# International Trade:

# Linking Micro and Macro

Jonathan Eaton (The Pennsylvania State University)

Samuel Kortum (University of Chicago)

Sebastian Sotelo (University of Chicago)

# Motivating Questions

- What do we learn from looking at firm-level trade?

- Are we too wedded to models with a continuum of goods and/or producers?

- Can we handle a finite-firm model?

# Motivating Data

- Bilateral trade in 1992 from Feenstra, Lipsey, and Bowen (1997).

- Firm-level exports in 1992 to 92 countries from:

  - Brazil: Arkolakis and Muendler (2010).

  - Denmark: Pedersen (2008, 2009) (1993 data).

  - France: Eaton, Kortum, and Kramarz (2010).

  - Uruguay: Raul Sampognaro (2009).

# Macro: Zeros (one-third of bilateral observations)

Table 1. Trade in Manufactures

| | | Value of Trade (Million USD) | | Trade Partners in Sample (out of a total of 91) | |
|---|---|---|---|---|---|
| | Country | Total Exports | Total Imports | No. Destinations | No. Sources |
| 9 | Brazil | 27212.22 | 13626.56 | 91 | 70 |
| 17 | Chile | 7067.69 | 7613.92 | 75 | 68 |
| 22 | Denmark | 23624.13 | 19651.31 | 91 | 83 |
| 29 | France | 141492.66 | 130104.82 | 91 | 91 |
| 45 | Korea (South) | 59662.13 | 47027.97 | 91 | 75 |
| 56 | Nepal | 124.93 | 290.90 | 26 | 36 |
| 59 | Nigeria | 261.50 | 5915.16 | 43 | 56 |
| 87 | United States of America | 359292.84 | 395010.78 | 91 | 91 |
| 88 | Uruguay | 1324.24 | 1672.66 | 56 | 56 |
| | Average | | | 59.6 | 59.6 |
| | Variance | | | 652.5 | 283.6 |

# Micro and Macro: Extensive Margin

Figure 2. Total Exports From Four Sources: Micro and Micro Data

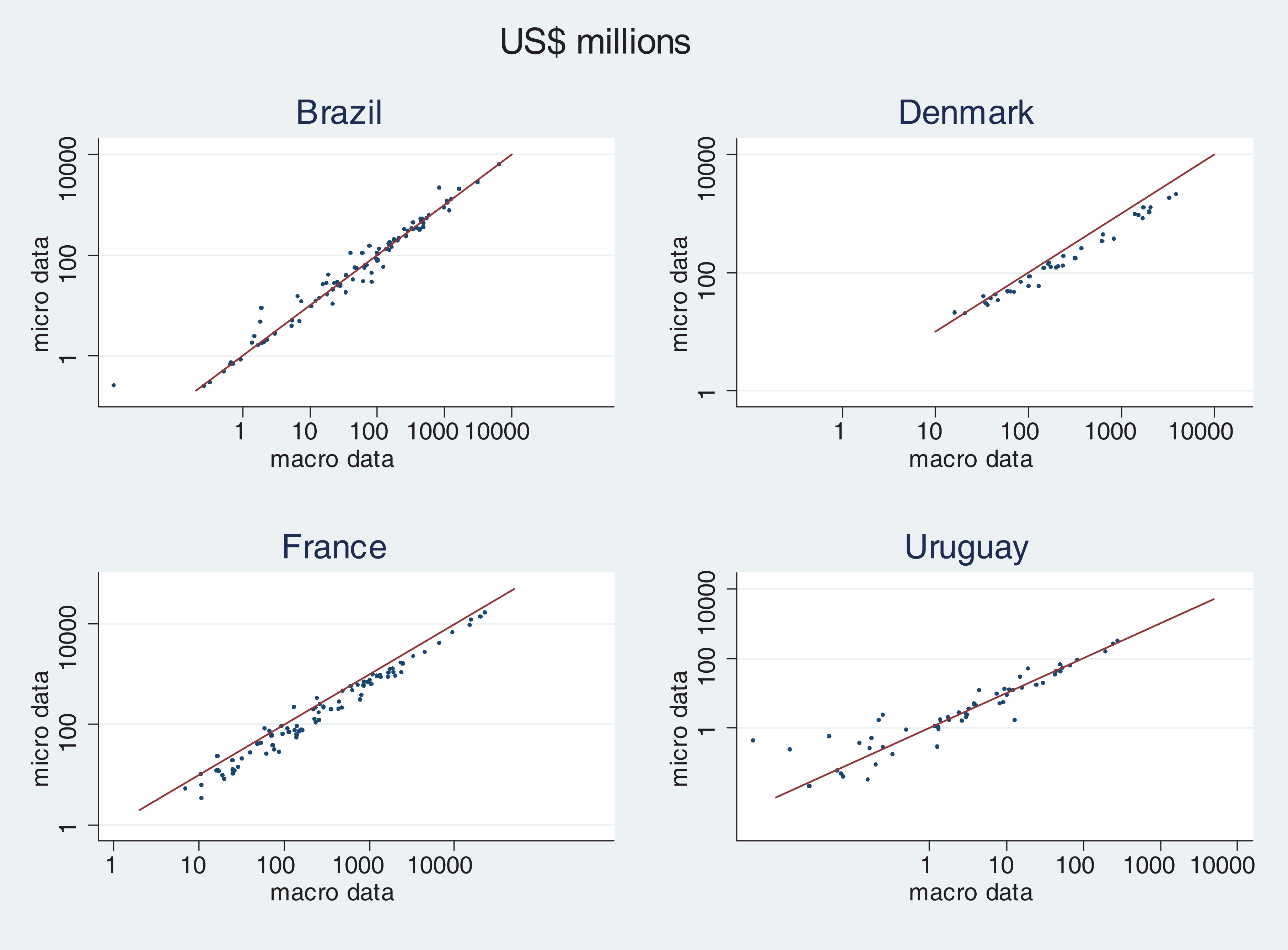
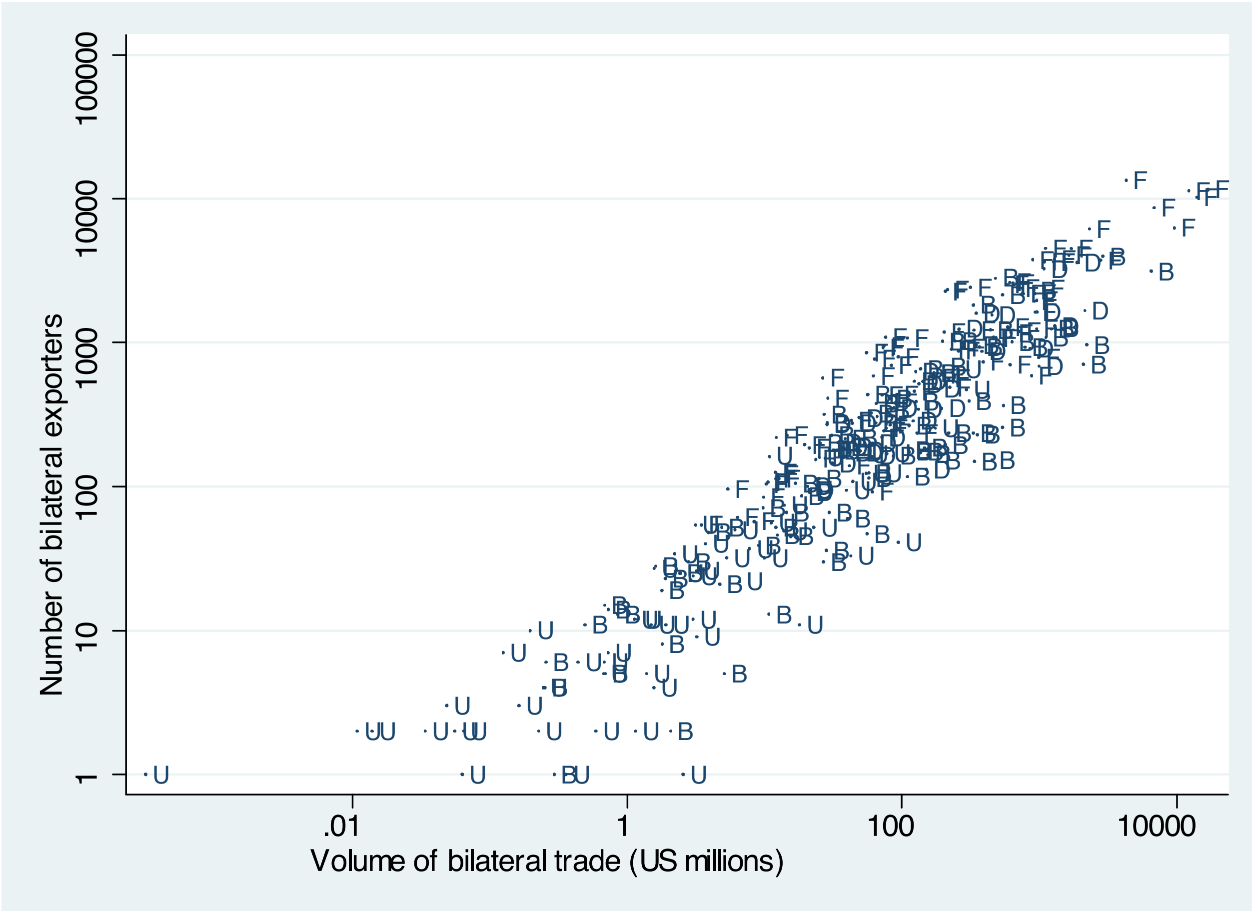


Figure 1. Micro and Macro Bilateral Trade



# Micro: Big Exporters (1986 data)

Table 2. Share of Largest French Exporters

| | French Exports to: | | | Std. Dev. of Shares |
|---|---|---|---|---|
| | Everywhere | United States | Denmark | across Destinations |
| Top 10 | 23.6 | 22.4 | 22.2 | 18.9 |
| Top 100 | 47.9 | 54.6 | 52.2 | 16.8 |
| Top 1,000 | 80.5 | 84.8 | 83.5 | 12.4 |
| Top 10,000 | 98.9 | 99.3 | 99.2 | 1.2 |

# Related Work

- Exporter facts: Bernard and Jensen (1995), Roberts and Tybout (1997).

- New firm-level theories: BEJK (2003), Melitz (2003), Bernard, Redding, and Schott (2007), Chaney (2008), Arkolakis (2011).

- Finite number of producers: Gabaix (2010), Canals, Gabaix, Vilarrubia, and Weinstein (2007), di Giovanni and Levchenko (2009), Armenter and Koren (2008).

- Zero problem: Eaton and Tamura (1994), Santo Silva and Tenreyro (2006), Helpman, Melitz, and Rubinstein (2008), ....

# Finite-Firm Model

# Overview

- Work with a parameterized Melitz model.

- But, a countable number of firms.

- Juxtapose traditional continuum model with the finite-firm model to emphasize similarities.

# Technologies

- Each produces unique good with efficiency $Z$. One firm per technology and one technology per firm.

- **Continuum model:** *Measure* of firms from country $i$ with $Z > z$:
$$\mu_i^z(z) = T_i z^{-\theta}.$$

- **Finite-firm model:** *Number* of such firms is distributed Poisson with parameter $\mu_i^z(z)$.

- Rank them: $Z_i^{(1)} > Z_i^{(2)} > Z_i^{(3)} > ...$

# Costs

- Wage $w_i$ taken as exogenous.

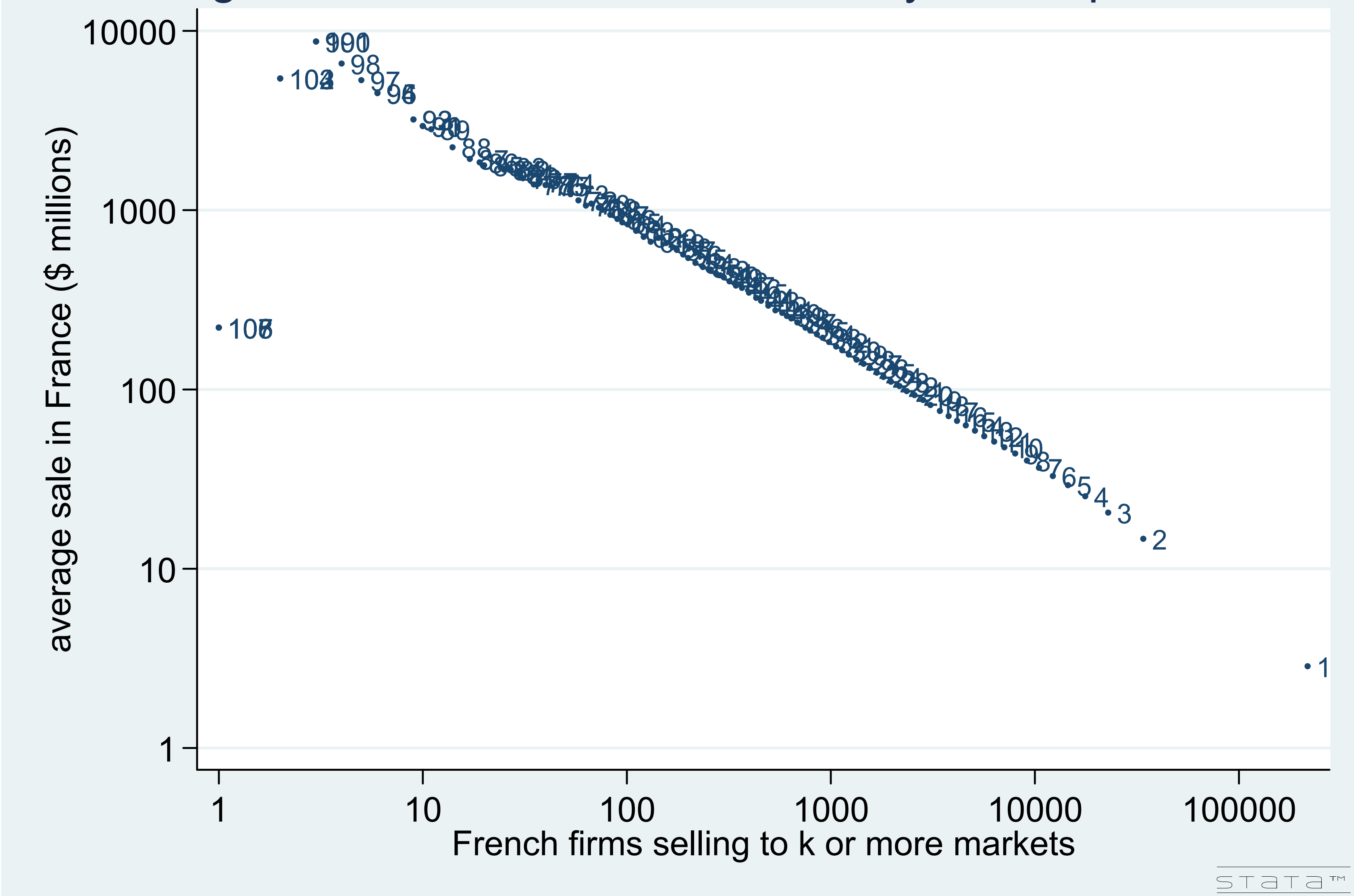
- Trade cost $d_{ni} \geq 1$, so that unit cost to $n$ from $i$:

$$C_{ni}(Z) = \frac{w_i d_{ni}}{Z}.$$

- Implies $C_{ni} \leq c$ iff $Z \geq z = w_i d_{ni}/c$.

# Micro: Signs of Pareto

Figure 2: Domestic Sales and Entry into Export Markets



# Costs II

- **Continuum model:** Measure of firms from $i$ that can supply $n$ at cost below $c$:

$$\mu_{ni}^{c}(c) = \Phi_{ni} c^{\theta},$$

where $\Phi_{ni} = T_i \left[w_i d_{ni}\right]^{-\theta}$.

- **Finite-firm model:** Number of such firms is distributed Poisson with parameter $\mu_{ni}^{c}(c)$.

# Costs in Destination

- **Continuum model:** Measure of firms from anywhere supplying $n$ at cost below $c$:

$$\mu_n^c(c) = \sum_{i=1}^{I} \mu_{ni}^c(c) = \Phi_n c^\theta.$$

- **Finite-firm model:** The sum of independent Poissons is Poisson with parameter $\mu_n^c(c)$.

- Can rank these costs: $C_n^{(1)} < C_n^{(2)} < \ldots < C_n^{(k)} < \ldots$, letting $I_{ni}^{(k)}$ indicate when $k$'th lowest cost is from $i$.

# Trade Share

- **Continuum model:** Of firms that deliver to $n$ at cost below $c$, fraction from $i$ is:

$$\pi_{ni} = \frac{\mu_{ni}^c(c)}{\mu_n^c(c)} = \frac{\Phi_{ni}}{\Phi_n},$$

  for any $c$.

- **Finite-firm model:** Now $\pi_{ni}$ becomes the probability that a firm selling in $n$ is from $i$.

- Thus $E[I_{ni}^{(k)}] = \pi_{ni}$ for any $k$.

# Preferences and Market Structure

- Dixit-Stiglitz preferences (elasticity of substitution $\sigma > 1$).

- Monopolistic competition, Bertrand competition, firms pay an entry cost $E_n = w_n F_n$ to sell in market $n$.

- A firm with cost $C$ charging price $p$ and facing aggregate price level $P_n$, has gross profit

$$\Pi_n(p, C) = (1 - \frac{C}{p}) \left(\frac{p}{P_n}\right)^{-(\sigma-1)} X_n.$$

- Firm takes $X_n$ as given (profits spent elsewhere), but realizes $P_n$ may depend on $p$.

# Continuum Case

- Firm takes $P_n$ as given so sets price $p_n(C) = \frac{\sigma}{\sigma-1}C = \overline{m}C$.

- Firm enters market $n$ iff $C \leq \overline{c}_n$, the cost threshold.

- Closed-form solutions for price index $P_n$ and cost threshold $\overline{c}_n$, if $\theta > \sigma-1$.

- Firm sales, conditional on entry:

$$\Pr\left[X_n(C) \geq x | C \leq \overline{c}_n\right] = \left(\frac{x}{\sigma E_n}\right)^{-\theta/(\sigma-1)},$$

  with mean $\overline{X}_n = \frac{\theta}{\theta-(\sigma-1)}\sigma E_n$.

# Explaining Figure 2 (with continuum model)

- Order countries by cost threshold: $\bar{c}_1 > \bar{c}_2 > \bar{c}_3 > ... > \bar{c}_I$.

- Measure of French firms with cost less than $\bar{c}_m$ (hence selling to $m$ or more):

$$N_{mF} = \mu_{mF}(\bar{c}_k) = \Phi_{mF} [\bar{c}_m]^{\theta} = T_F [w_F]^{-\theta} \left( \frac{\bar{c}_m}{d_{mF}} \right)^{\theta}.$$

- Minimum sales in France of such a firm (proportional to mean sales):

$$\underline{X}_{FF} = \left( \frac{\overline{m} [\bar{c}_m / d_{mF}]}{P_F} \right)^{-(\sigma-1)} X_F = \Lambda_F [N_{mF}]^{-(\sigma-1)/\theta}.$$

# Finite-Firm Model

- Consider market $n$ with costs $C_n^{(1)} < C_n^{(2)} < ... < C_n^{(k)} < ....$
- Let $I_n^{(k)}$ indicate whether the $k$'th lowest cost firm actually sells in $n$.
- Assume equilibrium with $I_n^{(k)} = 1$ for $k \leq K_n$ and 0 otherwise:
  1. Given $K_n$, Bertrand competition determines price: $p_n^{K_n}(C_n^{(k)})$, for $k = 1, ..., K_n$.
  2. Entry satisfies $\Pi_n^{K_n}(C_n^{(K_n)}) \geq E_n$ and $\Pi_n^{K_n+1}(C_n^{(K_n+1)}) < E_n$.

# Solving For Equilibrium

- Bertrand conditions in Atkeson and Burstein (2008) for given $K_n$:

  1. market share of the $k$'th firm:

$$s_n^{(k)} = \frac{X_n^{(k)}}{X_n} = \frac{\left[p_n^{K_n}(C_n^{(k)})\right]^{-(\sigma-1)}}{\sum_{k=1}^{K_n}\left[p_n^{K_n}(C_n^{(k)})\right]^{-(\sigma-1)}}$$

  2. markup of the $k$'th firm:

$$\frac{p_n^{K_n}(C_n^{(k)})}{C_n^{(k)}} = \frac{\left[\sigma - (\sigma-1)s_n^{(k)}\right]}{\left[\sigma - (\sigma-1)s_n^{(k)}\right] - 1}$$

# Easy to Simulate Costs

- Highest efficiency has extreme value distribution: $\Pr[Z_i^{(1)} \leq z] = e^{-T_i z^{-\theta}}$.

- Letting $U_i^{(1)} = T_i \left[ Z_i^{(1)} \right]^{-\theta}$, draw $U^{(1)}$ as a unit exponential.

- Climb the order statistics: $\Pr[U_i^{(k+1)} - U_i^{(k)} \leq u] = 1 - e^{-u}$.

- Construct ordered costs:

$$C_{ni}^{(k)} = \frac{w_i d_{ni}}{\left( U_i^{(k)} / T_i \right)^{-1/\theta}} = \left( \frac{U_i^{(k)}}{\Phi_n \pi_{ni}} \right)^{1/\theta}.$$

# Quantification

# Gravity Equation

- **Continuum model:**

$$\frac{X_{ni}}{X_n} = \pi_{ni}.$$

- Use directly for calibration, Dekle, Eaton and Kortum (2007, 2008).

- **Finite-Firm model:**

$$E\left[\frac{X_{ni}}{X_n}\right] = \pi_{ni} = \frac{T_i\left[w_i d_{ni}\right]^{-\theta}}{\sum_l T_l\left[w_l d_{nl}\right]^{-\theta}}.$$

- Calibration is out.

# Gravity Equation II

- Error term from randomness in $K_{ni}/K_n$ and in sales (and location) of largest firms $X_n^{(1)}$, $X_n^{(2)}$, ...

- Use Pseudo Maximum Likelihood, as in Santos Silva and Tenreyro (2006), but here multinomial likelihood.

- The moment condition ($m_n + g'_{nn}\alpha$ dropped):

$$E\left[\frac{X_{ni}}{X_n}\right] = \frac{\exp\left(S_i + m_n + g'_{ni}\alpha\right)}{\exp(S_n) + \sum_{l \neq n} \exp\left(S_l + m_n + g'_{nl}\alpha\right)}$$

- Gives estimates $\widehat{\pi}_{ni}$ of $\pi_{ni}$, positive even if $X_{ni} = 0$.

Table 3. Bilateral Trade Regressions

| | OLS | Poisson | Multinomial |
|---|---|---|---|
| Distance | -1.418*** | -0.699*** | -1.072*** |
| | (0.0379) | (0.0444) | (0.0511) |
| Lack of Contiguity | -0.442** | -0.694*** | -0.370** |
| | (0.156) | (0.181) | (0.136) |
| Lack of Common Language | -0.686*** | 0.121 | -0.511*** |
| | (0.0808) | (0.131) | (0.106) |
| Lack of Common Legal Origin | -0.184** | -0.281*** | -0.133 |
| | (0.0593) | (0.0778) | (0.0721) |
| Lack of Common Colonizer | -0.212 | 0.222 | -0.306 |
| | (0.146) | (0.199) | (0.204) |
| Lack of Colonial Ties | -0.684*** | 0.226 | -0.953*** |
| | (0.126) | (0.122) | (0.139) |
| Adjusted R sq. | 0.968 | | |
| Pseudo R sq. | | 0.993 | 0.563 |
| Number of observations | 5483 | 8464 | 8464 |

Standard errors in parentheses

*p<0.05, **p<0.01, ***p<0.001

# Mean Sales per Firm

- Since $E_n$ is common across sources $i$, mean sales per firm in $n$ is invariant to the source country, so can be inferred from our data on exporters from just 4 countries.

- Let $\Omega_n$ be the subset of these 4 with firms exporting to $n$:

$$\widehat{\overline{X}}_n = \frac{\sum_{i \in \Omega_n} K_{ni} \overline{X}_{ni}}{\sum_{i' \in \Omega_n} K_{ni'}}$$

- Results in Table 4.

- Gives us an estimate of entry $\widehat{K}_n = X_n / \widehat{\overline{X}}_n$.

Table 4. Mean Sales per Firm

| Destination Country | No. of Source Countries | Mean Sales per Firm |
|---|---|---|
| Brazil | 3 | 0.493 |
| Chile | 4 | 0.345 |
| Denmark | 3 | 0.323 |
| France | 3 | 0.904 |
| Japan | 4 | 1.124 |
| Jordan | 3 | 0.171 |
| Kenya | 3 | 0.230 |
| Korea (South) | 4 | 0.715 |
| Nepal | 3 | 0.173 |
| Nigeria | 3 | 0.618 |
| United States of America | 4 | 1.603 |
| Uruguay | 2 | 0.176 |

# Predicting Zeros

- Can use our estimates to calculate the probability of country $i$ not selling to $n$:

$$\Pr[K_{ni} = 0] = (1 - \pi_{ni})^{K_n}$$

replacing $\pi_{ni}$ with $\widehat{\pi}_{ni}$ and $K_n$ with $\widehat{K}_n$.

- Can also repeatedly simulate zeros over the whole matrix of country pairs, using the same draw for a single source across all destinations.

Figure 2a. Probabilities of observing zero trade, given no trade

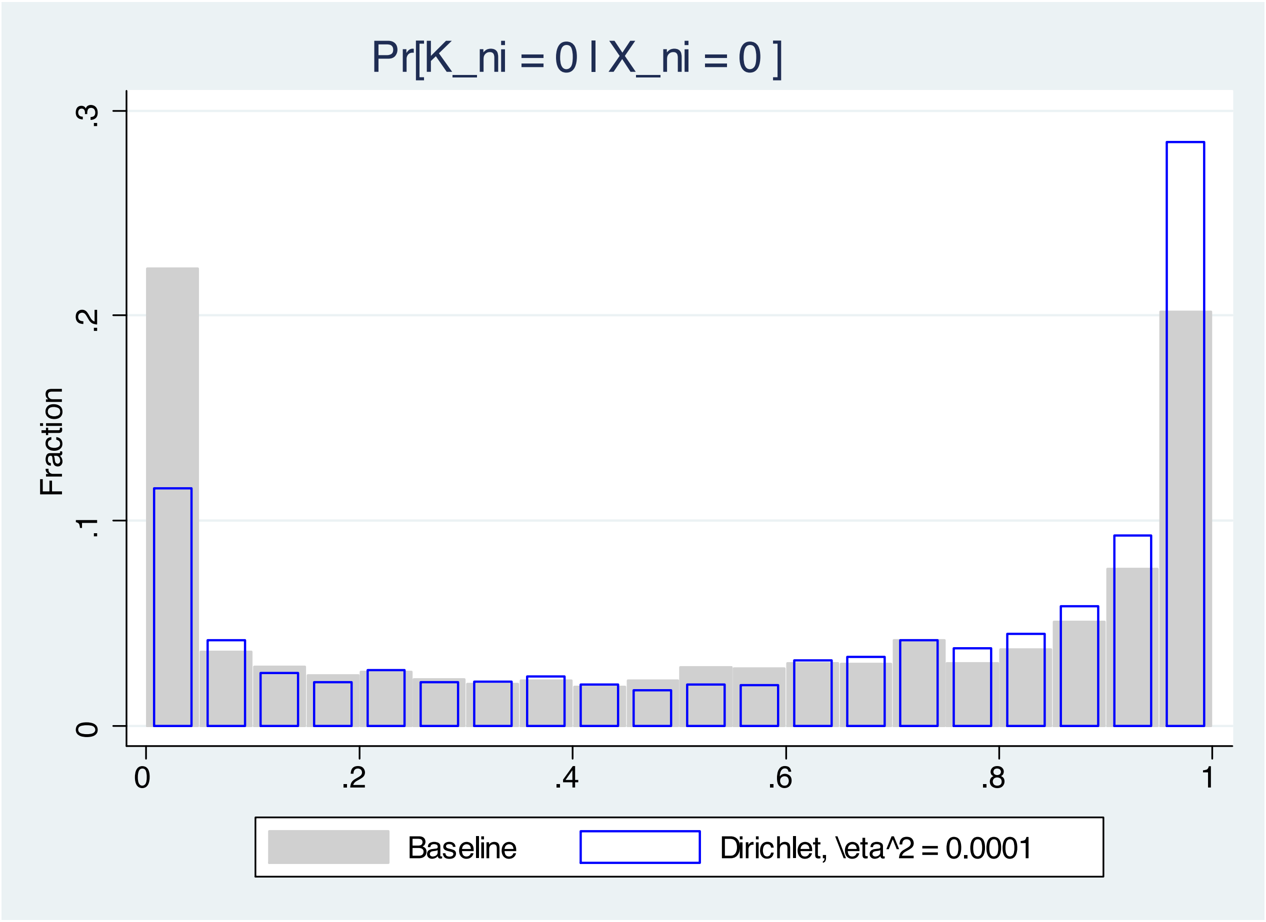


Figure 2b. Probabilities of observing zero trade, given positive trade

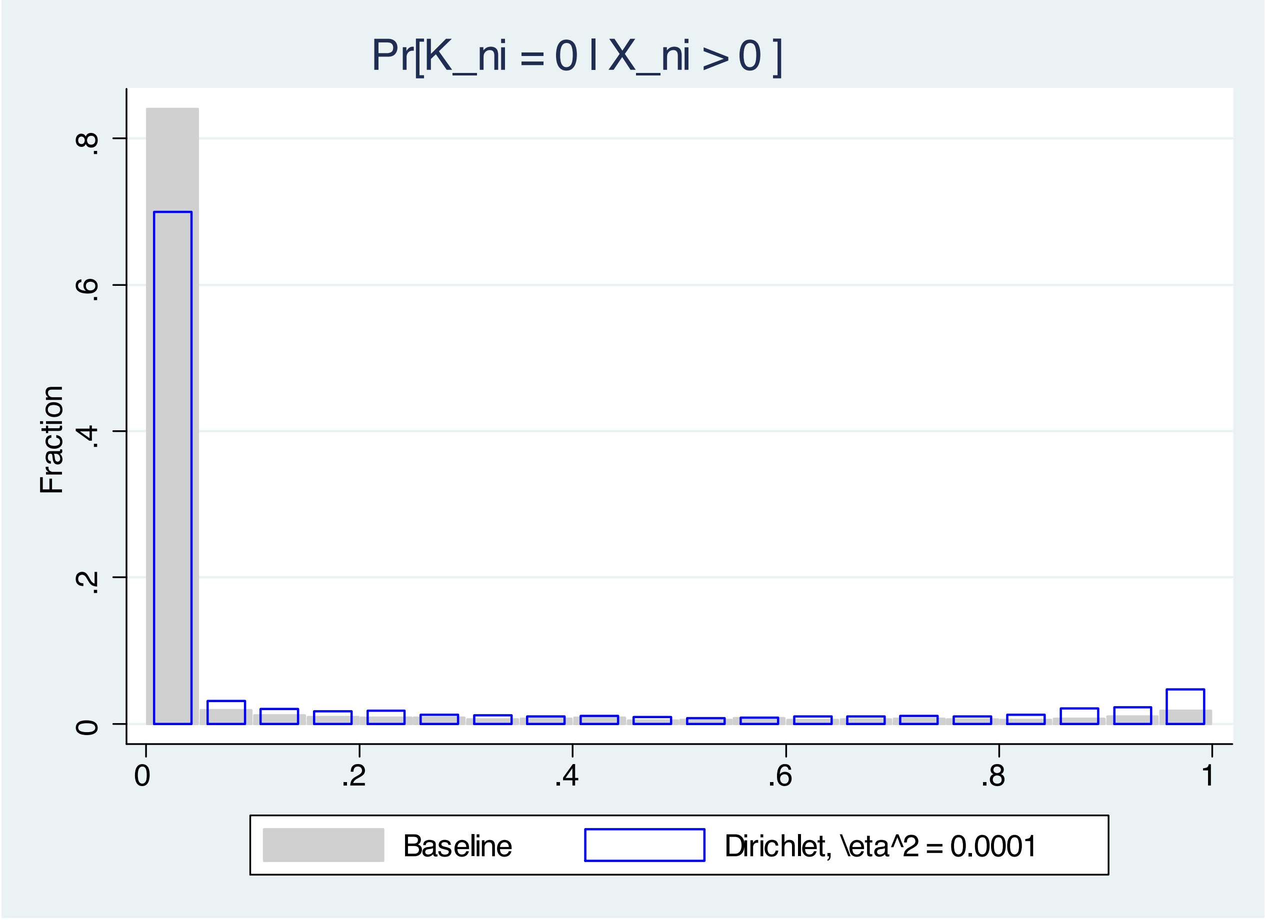


Figure 3a. Actual and Simulated Number of Destinations

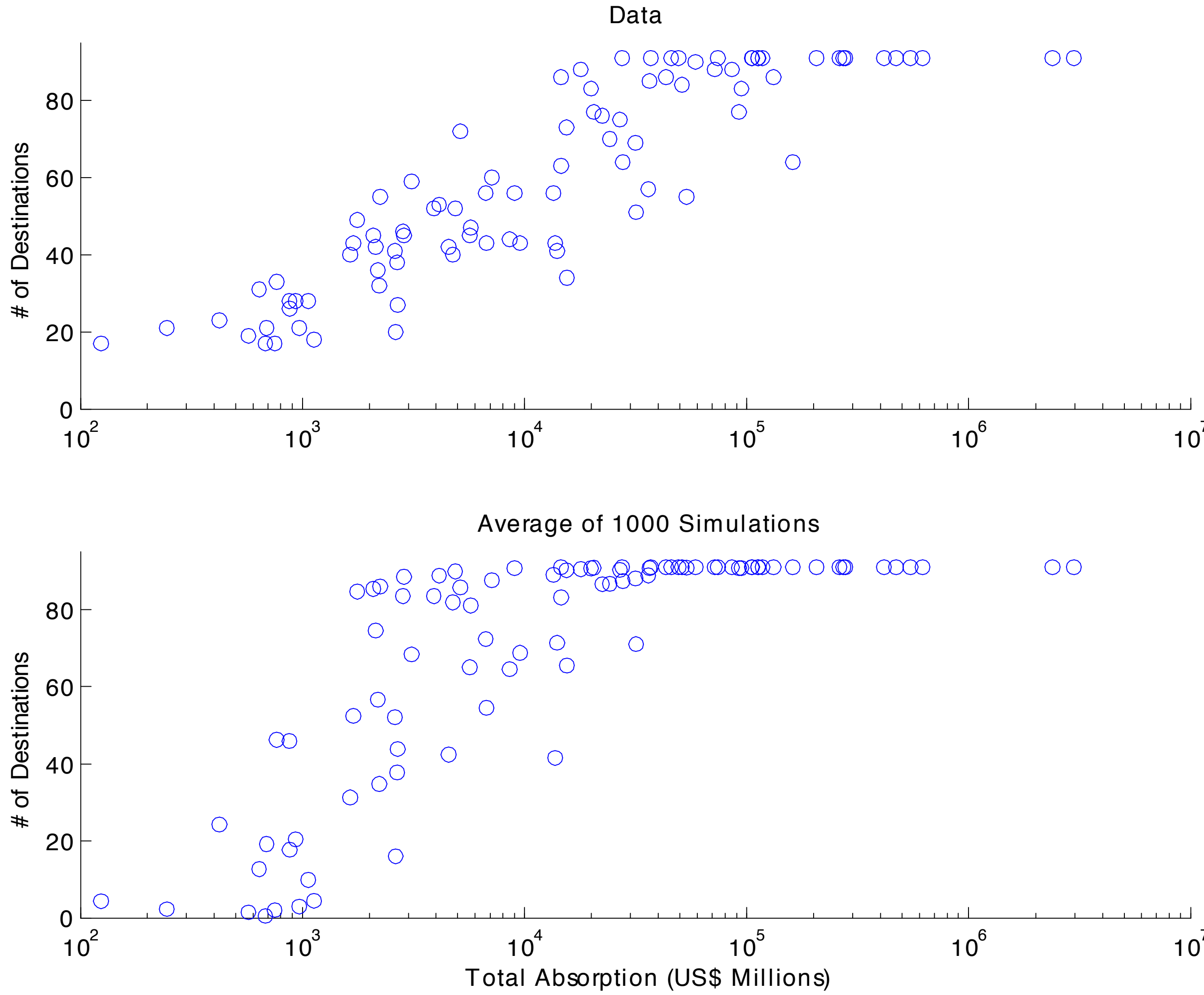
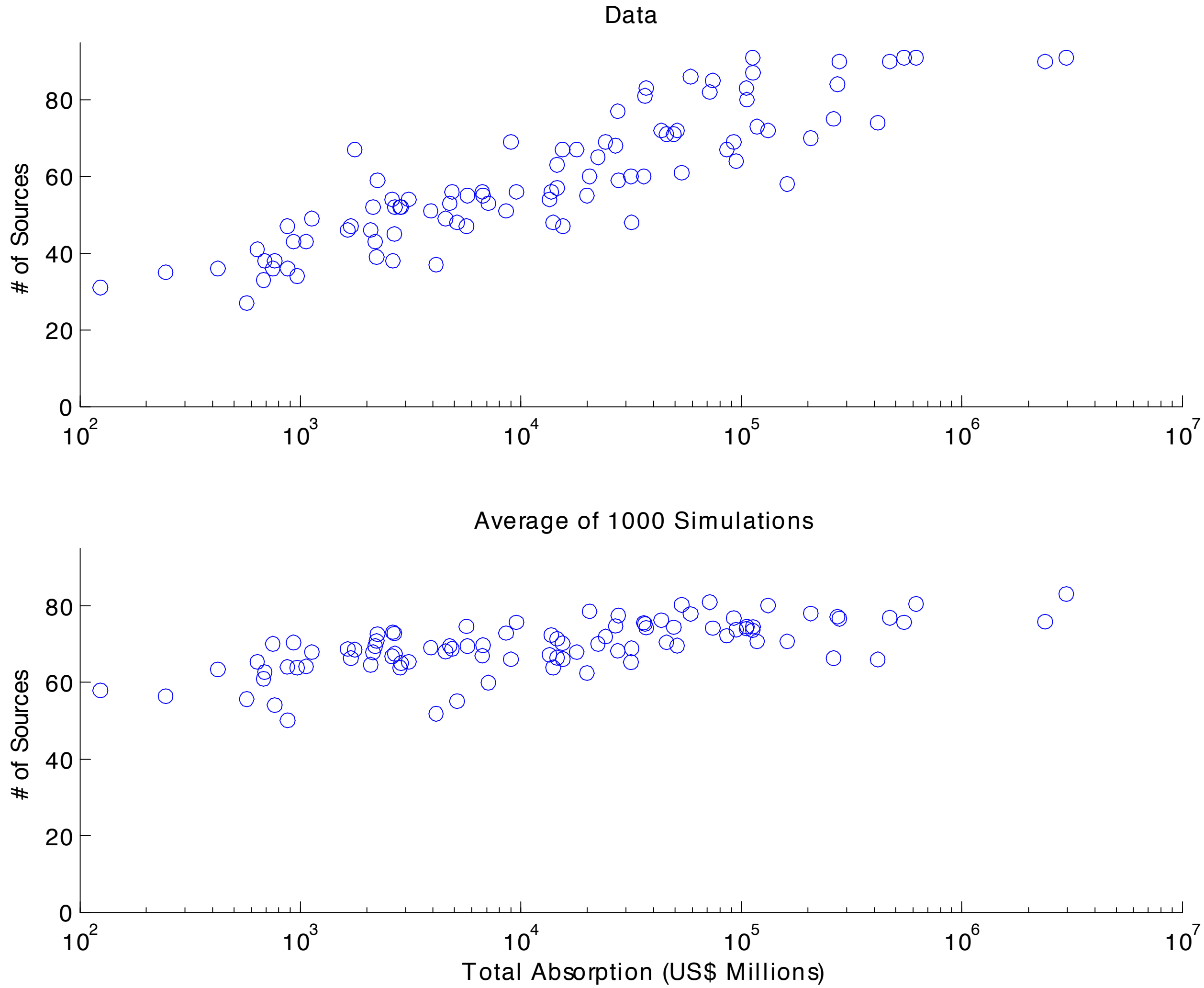


Figure 3b. Actual and Simulated Number of Sources



# Simulating Firm Costs

- Replacing $\pi_{ni}$ with $\widehat{\pi}_{ni}$, we can follow the procedure described above for simulating costs $C_{ni}^{(1)} < C_{ni}^{(2)} < C_{ni}^{(3)} < ....$

- Need a value of $\theta$: estimate of 4.87 from Eaton, Kortum, and Kramarz (2011).

- Combine cost simulation from all sources and reorder as $C_{n}^{(1)} < C_{n}^{(2)} < C_{n}^{(3)} < ...$

- Record $I_{ni}^{(k)}$ to reconstruct exports.

# Simulating Firm Sales

- Now calculate the Bertrand equilibrium, given $K_n$ with $\widehat{K}_n$.

- Need a value of $\sigma$ (no longer need $\theta > \sigma - 1$): estimate of 2.98 in EKK (2011).

- Also consider values consistent with Zipf: $\sigma = 5.64$ (so that $\theta/(\sigma - 1) = 1.05$) and $\sigma = 7.09$.

- Recover sales of firm's from $i$ in $n$ as:

$$X_{ni}^{(k)} = I_{ni}^{(k)} X_n^{(k)} = I_{ni}^{(k)} s_n^{(k)} X_n.$$

# Results

- Distribution of price markups among largest firms.

- Contribution to total French exports from the largest exporters (strong evidence for the middle values of $\sigma$).

Figure 4. Markups of Top 10 Entrants (Bertrand Competition)

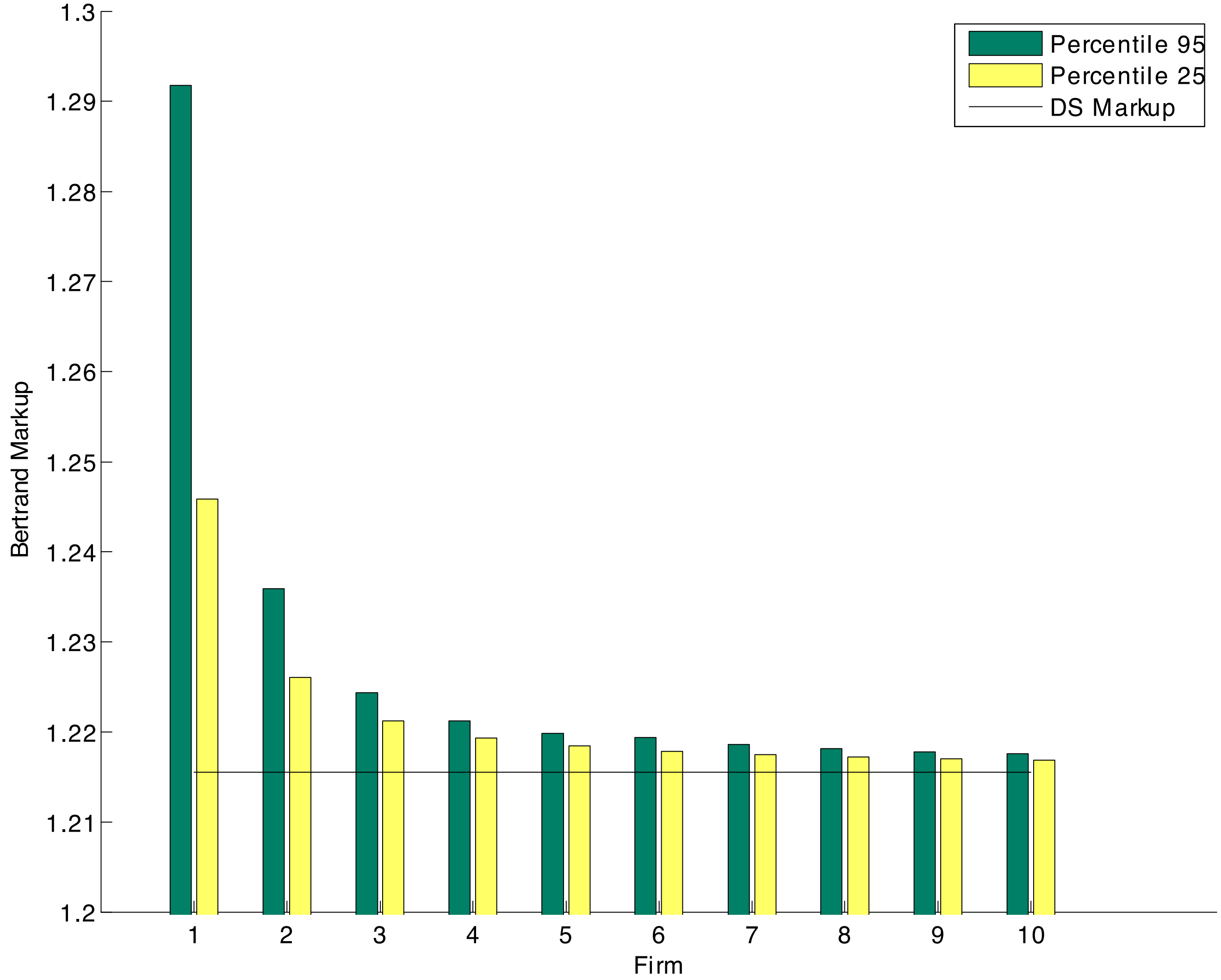
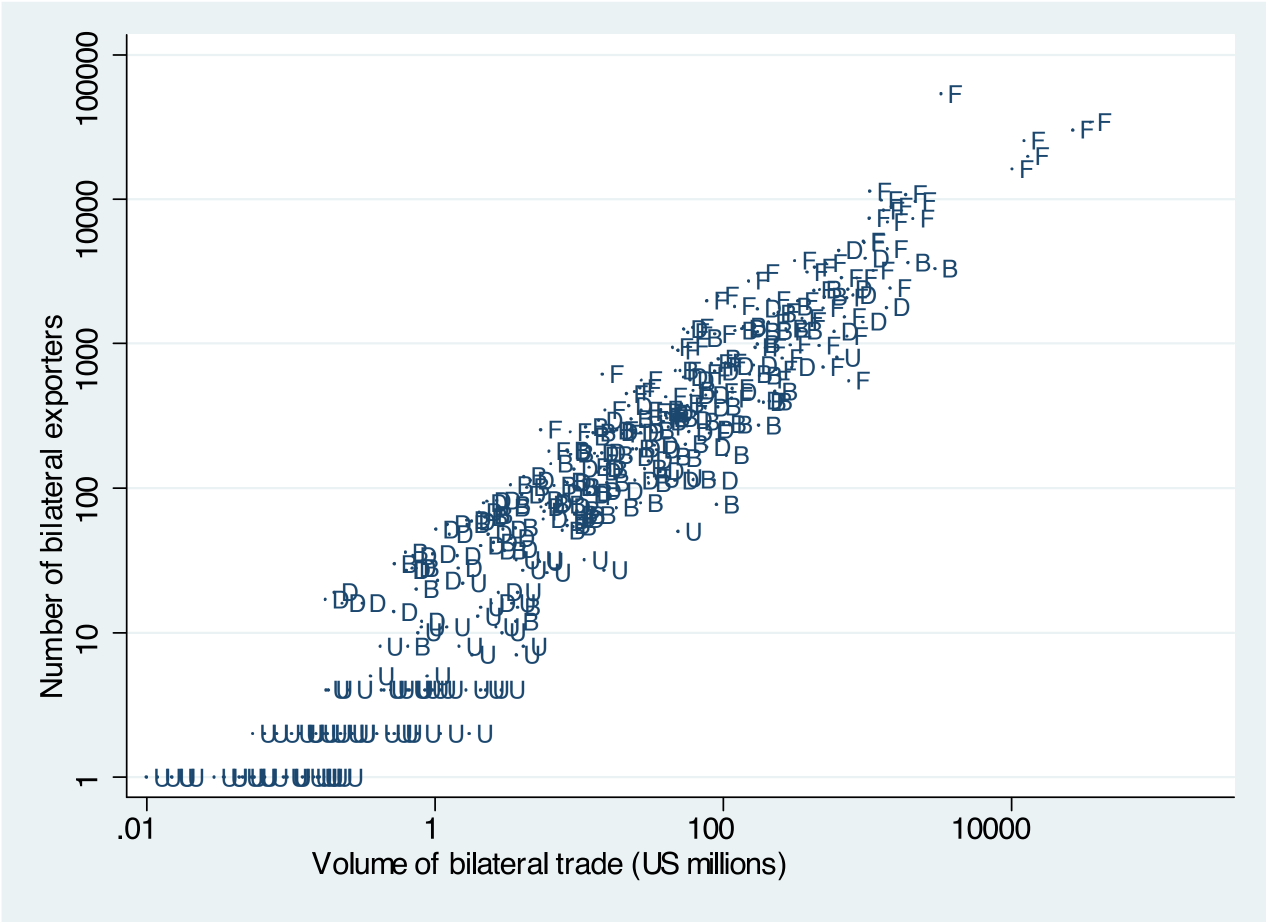


**Table 6. Share of Largest French Exporters**

| | Average ( Across 10 Simulations) | | | Standard Deviation (Across 10 Simulations) | | |
|---|---|---|---|---|---|---|
| | $\sigma = 7.09$ | $\sigma = 5.64$ | $\sigma = 2.98$ | $\sigma = 7.09$ | $\sigma = 5.64$ | $\sigma = 2.98$ |
| Top 10 | 64.86 | 32.85 | 1.55 | 21.02 | 15.58 | 0.38 |
| Top 100 | 82.99 | 51.27 | 6.13 | 10.12 | 11.34 | 0.39 |
| Top 1,000 | 93.34 | 71.79 | 22.93 | 3.91 | 6.51 | 0.43 |
| Top 10,000 | 98.73 | 92.05 | 65.86 | 0.76 | 1.86 | 0.24 |

Figure. Micro and Macro Bilateral Trade (Simulation)



# Entry Costs

- In anticipation of doing counterfactuals, want values for the entry costs.

- Simulated gross profit

$$\Pi_n^{\widehat{K}_n}(C_n^{(k)}) = \left[1 - \frac{C_n^{(k)}}{p_n^{\widehat{K}_n}(C_n^{(k)})}\right] \left[\frac{p_n^{\widehat{K}_n}(C_n^{(k)})}{P_n^{\widehat{K}_n}}\right]^{-(\sigma-1)} X_n.$$

- Upper bound on entry cost (see figures)

$$\widehat{E}_n = \Pi_n^{\widehat{K}_n}(C_n^{(\widehat{K}_n)}).$$

# Experiments

# Two Types

- Set to recompute the full equilibrium of the model under different scenarios.

- Type I: change parameters but fix the underlying technology draws.

- Example: globalization, which can now open up new trade links.

- Type II: draw a new set of technologies but fix all the parameters.

- Example: granularity so that luck-of-the-draw effects aggregates, such as welfare.

# Globalization

- Suppose all trade costs fall by 10%.

- As in DEK (2007, 2008), this change enters the model through the $\pi_{ni}$:

$$\widehat{\pi}'_{ni} = \frac{\widehat{\pi}_{ni}\,[1.1]^{\theta}}{\widehat{\pi}_{nn} + \sum_{l \neq n} \widehat{\pi}_{nl}\,[1.1]^{\theta}}$$

- Can apply $\widehat{\pi}'_{ni}$ to the same realizations of the $u_i^{(k)}$'s.

- Overall 206 new trade links arise, but they account for a tiny fraction of the growth in trade.

# Granularity

- Redraw (200 times) $U_i^{(k)}$'s, each time recomputing the world equilibrium with endogenous entry.

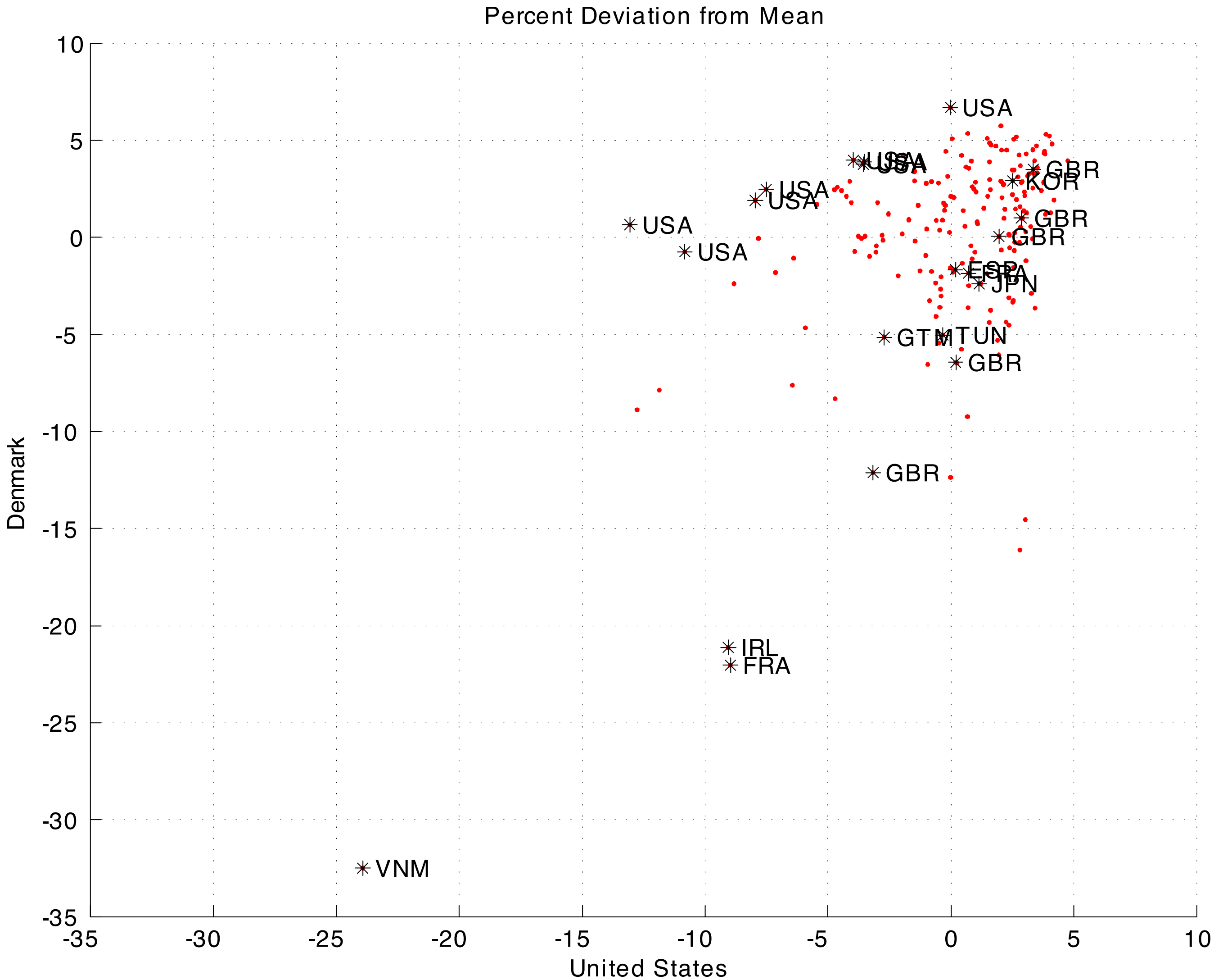
- For each new set of technologies, compute the price level (for $n$ equal to Denmark and United States):

$$\ln P'_n = \frac{-1}{\sigma - 1} \ln \left( \sum_{k=1}^{K'_n} \left[ p_n^{K'_n}(C_n^{(k)}) \right]^{-(\sigma-1)} \right)$$

as well as the location of the top firms.

- Results in last figure.

Figure 6. Variation of $P_n$ across simulations



# Conclusions

- Dropping the continuum opens up new possibilities for confronting the micro data.

- And, we don't lose the ability to compute aggregate implications.

- We've left a lot of room to make the model richer.

Table 5. Source Country Coefficients

| | Mean Sales* |
|---|---|
| Denmark | -0.0279 |
| | (0.0216) |
| Brazil | 0.0724** |
| | (0.0221) |
| Uruguay | -0.0265 |
| | (0.0680) |
| p-value for F test of joint significance | 0.0050 |
| Number of observations | 282 |

Standard errors in parentheses
*OLS Regression also includes all destination country effects as independent variables
*p<0.05, **p<0.01, ***p<0.001

**Table 1. Descriptive Statistics**

| Country | Total Trade ($ mil.) | | # of Zeros in Sample | |
|---|---|---|---|---|
| | Exports | Imports | Exports | Imports |
| Brazil | 27,212 | 13,626 | 0 | 21 |
| Chile | 7,067 | 7,613 | 16 | 23 |
| Denmark | 23,624 | 19,651 | 0 | 8 |
| France | 141,492 | 130,104 | 0 | 0 |
| Korea (South) | 59,662 | 47,027 | 0 | 16 |
| Nepal | 124 | 290 | 65 | 55 |
| Nigeria | 261 | 5,915 | 48 | 35 |
| United States | 359,292 | 395,010 | 0 | 0 |
| Uruguay | 1,324 | 1,672 | 35 | 35 |

Figure 1. Micro and Macro Bilateral Trade

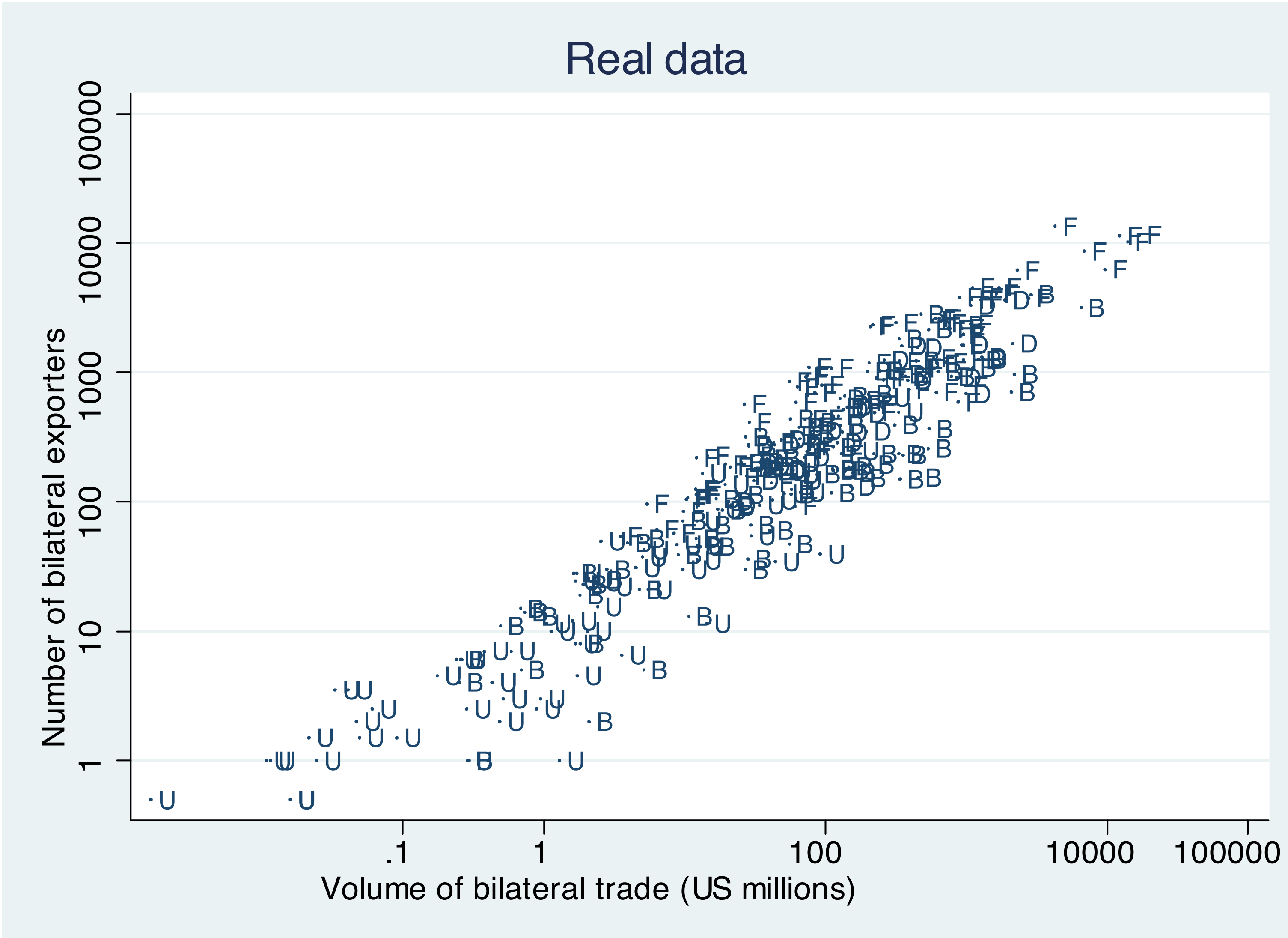


**Table 2. Entry Cost Estimation**

| Country | # of Source Countries | Mean Sales per Market |
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