CEMMAP Masterclass: Empirical Models of Comparative Advantage and the Gains from Trade[1] — Lecture 5: Trade Models with Distortions —

Dave Donaldson (MIT)

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

Models of Trade, with Distortions: Introduction

- So far, we have seen a wide range of models that capture the full set of motives for trade (and gains from trading) in models without any market imperfections ("neoclassical models")
  - NB: the monopolistic competition models we saw may have looked like they contain market imperfections (mark-ups) but with CES preferences, as we assumed, all firms charge the same mark-up all the time and so there is no distortion conditional on entry (and in the one-sector model with fixed factor supply, entry is effectively efficient too)
- This ignores a long line of thinking in the field in which a pre-existing market failure can be mitigated (or exacerbated) when a country begins to trade more.

Models of Trade, with Distortions: Introduction

- In this lecture we will consider a way to incorporate into the above framework two classic sources of market failure:
  1. Variable mark-ups, and "pro-competitive" effects of trade (Arkolakis, Costinot, Donaldson and Rodriguez-Clare; REStud, 2018)
  2. External economies of scale (Bartelme, Costinot, Donaldson and Rodriguez-Clare, 2018)
- Though one challenge here is that, just like Tolstoy's families in *Anna Karenina*, all perfect economies are alike, and every imperfect economy is imperfect in its own way. That is: which way do we depart from efficiency?
- And the literature has done relatively little on second-best issues when there are multiple sources of inefficiency.

How Large Are the Gains from Trade Liberalization?

- As we saw in Lecture 3, Arkolakis, Costinot, and Rodriguez-Clare (2012), have shown that for fairly large class of trade models, welfare changes caused by trade shocks only depend on two statistics:

    1. Share of expenditure on domestic goods, λ
    2. Trade elasticity, ε, in gravity equation

- Assume small trade shock so that, $d \ln \lambda < 0$: associated welfare gain is given by

$$d \ln W = -\frac{d \ln \lambda}{\varepsilon}$$

What About the Pro-Competitive Effects of Trade?

- Important qualification of ACR's results:
  - All models considered in ACR feature CES utility functions
  - Thus firm-level markups are constant under monopolistic competition
  - This de facto rules out "pro-competitive" effects of trade

Arkolakis, Costinot, Donaldson and Rodriguez-Clare; REStud, 2018

- **Goal:** Study the pro-competitive effects of trade, or lack thereof
  - Depart from CES demand and constant markups.
  - Consider demands with variable elasticity and variable markups
- **Focus:** Monopolistic competition models with firm-heterogeneity
- **Experiment:**
  - Consider two classes of models with CES and without
    - Impose restrictions so that all these models have same macro predictions
    - What are the welfare gains under these two scenarios?

Main Results

- Characterize welfare gains in this environment
  - Suppose small trade shock, $d\ln\tau$, raises trade openess, $d\ln\lambda < 0$
  - Welfare effect is given by

$$d\ln W = -(1-\eta)\,\frac{d\ln\lambda}{\varepsilon}$$

  - $\eta \equiv$ structural parameter depends on
    - Degree of pass-through
    - Magnitude of GE effects

Main Results (cont)

- Whether models with variable markups lead to larger or lower gains from trade liberalization depends on sign of η

- **What is the sign of η in theory?**
  - Under common alternatives to CES: $\eta \geq 0$
  - *Intuition:*
    Incomplete pass-through (Direct effect of changes in trade costs)
    GE effects (Direct effect of changes in trade costs dominates)

- **What is the sign of η in the data?**
  - Empirical literature points to incomplete pass-through
  - Demand parameter determines size of GE effects - non-parametric estimation

Related Work on Variable Markups

- Arkolakis Costinot Rodriguez-Clare '12 (ACR)
  - Characterize gains from trade with variable markups
- Large theoretical literature on markups and trade (e.g. Krugman '79, Feenstra '03, Melitz Ottaviano '07, Neary and Mrazova)
  - Consider a unified framework characterize gains from trade
- Large empirical literature on markups and trade (e.g. Levinsohn '93, Krishna Mitra '98, Loecker Warzynski '12, Loecker et al '12)
  - Consistent with Loecker at al '12: liberalization leads to MC declines but markup increases
- Feenstra Weinstein '10, Edmond Midrigan Xu '12 using Atkeson Burstein

Basic Environment

- World economy comprising $i = 1, ..., n$ countries, denote i the exporter, j the importer
- **Representative Consumers**
  - Continuum of differentiated goods $\omega \in \Omega$, variable elasticity demand
  - One factor of production, labor, immobile across countries
    - $L_i \equiv$ labor endowment, $w_i \equiv$ wage in country i
- **Firms**
  - Each firm can produce a single product under monopolistic competition
  - N_i is the measure of goods that can be produced in i
    - Free entry: potential entrants need to hire F_i^e units of labor

Consumers

- All consumers have same preferences. Marshallian demand for good ω of consumer with income w facing prices $\boldsymbol{p} \equiv \{p_\omega\}_{\omega \in \Omega}$ is given by

$$q_\omega(\boldsymbol{p}, w) = Q(\boldsymbol{p}, w)\, D\left(p_\omega / P(\boldsymbol{p}, w)\right)$$

- $Q(\boldsymbol{p}, w)$ and $P(\boldsymbol{p}, w)$ are aggregators of all prices and the wage s.t.

$$\begin{aligned}
\int_{\omega \in \Omega} \left[H\left(p_\omega / P\right)\right]^\beta \left[p_\omega Q D\left(p_\omega / P\right)\right]^{1-\beta} d\omega &= w^{1-\beta}, \\
Q^{1-\beta} \left[\int_{\omega \in \Omega} p_\omega Q D\left(p_\omega / P\right) d\omega\right]^\beta &= w^\beta,
\end{aligned}$$

with $\beta \in \{0, 1\}$ and $H(\cdot)$ strictly increasing and strictly concave

Examples

- All consumers have same preferences. Marshallian demand for good ω of consumer with income w facing prices $\boldsymbol{p} \equiv \{p_\omega\}_{\omega \in \Omega}$ is given by

$$q_\omega(\boldsymbol{p}, w) = Q(\boldsymbol{p}, w)\, D\left(p_\omega / P(\boldsymbol{p}, w)\right)$$

Covers demands suggested by
Krugman (1979): Symmetric Additively Separable Utility Functions
Feenstra (2014): QMOR Expenditure Functions (Homoth.)
Klenow and Willis (2016): Kimball Preferences (Homoth.)

Example I

- All consumers have same preferences. Marshallian demand for good ω of consumer with income w facing prices $\boldsymbol{p} \equiv \{p_\omega\}_{\omega \in \Omega}$ is given by

$$q_\omega(\boldsymbol{p}, w) = Q(\boldsymbol{p}, w) \, D(p_\omega / P(\boldsymbol{p}, w))$$

Example I:

- Symmetric Additively Separable Utility, $U = \int u(q_\omega) \, d\omega$, as in Krugman '79
  - $\beta = 0$, $D = u'^{-1}$, $P = 1/\lambda$ ($\lambda \equiv$Lagrange mult.)
  - see also Behrens et al '09, '11, Zhelobodko et al. '11

Example II

- All consumers have same preferences. Marshallian demand for good ω of consumer with income w facing prices $\boldsymbol{p} \equiv \{p_\omega\}_{\omega \in \Omega}$ is given by

$$q_\omega(\boldsymbol{p}, w) = Q(\boldsymbol{p}, w)\, D\left(p_\omega / P(\boldsymbol{p}, w)\right)$$

Example II:

- Kimball preferences. Utility Q is implicitly given by $\int \Upsilon\left(\frac{q_\omega}{Q}\right) d\omega = 1$
- Manipulating the first-order conditions of this problem we get

$$q_\omega = Q\Upsilon'^{-1}\left(\frac{\lambda \int q_\omega \Upsilon'\left(\frac{q_\omega}{Q}\right) d\omega}{Q} p_\omega\right) \text{ for all } \omega.$$

  - $\beta = 1$, $D \equiv \Upsilon'^{-1}$, $P \equiv Q / \left(\lambda \int q_\omega \Upsilon'\left(\frac{q_\omega}{Q}\right) d\omega\right)$, and $H \equiv \Upsilon(D)$,

Additional Restrictions on the Demand System

- All consumers have same preferences. Marshallian demand for good ω of consumer with income w facing prices $\boldsymbol{p} \equiv \{p_\omega\}_{\omega \in \Omega}$ is given by

$$q_\omega(\boldsymbol{p}, w) = Q(\boldsymbol{p}, w) \, D(p_\omega / P(\boldsymbol{p}, w))$$

- **[Choke Price]:** *There exists $a \in \mathbb{R}$ such that for all $x \geq a$, $D(x) = 0$.*
  - Comments:
    - CES can have welfare gains from new varieties but constant markup
    - Here variable markups but choke price guarantees that "cut-off" varieties have no welfare effect
    - Wlog we normalize $a = 1$ so that $P =$ choke price

Firms

- Monopolistic competition with free entry. N_i is measure of entrants in i

- Firms need to pay $w_i F_i^e$ to enter, production is subject to CRS
  - As in Melitz '03, firm-level productivity z is realization of r.v. Z_i
  - Z_i is drawn independently across firms from a distribution G_i

- G_i is Pareto with same shape parameter around the world:

- **[Pareto]** *For all* $z \geq b_i$, $G_i(z) = 1 - (b_i/z)^{\theta}$, *with* $\theta > \beta - 1$

- Pareto assumption is central to the ACDR experiment:
- *In spite of differences in demand system, model considered here will have same macro implications as model with CES in ACR*

Trade Costs

- Trade is subject to iceberg trade costs $\tau_{ij} \geq 1$
  - Good markets are perfectly segmented across countries (Parallel trade is prohibited)
- There are no exporting fixed costs of selling to a market
  - Selection into markets driven entirely by choke price

Firm-Level Markups

- Firm optimization problem is given by

$$\pi\left(c, Q, P\right) = \max_{p}\left\{\left(p - c\right) q(p, Q, P)\right\},$$

  taking Q, P as given.
  - $c \equiv \frac{w_i}{z}\tau_{ij}$ denotes marginal cost of this firm (production + shipping)

- Monopoly pricing implies:

$$\left(p - c\right)/p = -1/\left(\partial \ln q\left(p, Q, P\right)/\partial \ln p\right)$$

Firm-Level Markups

- Firm optimization problem is given by

$$\pi(c, Q, P) = \max_p \{(p - c)\, q(p, Q, P)\},$$

taking Q, P as given.

  - $c \equiv \frac{w_i}{z}\tau_{ij}$ denotes marginal cost of this firm (production + shipping)

- Monopoly pricing implies:

$$(p - c)/p = -1/(\partial \ln q(p, Q, P)/\partial \ln p)$$

- Define $m \equiv p/c$, $v \equiv P/c$ & use demand system:

$$m = \varepsilon_D(m/v)/(\varepsilon_D(m/v) - 1)$$

where $\varepsilon_D(x) \equiv -\partial \ln D(x)/\partial \ln x$ measures the elasticity of demand

Firm-Level Markups

- Given the ACDR demand system, firm-level markups satisfy

$$m = \varepsilon_D(m/v)/(\varepsilon_D(m/v) - 1)$$

- This implies that in any market:
  - Firm relative efficiency in a market, $v \equiv P/c = P_j z / w_i \tau_{ij}$, is a sufficient statistic for firm-level markup, $m \equiv \mu(v)$
  - With a choke price the marginal firm ($v = 1$) has no markup ($m = 1$)
  - More efficient firms charge higher markups, $\mu'(v) > 0$, if and only if demand functions are log-concave in log-prices, $\varepsilon'_D > 0$
  - Mrazova and Neary (2013) provide further discussion

Firm-Level Decisions

- **Note:**
  - Pareto implies distribution of markups is unaffected by trade costs
  - In addition, extensive margin response here is irrelevant for welfare
  - Variable markups **do matter** for welfare, as we will see

Closing the Model

- Free entry condition (Π_{ij} : aggregate profits of firms from i in j):

$$\sum_j \Pi_{ij} = N_i w_i F_i^e.$$

- Labor market clearing condition (X_{ij} : bilateral trade):

$$\sum_j X_{ij} = w_i L_i$$

- Given firm choices, conditions pin down measure of entrants, N_i, wages, w_i

- Pareto guarantees Π_{ij}/X_{ij} is constant (key restriction in ACR).
    - In turn, N_i does not change with different trade costs
    - This also implies that same results hold if entry is fixed

Bilateral Trade Flows and Pareto

- Under Pareto one can check that trade flows satisfy gravity equation:

$$\lambda_{ij} \equiv \frac{X_{ij}}{\sum_l X_{lj}} = \frac{N_i b_i^{-\theta} \left(w_i \tau_{ij}\right)^{-\theta}}{\sum_l N_l b_l^{-\theta} \left(w_l \tau_{lj}\right)^{-\theta}}$$

- The exact same structural relationship holds in ACR
  - see also Krugman '80, EK '02, Anderson van Wincoop '03, EKK '11
- Gravity equation has strong implications for welfare analysis
  - Changes in trade, relative wages caused by a trade shock same as in ACR
    (once calibrated to match initial trade flows, X_{ij}, and elasticity, θ)

Welfare Analysis

- Consider a small trade shock from $\tau \equiv \{\tau_{ij}\}$ to $\tau' \equiv \{\tau_{ij} + d\tau_{ij}\}$
- Let $e_j \equiv e(\mathbf{p}_j, u_j)$ denote expenditure function in country j

Welfare Analysis

- One can show that changes in (log-) expenditure are given by:

$$d\ln e_j = \underbrace{\textstyle\sum_i \lambda_{ij} d\ln(w_i\tau_{ij})}_{\text{Change in marginal costs}} + \underbrace{(-\rho)\textstyle\sum_i \lambda_{ij} d\ln(w_i\tau_{ij})}_{\text{Direct markup effect}} + \underbrace{\rho d\ln P_j}_{\text{GE markup effect}}$$

  where

$$\rho \equiv \int_1^\infty \frac{d\ln\mu(v)}{d\ln v} \frac{(\mu(v)/v)\, D(\mu(v)/v) v^{-\theta-1}}{\int_1^\infty (\mu(v')/v')\, D(\mu(v')/v')\,(v')^{-\theta-1}\, dv'} dv.$$

- Consider a "good" trade shock s.t. $\sum_i \lambda_{ij} d\ln(w_i\tau_{ij}) < 0$:
  - First term is what one would get if markups were constant
  - **Direct markup effect:** If $\rho > 0$ *lower* gains from trade liberalization (incomplete pass-through)
  - **GE markup effect:** If $\rho > 0$ tends to increase gains if good trade shocks lead to a lower P_j; see Melitz and Ottaviano '07

Welfare Analysis

- The rest of the analysis proceeds in two steps
- **Use labor market clearing condition**
  Relate change in choke price to overall magnitude of trade shock:

$$d \ln P_j = \frac{\theta}{1 - \beta + \theta} \sum_i \lambda_{ij} d \ln(w_i \tau_{ij})$$

- **Use gravity equation, as in ACR**
  Relate trade shock to change in share of expenditure on domestic goods, level of trade elasticity:

$$\sum_i \lambda_{ij} d \ln(w_i \tau_{ij}) = d \ln \lambda_{jj} / \theta$$

- Putting things together, we obtain ACDR's new welfare formula

A New Welfare Formula

- **Proposition:** *Compensating variation associated with small change in trade costs:*

$$d \ln W_j = -(1-\eta)\frac{d \ln \lambda_{jj}}{\theta}, \text{with } \eta \equiv \rho\left(\frac{1-\beta}{1-\beta+\theta}\right)$$

- **What determines the extent of "pro-competitive effects?"**
  - ρ determines the degree of pass-through. If $\varepsilon'_D > 0$, then $\rho > 0$
  - β and θ determine the GE effect.

A New Welfare Formula

- **Proposition:** *Compensating variation associated with small trade cost:*

$$d \ln W_j = -(1-\eta)\frac{d \ln \lambda_{jj}}{\theta}, \text{with } \eta \equiv \rho\left(\frac{1-\beta}{1-\beta+\theta}\right)$$

- **What is the sign of η** under common alternatives to CES?
  - Kimball preferences or QMOR expenditure functions correspond to $\beta = 1$ (same gains as in ACR). In this case, $\eta = 0$
  - Additively separable utility corresponds to $\beta = 0$, $\rho \in (0, 1)$. In this case, $\eta > 0$. Thus, lower gains from trade liberalization

Intuition

- If all countries are symmetric, compensating variation can be written as

$$d \ln W_j = -\sum_i \lambda_{ij} d \ln \tau_{ij} + \underbrace{\rho \sum_i \lambda_{ij} d \ln \tau_{ij}}_{\text{Direct markup effect}} + \underbrace{-\rho d \ln P_j}_{\text{GE markup effect}}$$

$$= -\sum_i \lambda_{ij} d \ln \tau_{ij} + cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right)$$

where $cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right) = \sum_i \int_{\omega \in \Omega_{ji}} \left[\mu_{\omega,i} d\left(L_{\omega,i}/L_j\right)\right] d\omega$

Intuition

- If all countries are symmetric, compensating variation can be written as

$$d \ln W_j = -\sum_i \lambda_{ij} d \ln \tau_{ij} + \underbrace{\rho \sum_i \lambda_{ij} d \ln \tau_{ij}}_{\text{Direct markup effect}} + \underbrace{-\rho d \ln P_j}_{\text{GE markup effect}}$$

$$= -\sum_i \lambda_{ij} d \ln \tau_{ij} + cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right)$$

where $cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right) = \sum_i \int_{\omega \in \Omega_{ji}} \left[\mu_{\omega,i} d\left(L_{\omega,i}/L_j\right)\right] d\omega$

  - Covariance term only appears if markups are variable

Intuition

- If all countries are symmetric, compensating variation can be written as

$$
\begin{aligned}
d \ln W_j &= -\sum_i \lambda_{ij} d \ln \tau_{ij} + \underbrace{\rho \sum_i \lambda_{ij} d \ln \tau_{ij}}_{\text{Direct markup effect}} + \underbrace{-\rho d \ln P_j}_{\text{GE markup effect}} \\
&= -\sum_i \lambda_{ij} d \ln \tau_{ij} + cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right)
\end{aligned}
$$

where $cov\left(\mu_{\omega,i}, \frac{dL_{\omega,i}}{L_j}\right) = \sum_i \int_{\omega \in \Omega_{ji}} \left[\mu_{\omega,i} d\left(L_{\omega,i}/L_j\right)\right] d\omega$

  - Covariance term only appears if markups are variable

- A new source of gains or losses depending on reallocation of labor and correlation with markups

What is the value of η in the data?

- In the homothetic case ($\beta = 1$) we then have $\eta = 0$, and hence no pro-competitive effects, irrespective of other parameters.
- In the non-homothetic case ($\beta = 0$) the value of η depends on $1/(1+\theta)$ and ρ.
  - θ is equal to the elasticity of aggregate trade flows with respect to trade costs. ACDR use $\theta = 5$, in line with recent estimates of "trade elasticity"
  - This implies that η lies between zero (for homothetic demand) and $\rho/6$ (for non-homothetic demand).
- If we want tighter bounds, need to estimate ρ

Estimation of ρ: Approach I

- **Approach I =** Estimate $D(\cdot)$ directly and use estimate to evaluate ρ (under monopolistic competition)
- ACDR focus on the the case of additively separable preferences in the "Pollak family". This corresponds to

$$D(p_\omega/P) = (p_\omega/P)^{1/\gamma} - \alpha.$$

- This nests the CES case (if $\alpha = 0$) but also allows for the possibility of either $\rho > 0$ (if $\alpha > 0$) or $\rho < 0$ (if $\alpha < 0$)
- ACDR estimate the inverse demand relation given by

$$\Delta_t \Delta_{gi} \ln p^k_{git} = \gamma \Delta_t \Delta_{gi} \ln(q^k_{git} + \alpha) + \Delta_t \Delta_{gi} \ln \epsilon^k_{git},$$

- Non-linear IV estimate is $\widehat{\gamma} = -0.347$ $[-0.373, -0.312]$ and $\widehat{\alpha} = 3.053$ $[0.633, 9.940]$. This leads to $\hat{\rho} = 0.36$ and $\hat{\eta} = \hat{\rho}/6 = 0.06$ (using $\theta = 5$)

Estimate of ρ: Approach II

- **Approach II =** Use estimates of pass-through of costs into prices
- Goldberg et al (ECMA, 2012): cross-sectional regression of (log) prices on (log) mc yields 0.35
  - With $\rho = 0.65$ and $\theta = 5$, we now get $\eta = 0.11$
- Burstein and Gopinath (2014): time series evidence on long-run exchange rate pass-through between 0.14 and 0.51
  - This gives ρ between 0.49 and 0.86 and, in turn, η between 0.08 and 0.14
- **Conclusion**: small downward adjustment in gains from trade liberalization (though with homotheticity, gains could be the same)
  - Hence the title "The Elusive Pro-Competitive Effects of Trade"

Bartelme, Costinot, Donaldson and Rodriguez-Clare (2018)

- **How large are sector-level external economies of scale (EES)?**
  - Classical consideration in fields of Trade and Development
  - Key remaining object of debate in multi-sector gravity models of Trade (Armington/Eaton-Kortum vs. Krugman/Melitz)
- **How much do they vary across sectors?**
  - This is what really matters for policy implications of EES
- **How successful could resulting optimal industrial policy be?**

BCDR: Preview of Results

1. Exploit trade data to
   - Infer country-sector productivity
   - Construct IV for scale from country-sector demand shocks
2. Estimate EES elasticity, γ_k, via IV regression of productivity on size
   - Pooled estimate: $\hat{\gamma} = 0.16$
   - Heterogenous estimates: $\hat{\gamma}_k \in [0.14, 0.19]$
3. Compute gains from optimal policy in small economy
   - Gains from optimal industrial policy $\approx 0.3\%$ of GDP
   - Similar to gains from optimal trade policy

Related Work on External Economies of Scale

- **Using trade data to infer productivity:**
  - Eaton and Kortum (2002)
  - Costinot, Donaldson and Komunjer (2012), Hanson, Lind, and Muendler (2016), Levchenko and Zhang (2016)
- **Empirical work on RTS and trade:**
  - Head and Ries (2001), Antweiler and Trefler (2002), Davis and Weinstein (2003)
  - Somale (2015), Lashkaripour and Lugovskyy (2017)
  - Costinot, Donaldson, Kyle and Williams (2016)
- **Empirical work on RTS in other settings:**
  - Caballero and Lyons (1990), Basu and Fernald (1997)
  - Firm-level production function estimation literature
  - Estimation of agglomeration economies in urban economics: Rosenthal and Strange (2004), Combes et al (2012), Kline and Moretti (2014), Ahlfeldt et al (2016), Bartelme (2018)

Basic Environment

- Origin and destination countries indexed by i and j
- Sectors indexed by k
- Each sector comprised of many goods, indexed by ω
- Technology:

$$q_{i,k}(\omega) = A_{i,k}(\omega) l_{i,k}(\omega) \quad \text{with} \quad A_{i,k}(\omega) = \alpha_{i,k}(\omega) A_k(L_{i,k})$$

- Preferences within industry:

$$U_{j,k}(\{B_{ij,k}(\omega) q_{ij,k}(\omega)\}) \quad \text{with} \quad B_{ij,k}(\omega) = \beta_{ij,k}(\omega) B_k(L_{i,k})$$

- Trade frictions $\tau_{ij,k} \geq 1$
- Firms maximize profits and consumers maximize utility taking $L_{i,k}$ as given $\rightarrow p_{ij,k}(\omega)$

Basic Environment

- Let $x_{ij,k} \equiv \int_{\omega} p_{ij,k}(\omega) q_{ij,k}(\omega) d\omega / X_{j,k}$

- Trade shares satisfy

$$x_{ij,s} = \chi_{ij,k}\left(c_{1j,k}, ..., c_{Ij,k}\right)$$

with

$$c_{ij,k} \equiv \eta_{ij,k} \cdot c_i / E_k(L_{i,k})$$

with $\eta_{ij,k} = \tau_{ij,k}$ plus systematic component of α and β and

$$E_k(L_{i,k}) \equiv A_k(L_{i,k}) B_k(L_{i,k})$$

Trade-revealed productivity

- Can think of $\chi_{ij,k}$ as demand for inputs, with $c_{ij,k}$ the price
- As we saw in Lecture 4: in Adao, Costinot and Donaldson (2017), if $U_{j,k}$ satisfies *connected substitutes property* then $\chi_{ij,k}$ is invertible and NPI
- Given χ function, get $c_{ij,k}$ from $x_{ij,k}$ data using

$$c_{ij,k} = \chi_{ij,k}^{-1}\left(x_{1j,k}, ..., x_{Ij,k}\right)$$

- $\hat{c}_{ij,k}$ is "trade-revealed" (inverse) measure of productivity
- Use $\hat{c}_{ij,k} = \eta_{ij,k} \cdot c_i / E_k(L_{i,k})$ to estimate $E_k(\cdot)$.

Non-parametric identification

- Double difference across i and k,

$$\ln \frac{\hat{c}_{i_1 j,k_1}}{\hat{c}_{i_2 j,k_1}} - \ln \frac{\hat{c}_{i_1 j,k_2}}{\hat{c}_{i_2 j,k_2}}$$
$$= \ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})} + \ln \frac{\eta_{i_1 j,k_1}}{\eta_{i_2 j,k_1}} - \ln \frac{\eta_{i_1 j,k_2}}{\eta_{i_2 j,k_2}}$$

- Regression in the form

$$y = h(l) + \epsilon$$

- Endogeneity is unavoidable here, so non-parametric identification achieved, as long as we have exogenous and complete IV
- Once $h(\cdot)$ is identified, then $E_{k_1}(\cdot)$ and $E_{k_2}(\cdot)$ are NPI

Alternative "Micro" approach

- With firm-level ("ω") micro data on physical output, inputs, and prices, could:
  - Estimate firms' production functions, then see how TFP residuals vary with $L_{i,k}$ to estimate $A_k(\cdot)$, with IV for $L_{i,k}$
  - Estimate cross-firm, within-sector demand system (from $U_{j,k}(\{B_{ij,k}(\omega)q_{ij,k}(\omega)\})$), then see how quality residuals vary with $L_{i,k}$ to estimate $B_k(\cdot)$, with IV for $L_{i,k}$
  - Combine these with $\chi_{ij,k}(.)$ to answer questions about industrial policy

Alternative "Micro" approach

- With firm-level ("ω") micro data on physical output, inputs, and prices, could:
  - Estimate firms' production functions, then see how TFP residuals vary with $L_{i,k}$ to estimate $A_k(\cdot)$, with IV for $L_{i,k}$
  - Estimate cross-firm, within-sector demand system (from $U_{j,k}(\{B_{ij,k}(\omega)q_{ij,k}(\omega)\})$), then see how quality residuals vary with $L_{i,k}$ to estimate $B_k(\cdot)$, with IV for $L_{i,k}$
  - Combine these with $\chi_{ij,k}(.)$ to answer questions about industrial policy
- Compared to this, BCDR approach has:
  - No need for micro data (what is ω, anyway?) from many countries
  - No need to estimate production functions or within-sector demand system
  - Jumps straight to $\chi_{ij,k}(.)$
  - Downsides: Can't estimate $A_k(\cdot)$ and $B_k(\cdot)$ separately (but only $E_k(\cdot)$ needed for policy), and can't see ω-level aspects of counterfactuals)

Empirical Strategy

- With data on just 4 time periods and 61 countries, BCDR's estimation needs to proceed parametrically

- Functional form assumptions (gravity models, a la Armington/Eaton-Kortum, but with EES):

$$\chi_{ij,k}\left(c_{1j,k},\ldots,c_{Ij,k}\right)=\frac{\left(c_{ij,k}\right)^{-\theta_k}}{\sum_{i'}\left(c_{i'j,k}\right)^{-\theta_k}}$$

$$E_k(L_{i,k})=\left(L_{i,k}\right)^{\gamma_k}$$

- NB: under these functional form restrictions, everything at sector level is isomorphic to monopolistically competitive gravity models with CES preferences (Krugman, Melitz-with-Pareto).
    - But those models restrict $\theta_k\gamma_k=1$

Empirical Strategy

- The previous functional form assumptions imply that

$$\frac{1}{\theta_{k_2}} \ln \left(\frac{x_{i_1 j, k_2}}{x_{i_2 j, k_2}} \right) - \frac{1}{\theta_{k_1}} \ln \left(\frac{x_{i_1 j, k_1}}{x_{i_2 j, k_1}} \right) =$$
$$\gamma_{k_1} \ln \left(\frac{L_{i_2, k_1}}{L_{i_1, k_1}} \right) - \gamma_{k_2} \ln \left(\frac{L_{i_2, k_2}}{L_{i_1, k_2}} \right) + \ln \left(\frac{\eta_{i_1 j, k_1}}{\eta_{i_2 j, k_1}} \right) - \ln \left(\frac{\eta_{i_1 j, k_2}}{\eta_{i_2 j, k_2}} \right)$$

- Using fixed effects, and pooling across years t, this is equivalent to

$$\frac{1}{\theta_k} \ln x^t_{ij,k} = \delta^t_{ij} + \delta^t_{j,k} + \gamma_k \ln L^t_{i,k} + \ln \mu^t_{ij,k}$$

- Set $\theta_k = 5$ for all k (Head and Mayer '14) — otherwise, estimate $\theta_k \gamma_k$ (results very insensitive to using Caliendo and Parro '14 elasticities instead; ongoing work uses global tariff variation to estimate θ_k)

Instrumental Variable Estimation of γ_k

- Need a demand shifter uncorrelated with unobserved comparative advantage
- Combine two sources of variation:
  - Distance, d_{ij}
  - Population of destination, L_j^t
- Construct IV in two steps...

IV Step 1

- Sectoral expenditure in i predicted by L_i^t, $\sum_{j \neq i} L_j^t d_{ij}^{-1}$:

$$\ln X_{i,k}^t = g_k \left(L_i^t, \sum_{j \neq i} L_j^t d_{ij}^{-1} \right) + \xi_{j,k}^t$$

- Logic: L_i^t and $\sum_{j \neq i} L_j^t d_{ij}^{-1}$ affect:
  - Income through market access (Frankel and Romer 1999)
  - Prices through HME (Hanson and Xiang 2004)
  - Income and prices $\rightarrow$ expenditures $X_{i,k}^t$ (Caron et al 2014)
- Log-quadratic approximation to $g_k(\cdot)$ to obtain $\widehat{\ln X}_{i,k}^t$

IV Step 2

- Trade costs $\rightarrow$ domestic demand is driver of industry size
- Construct IV as follows:

$$Z_{i,k}^{t} \equiv \widehat{\ln X}_{i,k}^{t} \equiv \hat{g}_k \left(L_i^t, \sum_{j \neq i} L_j^t d_{ij}^{-1} \right)$$

- 2SLS system: K endog. variables and K instruments

Exclusion Restriction

- Primitive assumptions:

$$E[\mu^t_{ij,k}|L^t_j] = 0, \quad E[\mu^t_{ij,k}|d_{ij}] = 0$$

- One concern is misspecification of cost function
  - Add controls for the interaction between per-capita GDP and a full set of sector dummies
- Ongoing work: explicitly model IO linkages

Data

- OECD Inter-Country Input-Output tables
  - 61 countries
  - 34 sectors (27 traded, 15 manufacturing)
  - Focus on manufacturing
  - Years 1995, 2000, 2005, 2010
- Population and per-capita GDP from PWT v8.1
- Bilateral distance from CEPII Gravity Database

Results: Pooled Across Sectors

	log (employment)	log (bilateral sales)	
	OLS	OLS	IV
	(1)	(2)	(3)
log (predicted demand)	0.944		
	(0.121)		
log (employment)		0.18	0.16
		(0.01)	(0.03)
Within R^2	0.0514	0.229	0.225
Observations	207,469	207,469	207,469
First-state F-statistic			60.59

Results: Separate γ_k for Each Sector

Sector	γ_k (OLS) (1)	γ_k (2SLS) (2)	First-stage SW F-statistic (3)
Food, Beverages and Tobacco	0.17 (0.01)	0.14 (0.04)	38.8
Textiles	0.18 (0.01)	0.15 (0.04)	37.7
Wood Products	0.18 (0.02)	0.15 (0.05)	32.5
Paper Products	0.20 (0.01)	0.18 (0.04)	51.1
Coke/Petroleum Products	0.16 (0.01)	0.15 (0.03)	34.5
Chemicals	0.17 (0.01)	0.16 (0.03)	40.5
Rubber and Plastics	0.19 (0.01)	0.16 (0.04)	41.4

Continued on next page

Sector	γ_k (OLS) (1)	γ_k (2SLS) (2)	First-stage SW F-statistic (3)
[0.1in] Mineral Products	0.20 (0.01)	0.18 (0.04)	36.9
Basic Metals	0.18 (0.01)	0.16 (0.03)	35
Fabricated Metals	0.19 (0.01)	0.17 (0.04)	39.4
Machinery and Equipment	0.18 (0.01)	0.16 (0.03)	41
Computers and Electronics	0.18 (0.01)	0.16 (0.04)	34
Electrical Machinery, NEC	0.19 (0.01)	0.17 (0.04)	38.2
Motor Vehicles	0.20 (0.01)	0.18 (0.03)	36.8
Other Transport Equipment	0.20 (0.01)	0.19 (0.04)	36.9

Planner's Problem: Objective Function

- Take any upper-tier preferences $U_i(U_{i,1}, ..., U_{i,K})$
- Following Adao et al. (2017), let $L_{ij,k}$ denote the demand, in efficiency units, for inputs from country i in country j within a given sector k
- And let $V_j(\{L_{ij,k}\}_{i,k})$ denote the reduced utility of the representative agent in country j associated with a given vector of input demand:

$$
\begin{aligned}
V_j(\{L_{ij,k}\}_{i,k}) &\equiv \max_{\{q_{ij,k}(\omega), l_{ij}^k(\omega)\}} U(\{U_{j,k}(\{\beta_{ij,k}(\omega) q_{ij,k}(\omega)\}_{i,\omega})\}_k) \\
q_{ij,k}(\omega) &\leq \alpha_{i,k}(\omega) l_{ij,k}(\omega) \text{ for all } \omega, \; i, \text{ and } k, \\
& \int l_{ij,k}(\omega) d\omega \leq L_{ij,k} \text{ for all } i \text{ and } k.
\end{aligned}
$$

Planner's Problem: Definition

- Expressed in terms of input choices, the planner's problem in country j is

$$\max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k},\{L_{j,k}\}_k} V_j(\{\tilde{L}_{ij,k}\}_{i,k})$$

$$\sum_{i\neq j,k} c_{ij,k}\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(\tilde{L}_{ji,k})\tilde{L}_{ji,k},$$

$$\sum_{i} \tau_{ji,k}\tilde{L}_{ji,k} \leq E_k(\tilde{L}_{j,k})\tilde{L}_{j,k}, \text{ for all } k,$$

$$\sum_{k} \tilde{L}_{j,k} \leq L_j.$$

- Second line: balanced trade condition
- Third and fourth lines: technology and resource constraints
- "Small country" assumption: choice of $\tilde{L}_{ji,k}$ affects export price $c_{ji,k}$. But too small to affect import prices $c_{ij,k} \equiv \tau_{ij,k} c_i / E_k(L_{i,k})$

Planner's Problem: Solution

- Implemented in a decentralized equilibrium by a combination of production subsidies ($s_{j,k}$) and trade taxes ($t_{ij,k}$) that are, up to a normalization (i.e. Lerner symmetry) given by:

$$
\begin{aligned}
1 + s_{j,k} &= 1 + \frac{d \ln E_k}{d \ln L_{j,k}}, \\
1 - t_{ji,k} &= 1 + \frac{d \ln c_{ji,k}}{d \ln L_{ji,k}} = 1 - \frac{1}{1 - \frac{d \ln \chi_{ji,k}}{d \ln c_{ij,k}}}
\end{aligned}
$$

- With BCDR's functional form assumptions on $E_k(\cdot)$ and $\chi_{ji,k}(\cdot)$, this boils down to

$$
\begin{aligned}
s_{j,k} &= \gamma_k, \text{ for all } k, \\
t_{ji,k} &= \frac{1}{1 + \theta_k}, \text{ for all } k \text{ and } i \neq j,
\end{aligned}
$$

Computations

- To compute gains from optimal policy for i, BCDR assume that
  - Upper-tier preferences in i are Cobb-Douglas
  - γ_{NM} in non-manufacturing $= 0$
  - $\theta_k = 5$ for all k
  - Data from equilibrium with no subsidies or taxes in i
  - Compute welfare effect of OP using exact hat algebra

Gains from Optimal Policy

Table 3: Gains from Optimal Policies, Selected Countries

Country	Optimal Policy (1)	Classic Trade Pol. (2)	Add Ind. Pol. (3)	Constrained Ind. Pol. (4)	Efficient Pol. (5)
United States	0.5%	0.2%	0.3%	0.2%	0.3%
China	0.6%	0.2%	0.3%	0.3%	0.0%
Germany	0.9%	0.4%	0.5%	0.3%	-0.5%
Ireland	1.6%	0.8%	0.8%	0.8%	-1.2%
Vietnam	1.4%	0.9%	0.5%	0.7%	1.2%
Avg, Unweighted	**1.0%**	**0.6%**	**0.5%**	**0.5%**	**0.2%**
Avg, GDP Weighted	**0.7%**	**0.3%**	**0.3%**	**0.3%**	**0.1%**

Why Are the Gains from Industrial Policy Small?

1. Necessary condition for gains: *heterogeneity* in γ_k
   - Spread in γ_k not that big across manufacturing sectors k. But have assumed $\gamma_{NM} = 0$ in non-manufacturing.
   - If instead set this γ_{NM} to (expenditure-weighted) average of manufacturing γ_k, gains fall from 0.3% to just 0.1%.

Why Are the Gains from Industrial Policy Small?

1. Necessary condition for gains: *heterogeneity* in γ_k
   - Spread in γ_k not that big across manufacturing sectors k. But have assumed $\gamma_{NM} = 0$ in non-manufacturing.
   - If instead set this γ_{NM} to (expenditure-weighted) average of manufacturing γ_k, gains fall from 0.3% to just 0.1%.

2. Gains rely on ability to shrink low-γ sectors and expand high-γ sectors. But here the main low-γ sector (non-manufacturing) is basically closed.
   - More open countries have more to gain from industrial policy (see figure)
   - But global gains still small (since world economy is closed)

Why Are the Gains from Industrial Policy Small?

1. Necessary condition for gains: *heterogeneity* in γ_k
   - Spread in γ_k not that big across manufacturing sectors k. But have assumed $\gamma_{NM} = 0$ in non-manufacturing.
   - If instead set this γ_{NM} to (expenditure-weighted) average of manufacturing γ_k, gains fall from 0.3% to just 0.1%.
2. Gains rely on ability to shrink low-γ sectors and expand high-γ sectors. But here the main low-γ sector (non-manufacturing) is basically closed.
   - More open countries have more to gain from industrial policy (see figure)
   - But global gains still small (since world economy is closed)
3. Even tradable manufacturing sectors are not that open.
   - If we pretended that all manufacturing output was exported (so no taste at home for those goods) then gains would be 1.8%.
   - Problem is $\theta = 5$: push own own price as sell more

Openness and Gains from Optimal Policy