	(1.046)	(1.259)	(0.392)	(0.381)
Joint significance of interacted competitors' fright costs: $\gamma_l = 0$ for all l				
F-stat		42.60**		209.24**
p-value		<0.001		<0.001
Disaggregation level	exporter-importer		exporter-importer-sector	
Observations	1,184		18.486	

Notes: Sample of exports from 37 countries to Australia and USA between 1995 and 2010 (aggregate and sector-level). All models include a full set of dummies for exporter-importer(-sector), importer-year(-sector), and exporter-year(-sector). Standard errors clustered by exporter-importer. ** p<0.01.

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