Session 1: The Theoretical Gravity Model

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Outline

Introduction

- The basic gravity model provides a respectable place to start.
- But if we look more closely, we will find that it has some unattractive implications from an economic point of view.
- Doing some theory allows us to reformulate the gravity model in much more attractive way.

The Relative Price Problem

The Basic Gravity Model

$$\log\left(X_{ij}\right) = b_0 + b_1 \log\left(Y_i\right) + b_2 \log\left(Y_j\right) + b_3 \log\left(d_{ij}\right) + e_{ij}$$

- Yesterday, we interpreted $b_3 = -1$ as indicating that a 1% increase in bilateral distance (transport costs) is associated with a 1% decrease in bilateral trade.
- In fact, this presents some serious problems in the context of a world with many countries.

The Relative Price Problem

The Basic Gravity Model

$$\log\left(X_{ij}\right) = b_0 + b_1 \log\left(Y_i\right) + b_2 \log\left(Y_j\right) + b_3 \log\left(d_{ij}\right) + e_{ij}$$

- Do trade flows between i and j only depend on bilateral trade costs, without any adjustment for the level of trade costs prevailing on other routes?
- If trade costs fall between i and j, will trade flows with all other countries remain unchanged?
- If trade costs on all routes fall by the same proportion, will trade everywhere increase by the same proportion?

The Theoretical Gravity Model

- To try and fix these problems, it makes sense to go back to fundamentals.
- The basic gravity model picks up some important empirical regularities, but has been posited without any explicit theoretical foundation.
- If we add in some micro-foundations, hopefully we will be able to derive something that looks a lot like gravity, but deals with the relative cost problem.

The Theoretical Gravity Model

- A number of papers develop solid theoretical bases for the gravity model.
- We will focus on the “gravity with gravitas” model set out by Jim Anderson and Eric Van Wincoop in the AER (2003) and JEL (2004).
- It is treated by many (most?) applied trade researchers as the empirical baseline.
- Build on it by all means, but ignore it at your peril!

Outline

The Theoretical Gravity Model

To derive the AvW model, we proceed as follows (see handout):

1. Set out a consumption side based on love of variety preferences;
2. Set out a production side with large group monopolistic competition;
3. Introduce trade costs, and relate domestic and foreign prices;
4. Impose some macro identities and aggregate to produce a gravity-like model.

The Theoretical Gravity Model
Consumption Side

Love of Variety Preferences

$$U_i = \sum_{k=1}^{K} \left\{ \int_{v \in V_i^k} \left[x_i^k(v) \right]^{1-\frac{1}{\sigma_k}} dv \right\}^{\frac{1}{1-\frac{1}{\sigma_k}}}$$

- C countries (i), K sectors (k), each with measure V varieties (v).
- Intrasectoral (between varieties) elasticity of substitution σ_k.
- Can easily be varied: one sector only, Cobb-Douglas first tier, etc.
- Utility increases with greater consumption of each variety, and consumption of more varieties.

The Theoretical Gravity Model

Production Side

Constant Markup Pricing

$$p_i^k(v) = \left(\frac{\sigma_k}{\sigma_k - 1}\right) w a_i^k$$

- Each firm makes a unique variety under increasing returns to scale. Marginal cost a is constant by country-sector.
- With a very large number of firms, each one of them takes the overall price level as given.
- This allows us to shut down strategic interactions: all firms in a sector price at the same, constant markup over marginal cost.

The Theoretical Gravity Model

Introducing Trade Costs

Domestic/Foreign Price Linkages

$$p_j^k(v) = \tau_{ij}^k p_i^k(v)$$

- International trade is costly: if I want one unit to arrive, I must ship $\tau_{ij} \geq 1$ units.
- Thus, the price of a variety produced in one country and consumed in another is increased by the same factor over the price in the home country.
- Think of it like an ad valorem tariff, or variable transport costs. No fixed costs of market entry.

The Theoretical Gravity Model

Aggregate and use Macro-Identities to get Gravity with Gravitas

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^C \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k}$$

$$\left(P_j^k\right)^{1-\sigma_k} = \sum_{j=1}^C \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- Bilateral trade depends positively on the size of the importing and exporting countries, but negatively on trade costs.
- The two price indices capture the fact that it is relative trade barriers that matter.

The Theoretical Gravity Model

Gravity with Gravitas

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^{C} \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k}$$

$$\left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^{C} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- Π_i^k is outward multilateral resistance.
- Exports from i to j depend on bilateral trade costs, but also on trade costs affecting i's exports to all other markets.

The Theoretical Gravity Model

Gravity with Gravitas

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^{C} \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k}$$

$$\left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^{C} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- P_j^k is inward multilateral resistance.
- Exports from i to j depend on bilateral trade costs, but also on trade costs affecting j's imports from all other markets.

Outline

Implications of the AvW Model

- AvW looks like gravity, but also has some important differences with respect to the basic model.
  - Inclusion of the multilateral resistance terms.
  - Selection of variables.
  - Interaction between trade costs and the substitution elasticity.
- What are the implications of these differences for empirical work?

Theory-Consistent Gravity Data

Trade Data

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \Sigma_{j=1}^C \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k} \; ; \left(P_j^k\right)^{1-\sigma_k} = \Sigma_{i=1}^C \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- The AvW gravity model needs trade data in nominal value terms.
- Each observation should represent a unidirectional flow between a pair of countries, e.g. exports from i to j, not total trade in both directions (i to j or j to i), or the average, etc.

Theory-Consistent Gravity Data

GDP Data

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^{C} \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k} \; ; \; \left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^{C} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- GDP should be in nominal, not real, terms.
- When the model is estimated sector by sector, we would ideally like sectoral expenditures and production, not economy-wide GDP.

Theory-Consistent Gravity Data

Price Data

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^C \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k} \; ; \; \left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^C \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- We need to do something to take account of multilateral resistance.
- Standard price indices (CPI, PPI, etc.) are not aggregated in the way implied by theory, and so can at best be a poor proxy for the true (ideal) price indices we need.

The Trade Costs Function

The AvW Gravity Model

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right\}^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^{C} \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y^k} \; ; \; \left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^{C} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y^k}$$

- The model depends on trade costs τ_{ij}^k, but they are not directly observable as an aggregate. We need to build them up by specifying them in terms of observables.
- Most commonly, the trade costs function is specified as follows:

$$\ln\left(\tau_{ij}^k\right) = t_1 \ln\left(d_{ij}\right) + t_2 lang_{ij} + t_3 \ln\left(1 + tariff_{ij}\right) + t_4 border_{ij} + \ldots$$

Taking Account of Multilateral Resistance

The AvW Gravity Model

$$\ln\left(X_{ij}^k\right) =$$
$$\ln\left(Y_i^k\right) + \ln\left(E_j^k\right) - \ln\left(Y^k\right) + (1-\sigma_k)\left[\ln\tau_{ij}^k + \ln\Pi_i^k + \ln P_j^k\right]$$

- The basic gravity model gets the first four terms approximately correct, but leaves out the last two.
- Unless the MR terms have zero correlation with exports and trade costs (or GDP), then we have omitted variables bias.

Taking Account of Multilateral Resistance

- How serious is this OV bias empirically?
- Distance coefficient from the original gravity model without fixed effects = -1.277***.
- Distance coefficient from the fixed effects gravity model = -1.596***.
- The difference between these estimates is statistically signficant at the 1% level. Is it economically significant?

Taking Account of Multilateral Resistance

What to Do?

The AvW Gravity Model

$$X_{ij}^{k} = \ln\left(Y_i^k\right) + \ln\left(E_j^k\right) - \ln\left(Y^k\right) + (1-\sigma_k)\left[\ln\tau_{ij}^k + \ln\Pi_i^k + \ln P_j^k\right]$$

- The problem is easier stated than solved, because there is no way to observe $\ln\Pi_i^k + \ln P_j^k$.
- We cannot just find some data, include it, and fix the OV bias!

Summary

- The basic gravity model is fine as a starting point for an empirical analysis.
- But gravity models now need to take account of multilateral resistance, i.e. “relative prices matter”.
- Next session looks at the two most common ways of accounting for multilateral resistance in applied work.