The Gravity Model of Trade

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August 2020

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The Gravity Model

Gravity model

In the monopolistic competition model, each country specializes in different product varieties (leads to "intra-industry trade")

This leads to a very simple equation that explains trade: the gravity equation

Gravity equation:: "*bilateral trade between two countries is directly proportional to the product of their GDPs*".

This implies that:
1. Larger countries trade more with each other.
2. Countries that are more similar in size will trade more.

Gravity from EK

- From the EK model: $$\pi_{ni} = \frac{T_i(c_i d_{ni})^{-\theta}}{\Phi_n}$$
- Also, we define $$\pi_{ni} = \frac{X_{ni}}{X_n}$$
- Using the fact that $Y_i = \sum_n X_{ni}$
- We can show: $$X_{ni} = \frac{X_n Y_i {d_{ni}}^{-\theta} \Omega_i^{\theta}}{\Phi_n}$$

$$\Omega_i^{-\theta} = \sum_n \frac{{d_{ni}}^{-\theta} X_n}{\Phi_n}$$

The Gravity Equation

A 'gravity equation' in its simplest form predicts trade flows (expenditures) as:

$$lnX_{ij} = \alpha lnY_i + \beta lnE_j + \epsilon\tau_{ij} + \varepsilon_{ij}$$

X: Exports from 'i' to 'j'

Y, E: GDP/Expenditure

τ: Bilateral transport cost or distance

Multilateral Resistance (Anderson vanWincoop 2003 AER)

Bilateral frictions alone seem inadequate to explain trade flows

Flows from i to j are influenced by

- resistance to i's shipments on its other possible destinations

- resistance to shipments to j from j's other possible sources of supply

IMPLICATION: Example: Japan, Australia, Russia

Selection, Intensive and Extensive Margins

Helpman, Melitz, Rubinstein (HMR, 2008):

$X^{ij}=\alpha+\eta^{i}+\lambda^{j}+\beta d^{ij}+w^{ij}+u^{ij}$

Firm Heterogeneity: The extra term here is w^{ij}: The fraction of exporting firms (a function of the productivity cut-off)

Not accounting for this (extensive margin) results in over estimation of distance/trade frictions on trade volume (intensive margin)

Selection: Not accounting for zero trade flows and selection will bias estimates

HMR

To deal with selection, use Heckman two-stage procedure.

Estimate probability of trading in first stage probit.

Instrument using estimated probability in second stage (standard Heckman 2 step).

Probability of trading is probability that firms are productive enough to jump fixed cost.

Need excluded variable in first stage – use religion.

TRADE AND FIRMS – Empirics

Productivity and Markups: Estimation

- Carefully estimating productivity and markup crucial
  - *Particularly with globalization*

- The literature is sizeable.

- We will study some key papers (old and new) estimating both.

Melitz type effects in the Data: Empirics
Reallocation due to Trade Liberalization, Pavcnik (2002)

Estimating plant level productivity (for Chilean plants):

Let technology of the firm at time t be given by:

$$y_t = \beta_0 + \beta x_t + \beta_k k_t + e_t,$$

where x_t is other intermediate inputs.

$e_t = \omega_t + \mu_t,$ μ_t is mean zero.

The standard method to compute productivity is to run OLS on the above equation and then compute:

$$\widehat{\omega}_t = y_t - \widehat{\beta}_0 - \widehat{\beta} x_t - \widehat{\beta}_k k_t.$$

$\widehat{\beta}_k$ estimates likely to be biased.

The Plant's problem

Plant solves the problem: $\Pi_{ijt} = f\left(k_{ijt}, \omega_{ijt}\right)$

$$V_t\left(\omega_t, k_t\right) = \max\left\{L_t, \sup \Pi_t\left(\omega_t, k_t\right) - c\left(i_t\right) + dE\left[V_{t+1}\left(\omega_{t+1}, k_{t+1}\right) | \Omega_{it}\right]\right\}$$

Subject TO the evolution of capital:

$$k_{t+1} = (1-\delta)\, k_t + i_t.$$

With certain assumptions on how ω_{ijt} evolves, the solution to this problem is given by:

a. the threshold exit rule: $\omega_t < \underline{\omega}_t\left(k_t\right),$

b. An investment rule: $i_t = i_t\left(\omega_t, k_t\right)$

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Estimating plant level productivity:

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a. Simultaneity bias from investment rule.

b. Selection bias because of exit rule.

Pavcnik 2002, Estimating Productivity, Olley and Pakes (1996)

1. Correct simultaneity bias:

   Invert the investment rule to get productivity as a function of capital stock and investment.

$$y_t = \beta x_t + \lambda_t (k_t, i_t) + \mu_t,$$

   Approximate $\lambda_t(\cdot)$ *with a polynomial series expansion in capital and investment. Estimate* $\widehat{\beta}.$ *consistently.*

   To estimate $\beta_k.$

$$\begin{aligned}
y_{t+1} - \beta x_{t+1} &= \beta_0 + \beta_k k_{t+1} + \omega_{t+1} + \mu_{t+1} = \\
&= \beta_0 + \beta_k k_{t+1} + E\left[\omega_{t+1} | \omega_t, k_{t+1}\right] + \xi_{t+1} + \mu_{t+1} = \\
&= \beta_k k_{t+1} + g(\omega_t) + \xi_{t+1} + \mu_{t+1} = \\
&= \beta_k k_{t+1} + g(\lambda_t(k_t, i_t) - \beta_k k_t) + \xi_{t+1} + \mu_{t+1},
\end{aligned}$$

Pavcnik 2002, Estimating Productivity

2. Correct selection bias

Estimate probability of staying in the market with a probit:

$$P_t = \Pr\left[\omega_{t+1} > \underline{\omega}_{t+1}\left(k_{t+1}\right)\right] = p_t\left(\underline{\omega}_{t+1}\left(k_{t+1}\right), \omega_t\right) = p_t\left(\underline{\omega}_{t+1}\left(k_t, i_t\right), \omega_t\right) = p_t\left(k_t, i_t\right),$$

$$y_{t+1} - \beta x_{t+1} = \beta_k k_{t+1} + \Phi\left(\lambda_t\left(k_t, i_t\right) - \beta_k k_t, P_t\right) + \xi_{t+1} + \mu_{t+1},$$

Scale efficiency and trade: Evidence

Tybout and Westbrook (1995) look at Mexico's unilateral trade liberalisation of 1984-1990:

Find that the cumulative weighted-average growth rate in output was 53 percent for manufactured sector.

BUT associated productivity growth rate due to scale-efficiency effects was only one-half of one percentage point.

Large firms operating in flat portions of their average cost schedules, and these account for bulk of output adjustments.

Mark-ups and trade: Evidence

Krishna and Mitra (1998) look at India's trade liberalization episode:

Methodological framework 'allows' for returns to scale to change after the liberalization.

They use firm-level data from a variety of industries, find strong evidence of an increase in competition.

This is reflected in the reductions in price-marginal cost mark-ups.

Also find some evidence of an increase in the growth rate of productivity.

Mark-ups and trade

The Krugman model and subsequent models of its class (Melitz) incorporate imperfect competition

Trade brings gains by squeezing firm mark-ups (Pro-competitive effect)

Looking for evidence of pro-competitive effects requires estimation of the mark-up

- Preferably from firm-level data

Productivity and mark-up estimation

- Both require backing out output elasticities of inputs.
- This can be done using revenue-based production functions
- OR, quantity based production functions

Estimating Mark-ups: Revenue

The revenue based production function:

- Estimate output elasticities by regressing revenue on input expenditures

- Output elasticity of a factor equals expenditure share in revenue only when P = MC

- Imperfect competition drives a wedge between output elasticity and expenditure share

- The revenue production function hence conflates productivity and mark-up

Estimating Mark-ups: Physical (TFPQ)

Once can use data on physical output and inputs:

- *Involves obtaining output elasticities of inputs by estimating a physical production function*

- *Use physical quantities of output and inputs*

Estimating Mark-ups: Price Deflators

- *If one can calculate price deflators, one can convert dollar values to physical quantities*
- *Traditionally, industry price deflators have been used (not ideal)*
- *The best way is to calculate output and input price deflators at the firm level (Smeets and Warzynski JIE 2013)*
- *Or, use a control function approach (DeLoecker et al, 2016)*

DeLoecker and Warzynski (2012) AER

DW study the relationship between mark-ups and exporting among Slovenian firms.

Use a revenue production function, but argue that only level of mark-up affected.

Not correlation between mark-up and firm characteristics.

DW, findings

- Mark-ups significantly higher for exporting firms (a la Mellitz)
- Focusing on changes: mark-ups significant increase when firms enter export markets

DW: Estimation

A firm i at time t produces output combining fixed and variable inputs using the following technology:

$$Q_{it} = Q_{it}(X_{it}^{1}, \ldots, X_{it}^{V}, K_{it}, \omega_{it}),$$

Cost-minimization

The Lagrangian for cost-minimization is given by:

$$L(X_{it}^1, \ldots, X_{it}^V, K_{it}, \lambda_{it}) = \sum_{v=1}^{V} P_{it}^{X^v} X_{it}^v + r_{it} K_{it} + \lambda_{it}(Q_{it} - Q_{it}(\cdot))$$

Note that

$$\frac{\partial L_{it}}{\partial X_{it}^v} = P_{it}^{X^v} - \lambda_{it} \frac{\partial Q_{it}(\cdot)}{\partial X_{it}^v} = 0,$$

$$\frac{\partial L_{it}}{\partial Q_{it}} = \lambda_{it}.$$

Output elasticity of inputs

Re-arranging:

$$\frac{\partial Q_{it}(\cdot)}{\partial X_{it}^{v}} \frac{X_{it}^{v}}{Q_{it}} = \frac{1}{\lambda_{it}} \frac{P_{it}^{X^{v}} X_{it}^{v}}{Q_{it}}$$

Or, output elasticity of an input equals a function of the expenditure share in output.

Define the mark-up as

$$\mu_{it} \equiv \frac{P_{it}}{\lambda_{it}}$$

Mark-up

We can write the output elasticity of an input as

$$\theta_{it}^{X} = \mu_{it} \frac{P_{it}^{X} X_{it}}{P_{it} Q_{it}}$$

And hence

$$\mu_{it} = \theta_{it}^{X} \left(\alpha_{it}^{X}\right)^{-1}$$

Estimation procedure

- Estimate a revenue production function correcting for simultaneity and exit bias.
  - *DW use the LP approach (see next slide)*

- Obtain the output elasticities.

- Use these to calculate mark-up noting that

$$\hat{\alpha}_{it}^{X} = \frac{P_{it}^{X} X_{it}}{P_{it} \frac{\widetilde{Q}_{it}}{\exp\left(\widehat{\epsilon}_{it}\right)}}$$

Levinsohn-Petrin (2003)

- The LP approach to estimating productivity is the same as the Olley-Pakes 1996 (OP) approach, except:

- LP use material inputs to proxy for productivity rather than investment

- This is because many firms (particularly in developing countries) do not invest each year

- The idea is to regress output on labor input and polynomial in K and M in the first stage

Ackerberg Caves and Frazer ACF correction (2006)

ACF point out that labor cannot be treated differently from materials in the first stage

They hence propose a method where in the second stage:

- labor and capital coefficients are estimated jointly