Firms and Global Production

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The world is a cube, not a square

Trade economists need to think more "inside the box":

- The volume of trade by firms that originate in country i, are produced in country l, for destination n is X_{iln}
- Trade models generally ignore i and focus instead on

$$X_{ln} = \sum_i X_{iln}$$

  This approach misses much.

Inconvenient Facts from the US

Consider the case for $i =$ United States (2004)

- Most US firm sales abroad are produced by their plants outside the US:

$$\frac{\sum_{l \neq i, n \neq i} X_{iln}}{\sum_{l, n \neq i} X_{iln}} = 0.65$$

- Of this, one-third is exported to foreign countries other than the host:

$$\frac{\sum_{l \neq i, n \neq i, l} X_{iln}}{\sum_{l \neq i, n \neq i} X_{iln}} = 0.37$$

Further, for $l =$ US

- Foreign affiliates in US account for substantial fraction of US exports:

$$\frac{\sum_{i \neq l, n \neq l} X_{iln}}{\sum_{i, n \neq l} X_{iln}} = 0.19$$

Our way of thinking inside the box

A tractable multicountry, monopolistic competition model of trade & MP

- Starting point: ingredients by Melitz/Chaney; Eaton, Kortum, Kramarz
  - Monopolistically competitive firms
  - Fixed marketing & variable trade costs– not all firms serve all markets.
  - Pareto parameterization of heterogeneous firm productivity
- To look inside the box, we add
  - Extend probabilistic productivity draws by firm to all countries
  - Add variable MP costs (friction to moving ideas)
  - Firms compare costs of exporting, MP and BMP
- New theory of trade **and** MP: *Proximity vs Comparative Advantage*
  - No fixed costs of production: avoid very difficult discrete choice problem

Quantitative Models in trade and MP

Existing literature

- Trade Only models: Melitz; Chaney; EKK
- MP Only models: Burstein, Monge-Naranjo; Ramondo; McGrattan, Prescott
- Models with both trade and MP
  - NO BMP: Variants of Helpman et al, e.g. Moxnes et al
  - With BMP, Ramondo and Rodríguez-Clare

Quantitative Models in trade and MP

This paper

- Use more data in calibration
  - Deepen insight into gravity relationships
  - Jointly estimate trade and MP frictions
- Role of profits in welfare results
  - 20% of Irish GDP shipped abroad as payments to foreign ideas
- Allow for free entry $\longrightarrow$ specialization in innovation vs production
- Effect of trade & MP liberalization on firm decisions & key aggregates?
  - U.S.-Canadian FTA – substitution away from local MP for exports
  - Example: increase in Greek openness to MP: trade & MP flows, welfare
    - Increase Greek openness to match Irish episode
    - By some estimates, foreign firms in Ireland account for 75% ind. output

Model

Notation

- N countries. i : origin, l: location, n : destination
- X_{iln} : sales of firms from i, producing in l, selling to n
- Y_l : GDP, total production by all firms in location l
  - $\sum_{i,n} X_{iln} = Y_l$
- X_n : GNI, total income (and spending) of country n
  - $\sum_{i,l} X_{iln} = X_n$

Setup

- Measure of L_i consumers/workers, and measure M_i of firms (exogenous if no free entry)

- **Consumers**
  - Dixit-Stiglitz preferences over varieties, elasticity of substitution σ
  - Income from labor & profits from national firms (profits zero if free entry)

Setup

- **Firms**
  - Monopolists over their variety. Enter in i with fixed cost $w_i f_i^e$
  - Can serve n from any location l at "marketing" cost $w_n F_n$
  - Linear production technology. Productivity in location l is z_l, use $\mathbf{z} \equiv (z_1, ..., z_N)$
  - τ_{ln} iceberg trade costs, γ_{il} iceberg MP costs
  - Marginal production and shipping cost from l to n

$$C_{iln} = \frac{w_l \tau_{ln} \gamma_{il}}{z_l} \equiv \frac{\xi_{iln}}{z_l}$$

Firm Productivities

- Productivity vector $\mathbf{z}$ is drawn from a multivariate Pareto distribution

$$\Pr(Z_1 \leq z_1, ..., Z_N \leq z_N) = H(z_1, ..., z_N) = 1 - \left(\frac{1}{N} \sum_{v=1}^{N} z_v^{-\theta/\rho} \right)^{\rho}$$

  for $z_v \geq 1$, $\theta > \sigma - 1$, $\rho \in]0, 1]$.

- Properties of the distributions
  - Marginals are not Pareto, but do have Pareto tails – for $z_l \geq a > 1$,

$$\Pr(Z_l \geq z_l \mid Z_l \geq a) = (z_l / a)^{-\theta}$$

  - As $\rho \to 0$ then perfect correlation among z_v.
- With no free entry and $\gamma_{il} \to \infty \; \forall i \neq l$ then this is the Chaney-EKK version of Melitz

Firm Problem: Entry

- Firm i chooses to sell to n from I if

$$\arg\min_{v} C_{ivn} = I \cap C_{ivn} \leq c_n^*$$

where

$$c_n^* = \left(\frac{\sigma w_n F_n}{\widetilde{\sigma} X_n} \right)^{1/(1-\sigma)} P_n$$

and where P_n is the Dixit-Stiglitz price index.

Firms

Lemma

The probability that a firm from i will serve market n from l is

$$\int_0^{c_n^*} \theta \Psi_{in}^{\rho-1} \xi_{iln}^{-\theta/\rho} c^{\theta-1} dc = N^{-\rho} \Psi_{in}^{\rho-1} \xi_{iln}^{-\theta/\rho} \left(c_n^*\right)^{\theta}. \tag{1}$$

where $\Psi_{in} \equiv \sum_v \xi_{ivn}^{-\theta/\rho}$ and the measure of firms from i that serve market n from l at cost $c < \xi_{ivn}$ is $\theta M_i N^{-\rho} \Psi_{in}^{\rho-1} \xi_{iln}^{-\theta/\rho} c^{\theta-1}$.

- Conditional on selling to n from l, distribution of $c \leq c_n^*$ is $\left(c/c_n^*\right)^{\theta}$

Trade Flows

Since the sales of a firm with cost c in a market n are $\widetilde{\sigma} X_n P_n^{\sigma-1} c^{1-\sigma}$, the previous results imply that

$$X_{iln} = \psi_{iln} \pi_{in} X_n,$$

where

$$\pi_{in} = \frac{\sum_l X_{iln}}{\sum_{j,l} X_{jln}} = \frac{M_i \Psi_{in}^{\rho}}{\sum_j M_j \Psi_{jn}^{\rho}}$$

and

$$\psi_{iln} \equiv \frac{\zeta_{iln}^{-\theta/\rho}}{\sum_v \zeta_{ivn}^{-\theta/\rho}}$$

Trade and MP shares

- Expenditure shares of consumers in n on goods produced in l (trade shares)

$$\lambda_{ln} = \frac{\sum_i X_{iln}}{\sum_{j,l} X_{jln}} = \sum_i \psi_{iln} \pi_{in}$$

- Production shares of firms from i in l (MP shares)

$$\mu_{il} = \frac{\sum_n X_{iln}}{\sum_{j,n} X_{jln}} = \frac{\sum_n \psi_{iln} \pi_{in} X_n}{Y_l}$$

Equilibrium

- **Lemma:** Profits are a constant fraction $\eta \equiv (\sigma - 1) / (\sigma\theta)$ of aggregate sales.
- Equilibrium can be determined by $3 \times N$ equations on X_i, w_i, M_i
  - Current Account balance

$$X_i = w_i L_i^p + \eta \sum_n \pi_{in} X_n$$

  - Labor market equilibrium

$$\begin{aligned} w_i L_i &= w_i L_i^p + w_i L_i^e \\ w_i L_i^p &= (1 - \eta) \sum_n \lambda_{in} X_n \\ w_i L_i^e &= w_i M_i f_i^e \end{aligned}$$

  - Free entry condition

$$M_i w_i f_i^e = \eta \sum_l \mu_{il} Y_l$$

MP and Entry: An Illustration

Let L_i^e be labor devoted to entry and $L_i^p = L_i - L_i^e$ be labor devoted to production. From equilibrium conditions, we have

$$\frac{L_i^e}{L_i^p} = \frac{\eta}{1-\eta}\frac{X_i}{Y_i}.$$

- With no MP ($\gamma_{il} = \infty$ for $i \neq l$) then $X_i = Y_i$, so $L_i^e / L_i^p = \eta / (1-\eta)$
  - Standard feature of Melitz/Chaney
- With MP a country facing lower entry costs now has

$$\frac{L_i^e}{L_i^p} > \frac{\eta}{1-\eta}$$

  - Countries with lower entry cost specialize in entry
  - Countries with high entry cost specialize in production.

Welfare Measurement

- The gains from openess can be written

$$GO_n = \lambda_{nn}^{-\rho/\theta} \pi_{nn}^{-(1-\rho)/\theta} \varepsilon_{nnn}^{-\rho/\theta} \left(\frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}}$$

  where $\varepsilon_{nnn} \equiv X_{nnn} / \sum_i X_{inn}$

- In the special case with $\rho = 1$ and we have that $\varepsilon_{nnn} = \mu_{nn}$, so

$$GO_n = \underbrace{\lambda_{nn}^{-1/\theta}}_{\text{gains from trade}} \times \underbrace{\varepsilon_{nnn}^{-1/\theta} \left(\frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}}}_{\text{gains from MP}}$$

- Inward versus Outward MP gains

Taking the Model to Data (Preliminary)

Calibrating the Model

- Parameters to obtain M_i, σ, θ/ρ, τ_{ln}, γ_{il}, and ρ

- Main Idea
  - Step 1: calibrate M_i and σ
  - Step 2: use structural relationship to estimate θ/ρ; pick a value for ρ
  - Step 3: given ρ & θ, get τ_{ln} & γ_{il} by fitting model to trade and MP data
  - Step 4: loop until calibrated model is consistent with the *trade elasticity* in the data

Calibration: Step 1

- Calibrate M_i and σ
  - M_i proportional to equipped labor
  - $\sigma = 6$ to match a 20% markup (Martines et. al.)
    - σ does not affect rest of estimation (minor effects on gains)

Calibration: Step 2

- We get θ/ρ as the trade elasticity in a *restricted* gravity equation
- Recall that

$$\begin{aligned} X_{iln} &= \psi_{iln}\pi_{in}X_n \\ &= (\tau_{ln})^{-\theta/\rho}\left(\frac{M_i\Psi_{in}^{\rho-1}X_n}{\sum_j M_j\Psi_{jn}^{\rho}}\right)(w_l\gamma_{il})^{-\theta/\rho} \end{aligned}$$

- Within network of i firms gravity holds and coefficient on $\log(\tau_{ln})$ is $-\theta/\rho$ (trade elasticity)

Calibration: Step 3

- Backing out trade and MP costs
- From the model, we have

$$\begin{aligned} \lambda_{ln} &= \sum_i \psi_{iln} \pi_{in} \\ \mu_{il} &= \frac{\sum_n \psi_{iln} \pi_{in} X_n}{Y_l} \end{aligned}$$

where

$$\pi_{in} = \frac{M_i \Psi_{in}^{\rho}}{\sum_j M_j \Psi_{jn}^{\rho}}$$

while $\Psi_{in} = \sum_v \xi_{ivn}^{-\theta/\rho}$, $\xi_{iln} \equiv w_l \gamma_{il} \tau_{ln}$, and $\psi_{iln} \equiv \xi_{iln}^{-\theta/\rho} / \Psi_{in}$.

Calibration: Step 3

- Given
  - w_l (GDP per equipped labor),
  - M_i (proportional to equipped labor),
  - aggregate bilateral trade and MP shares, λ_{ln} and μ_{il},
  - an estimate of θ/ρ and a guess of ρ

Then all τ_{ln} and γ_{il} are exactly identified.

Calibration: Step 4

- Simulate the model and run a standard (unrestricted) gravity regression to get the trade elasticity implied by the calibrated model
- Compare this trade elasticity with the one in the data
- Loop on ρ until these elasticities match

Note: *we do not directly use info on* X_{iln} *to estimate* τ_{ln}, γ_{il} *only* X_{ln}, Y_{il}*!*

Calibration: Step 4

- The unrestricted gravity equation is associated with following equation

$$\begin{aligned} X_{ln} &= \sum_i X_{iln} \\ &= (\tau_{ln})^{-\theta/\rho} \left(\frac{X_n}{\sum_j M_j \Psi_{jn}^{\rho}} \right) (w_l)^{-\theta/\rho} \left[\sum_i M_i \Psi_{in}^{\rho-1} (\gamma_{il})^{-\theta/\rho} \right] \end{aligned}$$

  Note that last term in brackets cannot be decomposed.

- **Key Implication:** *restr. gravity trade elasticity* $>$ *unrestr. gravity trade elasticity*
  - Only when $\rho = 1$ or when $\gamma_{il} = \infty$ for all $i \neq l$ restricted and unrestricted trade elasticities are the same (and equal to $-\theta$)

Gravity Equations: Specification

For restricted and unrestricted sample, we estimate the following equation:

$$\log X_{iln} = \alpha_l + \eta_n + \beta \log(1 + T_{ln}) + \sum_j \delta_j [1 | d_{ln} \in d_j] + \Theta Z_{ln},$$

where

- T_{ln}: simple average tariff applied by n on goods from l (WTO tariffs)
  - Estimate of $\beta = -\theta/\rho$
- δ_j: indicator variables for a given distance between n and l (CEPII)
- Z_{ln}: standard gravity controls such as language (also dummy for "self")

Gravity Equations: Data

For restricted and unrestricted sample, we estimate the following equation:

$$\log X_{iln} = \alpha_l + \eta_n + \beta \log(1 + T_{ln}) + \sum_j \delta_j [1 | d_{ln} \in d_j] + \Theta Z_{ln},$$

- **Data sources** X_{iln}: BEA. X_{ln}: Feenstra et al, UNIDO, and STAN, '99
  - BMP data for Canada, EU (minus UK), Japan, UK, and US as destinations for everywhere
  - 55 countries local sales versus imports from the United States

Gravity Regression Results

	Restricted	Unrestricted
T_{ln}	**-7.0**	**-4.8**
δ_1	**-0.9**	-0.4
δ_2	**-2.3**	**-1.6**
δ_3	**-2.7**	**-2.4**
δ_4	**-1.9**	**-1.5**
δ_5	**-2.0**	**-1.6**
Self	**1.0**	**2.4**

n=255

Bold indicates standard statistical significance.

Other controls: Language, Shared Colonial History, Border

Benchmark Calibration

	Parameters	Target	Source
M_i		Equipped labor	Klenow & Rodríguez-Clare
σ	6	20% markup	Martines et al
θ/ρ	7	Restricted Trade Elast.	BEA data
ρ	.6	Unrestricted Trade Elast.	Feenstra et al.
γ_{il}		Fit bilateral trade ...	Feenstra et. al., and ...
τ_{ln}		... and MP data	... STAN, UNCTAD

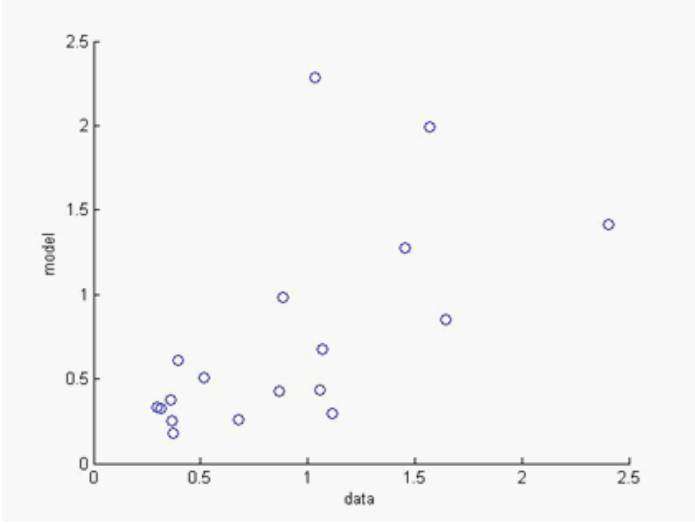
Fit Inside the Cube: U.S. BMP

The unrestricted gravity elasticity is reproduced for $\rho = 0.6$. For BMP data for $i =$U.S., we obtain

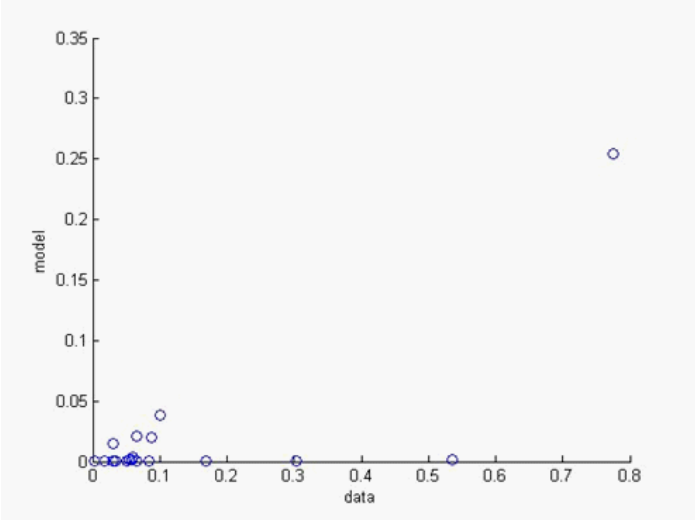
	Average		Correlation
	Data	Model	Data & Model
$\frac{X_{iln}}{X_{inn}}$	0.91	0.76	0.63
$\frac{X_{ili}}{X_{ill}}$	0.14	0.02	0.76
BMP share	0.38	0.16	

Model does generates BMP of the right order of magnitude, except for United States as a destination.

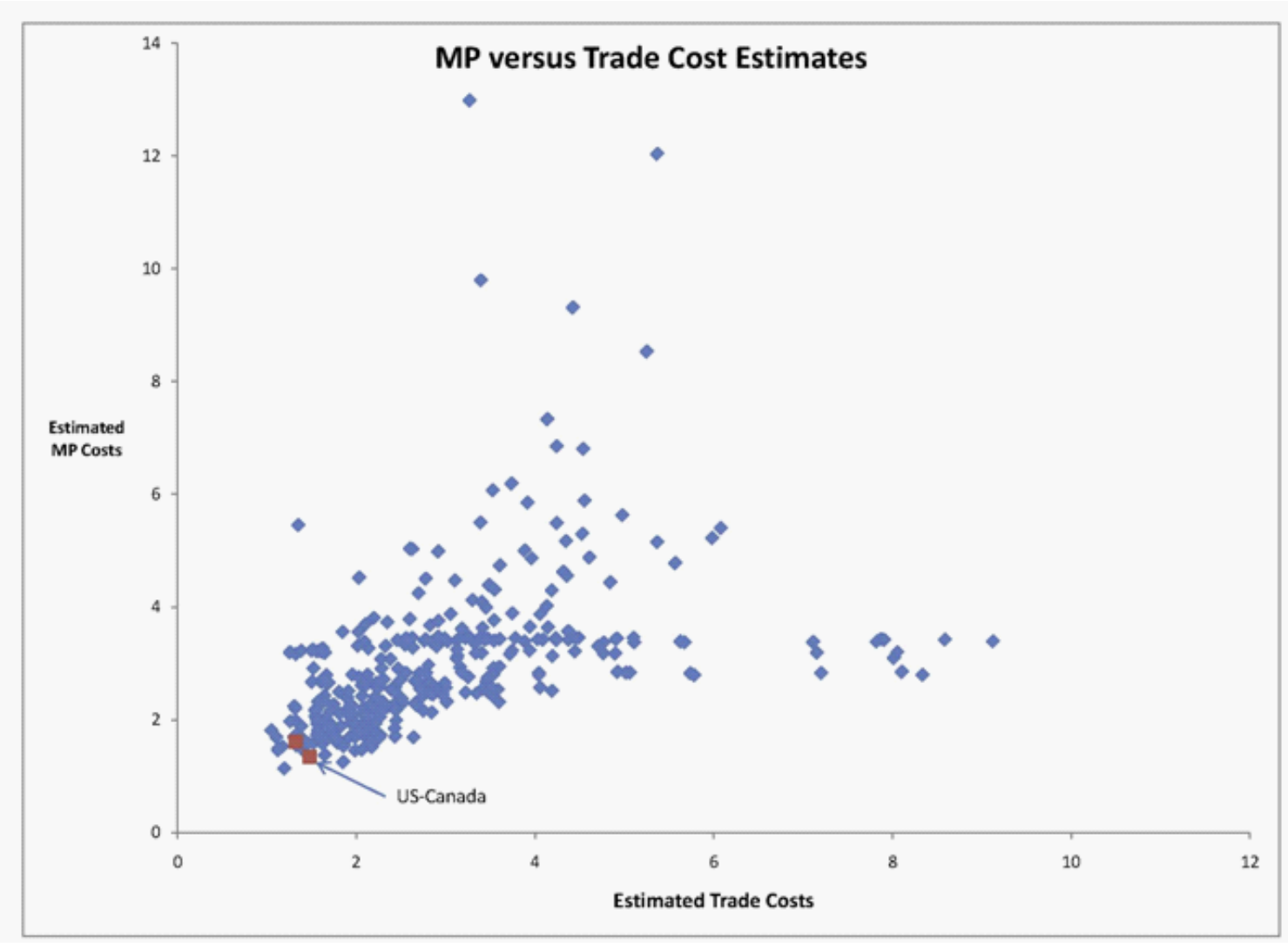
BMP Fit: All Countries



Just to US

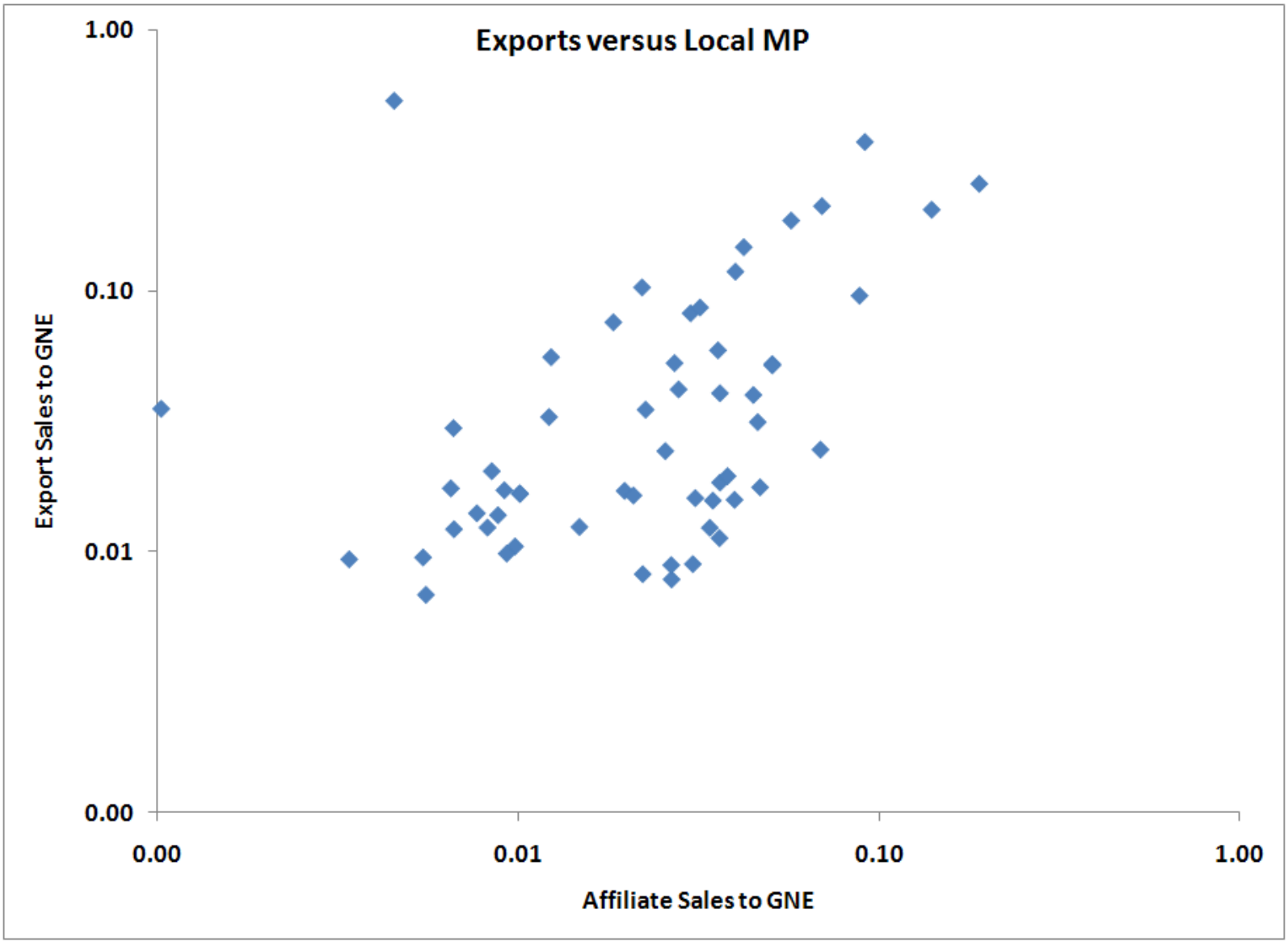


Implied Taus and Gammas



Fact from Inside the Box

For i =US, high Correlation between actual X_{iin} and X_{inn}



Consistent with high correlation between γ_{in} and τ_{in}.

A Counterfactual Experiment

Counterfactual Experiment

- We use the model as a device to evaluate the gains from a reform
- Irish episode in the 90s: dramatically decreased the barriers to US MP
  - Result: an unprecented increase in investment of US firms
  - Can the same experiment work for other countries?
- Simulate a decrease in the Greek γ's that simulates the Irish experience
  - Can Greece become Ireland (rather than the other way!)?

Benefits of Openess for a Small Country

- According to some estimates $\mu_{I,I} = .25$ (cite: Taylor)
- Counterfactual: Greece opens to US Multinationals
  - $\mu_{G,G} = .575 \rightarrow \mu_{G,G} = .242$
  - Requires an across the board reduction of Greek (inward) γ's by 30%
- Policies reducing MP costs (e.g. Irish Industrial Development Agency)
  - New "Fast-Track" Greek law for FDI (lets not be so optimistic!)

Counterfactual Results

- Gains from openess can be decomposed

$$GO_n = \lambda_{nn}^{-\rho/\theta} \times \pi_{nn}^{-(1-\rho)/\theta} \varepsilon_{nnn}^{-\rho/\theta} \times \left(\frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}}$$

- Greece a small-low tech country

Counterfactual Results

- Gains from openess can be decomposed

$$17.8\% \approx (-1.4\%) + 28.3\% + (-6.9\%)$$

- Greece a small-low tech country
  - Large drop in imports (Greek demand served by foreign firms)
  - Foreign firms take over, crowd out inefficient Greek firms
  - Large decrease in Greek firm's profits

Extensions/Future Work

- (Very Soon) Allow for free entry in calibration/counterfactual exercises
- (Soon-ish) Model multi-product firms in order to make direct contact with firm-level data
- (A different paper, but we know how) Fixed Production costs