Session 1: Counterfactual Simulations Using the Gravity Model

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Outline

1. Introduction
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Thus far, we have focused on using the gravity model to obtain estimates of the sensitivity of trade to changes in particular geographical or policy factors.

We have been interested in measuring the strength of these effects through parameters such as elasticities, focusing on estimated sign, magnitude, and statistical significance.

That is not the only way to interpret gravity model results...
Counterfactual simulations are an alternative way of presenting results from the gravity model.

We take observed data and estimated elasticities, and use them to map a “shock” to some independent variable onto projected trade effects:

$$\ln \left( \frac{\tilde{X}_{ij}}{X_{ij}} \right) = \hat{b} \ln \left( \frac{\tilde{\tau}_{ij}}{\tau_{ij}} \right)$$

Gravity is a very crude method for performing such simulations, and should only ever be used for “back of the envelope” numbers. For a rigorous analysis (including economic welfare), a CGE model is really required.
The AvW model has serious implications for the way in which we estimate gravity models.

It turns out also to have serious implications for the way in which we conduct counterfactual simulations.

Because of the computational complexity of the problems involved, we will only consider an approximate approach here. For more details, see AvW (2003, 2004).
Simulations and the AvW Model

The AvW Gravity Model–Aggregate Data

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

- As we have seen, the MR terms play a crucial role in setting up and estimating gravity models.
- One motivation for going back to theory was that we didn’t believe that trade costs elsewhere could not influence trade on a particular bilateral route.
- An alternative motivation is that it is unlikely that changes to trade costs on one bilateral route do not influence trade elsewhere.
- These effects need to be picked up properly when we conduct counterfactual simulations.
Simulations and the AvW Model

- Recall the definitions of inward and outward MR:
  \[
  \left(\Pi^k_i\right)^{1-\sigma_k} = \sum_{j=1}^{C} \left\{ \frac{\tau_{ij}^k}{P_j^k} \right\}^{1-\sigma_k} \frac{E_j^k}{Y_j^k}
  \]
  \[
  \left( P_j^k \right)^{1-\sigma_k} = \sum_{i=1}^{C} \left\{ \frac{\tau_{ij}^k}{\Pi_i^k} \right\}^{1-\sigma_k} \frac{Y_i^k}{Y_k}
  \]

- From a simulation standpoint, the important thing to note is that both MR terms are functions of all bilateral trade costs.

- Thus, any counterfactual simulation based on a shock to trade costs needs to account for two effects:
  - A direct trade impact through the trade costs function in the main gravity model; and
  - An indirect trade impact through the MR terms.
Simulations and the AvW Model

- The fixed effects AvW model takes account of the MR terms at the estimation stage.
- However, if we conduct counterfactual simulations based on a fixed effects model, we can only obtain the first-order (direct) effect.
- The fixed effects do not tell us anything about how changes in trade costs translate into changes in MR, and how changes in MR map to changes in trade flows.
Simulations and the AvW Model

To see this more clearly, take the AvW model:

\[
\ln(X_{ij}) = \ln(Y_i) + \ln(E_j) - \ln(Y) + (1 - \sigma) [\ln(\tau_{ij}) + \ln(\Pi_i) + \ln(P_j)]
\]

and

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

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

Clearly,

\[
\frac{1}{X_{ij}} \frac{\partial X_{ij}}{\partial \tau_{ij}} = \frac{1-\sigma}{\tau_{ij}} + \frac{1-\sigma}{\Pi_i} \frac{\partial \Pi_i}{\partial \tau_{ij}} + \frac{1-\sigma}{P_j} \frac{\partial P_j}{\partial \tau_{ij}}
\]
However, for the fixed effects model:

\[
\ln(X_{ij}) = c + a_i + a_j + (1 - \sigma) \ln \tau_{ij}
\]

And so in practice, \( \frac{1}{X_{ij}} \frac{\partial X_{ij}}{\partial \tau_{ij}} = \frac{1 - \sigma}{\tau_{ij}} \) because we have no way of evaluating the MR terms.

The problem is even more acute for \( \frac{\partial X_{ij}}{\partial \tau_{kl}} \), because that term appears in the MR terms but not at all in the FE model.
To deal with this problem, we need to use an empirical model that includes the MR terms more directly than does FE.

Two possible solutions, neither of which is (yet) widely used in the literature:

- Direct estimation as per AvW;
- Baier-Bergstrand estimation via a Taylor series approximation.

The first solution is difficult to implement. The second gives a relatively good approximation, and is much simpler.
Recall that the BB Taylor expansion gives a gravity model that looks like this:

\[
\ln \left( X^k_{ij} \right) = \ln \left( Y^k_i \right) + \ln \left( E^k_j \right) - \ln \left( Y^k \right) +
\]

\[
(1 - \sigma_k) \left[ \ln \tau^k_{ij} - \frac{1}{N} \sum_i \ln \tau_{ij} - \frac{1}{N} \sum_j \ln \tau_{ij} + \frac{1}{N^2} \sum_i \sum_j \ln \tau_{ij} \right]
\]

The correction introduced by the approximate MR terms means that just as the estimates take account of MR, so too do simulation results based on the BB model.
The Baier-Bergstrand Model

1. Calculate the MR adjustment term
   \[ \frac{1}{N} \sum_i \ln \tau_{ij} + \frac{1}{N} \sum_j \ln \tau_{ij} - \frac{1}{N^2} \sum_i \sum_j \ln \tau_{ij} \] for each trade cost variable, and transform the original variable by subtracting the adjustment term. Thus,
   \[ \tau_{ij}^* = \ln \tau_{ij} - \frac{1}{N} \sum_i \ln \tau_{ij} - \frac{1}{N} \sum_j \ln \tau_{ij} + \frac{1}{N^2} \sum_i \sum_j \ln \tau_{ij}. \]

2. Estimate a gravity model using the transformed trade cost variables.
The Baier-Bergstrand Model

1. Design a policy simulation, and create a new trade cost variable $\tilde{\tau}_{ij}$ that represents the counterfactual value of trade costs you are interested in.

2. Calculate the MR adjustment term for the counterfactual trade cost variable, and transform the counterfactual variable by subtracting the counterfactual adjustment term to produce $\tilde{\tau}_{ij}^*$. 

3. Calculate the percentage change in the transformed trade cost variable (counterfactual relative to baseline), then map the percentage change to trade using the estimated elasticity.
More formally:

\[ \ln \left( \frac{\tilde{X}_{ij}}{X_{ij}} \right) = \hat{b} \ln \left( \frac{\tilde{\tau}_{ij}}{\tau_{ij}^*} \right) \]

where \( \sim \) indicates counterfactual variables, and \( * \) indicates trade costs transformed according to BB’s procedure for taking account of the MR terms.
It is important to choose a policy-relevant counterfactual. “What if” Swaziland turns into Switzerland is not relevant.

WMO look at regional averages: this can represent a reasonable and achievable benchmark, so counterfactual results can be meaningful.

Be aware that technically, counterfactuals involving large shocks are unlikely to be valid: parameters might change, or linear approximations break down.
Particularly in the context of trade facilitation, independent variables in the gravity model can tend to be strongly correlated.

Econometric techniques can help us identify independent effects of particular variables.

But when we perform variable-by-variable counterfactuals, we are implicitly assuming that it is possible to shock one variable without shocking the others.

Conversely, if we add together variable-by-variable shocks, the total effect may well be overstated due to the fact that things tend to move together in practice.
Gravity models often do not include data on NTBs—including binding quotas—due to lack of cross-country data.

Thus, counterfactuals can grossly overstate trade effects in situations where NTBs are binding, and effectively inhibit export expansion.

When working in regions and sectors where NTBs are an issue, it is important to be clear about this.

More generally, be skeptical of overly large counterfactual results!
The gravity model does not give us certain values for the elasticity of trade with respect to trade costs. It only gives us estimated values, which are subject to sampling error and, thus, to uncertainty. By choosing only the core estimate for counterfactuals, we can give an impression of undue precision to an audience that does not appreciate the mechanics of this approach.
One way to deal with this is to provide a measure of uncertainty for the counterfactual results too.

Calculate the counterfactual results using the core coefficient estimate.

Then repeat the calculation twice more using:

- The core estimate + 1 standard deviation;
- The core estimate - 1 standard deviation.

This is a very approximate approach, but it gets the point across: counterfactuals produce a zone of results, rather than just a single number.
Gravity counterfactuals can be a good way of explaining model results to a policy audience. However, it is important to make the caveats clear:

- Gravity models trade effects, not welfare;
- Results are indicative only, subject to uncertainty, and do not take account of constraints that may be binding in practice;
- Counterfactual results lose validity as the shock becomes larger.
A FE gravity model can be a starting point for counterfactuals, but it misses out on indirect effects through the MR terms.

BB is a better way of taking account of such indirect effects.

In general, treat gravity counterfactuals as a “back of the envelope” calculation. If quantification is important, they should be backed up with CGE results.