Gravity with Gravitas: A Solution to the Border Puzzle

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4. Conclusion
Regression estimated

\[ \ln x_{ij} = k + \alpha_1 \ln y_i + \alpha_2 \ln y_j + \alpha_3 \ln d_{ij} + \alpha_4 \ln (B \ - \ Dummy)_{ij} + \varepsilon_{ij} \]

Data from 1988

- trade flows between US states and Canadian provinces (state-province trade)
- Canadian interprovincial trade flows

Estimation results

- \( \exp(\alpha_4) = \exp(3.06) = 22 \)
McCallum (1995):
US-Canadian Border meant that 1988 trade between Canadian provinces is a factor 22 (2,200 %) times trade between US states and Canadian provinces!
Assumptions

- Goods are differentiated by place of origin
- Constant elasticity of substitution utility function
- Multiplicative transportation costs

Maximization problem

\[
\max_{c_{ij}} U(c_{ij}) = \left( \sum_i \beta_i^{(1-\sigma)/\sigma} c_{ij}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}
\]

\[
\text{s.t. } \sum_i p_{ij} c_{ij} = y_j
\]

Trade cost factor \( t_{ij} \)

\[
p_{ij} = p_i t_{ij}
\]

Nominal export value

\[
x_{ij} = p_i c_{ij} + (t_{ij} - 1) p_i c_{ij} = p_{ij} c_{ij}
\]

Total income of exporting region \( i \)

\[
y_i = \sum_j x_{ij}
\]
2. The Gravity Equation: Theory taken seriously

2.1 Model Set-up

Solution

\[ x_{ij} = \left( \frac{\beta_i p_i t_{ij}}{P_j} \right)^{(1-\sigma)} y_j \] with

\[ P_j = \left( \sum_i (\beta_i p_i t_{ij})^{1-\sigma} \right)^{1/(1-\sigma)} \]

General equilibrium through substitutions

\[ x_{ij} = \frac{y_i y_j}{y_{World}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \] with

\[ P_j^{1-\sigma} = \sum_i P_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma} \]

New equation

McCallum's equation

Price index: Multilateral resistance
The theoretical gravity equation predicts that trade between countries – after controlling for country sizes – is dependent on the bilateral trade barrier between them relative to average trade barriers that both countries face with all of their trading partners.

\[ x_{ij} = \frac{y_i y_j}{y_{\text{World}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma}} \text{ with } P_j^{1-\sigma} = \sum_i P_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma} \]
2. The Gravity Equation: Theory taken seriously

2.2 Model Solution

- **Size matters!** Larger (richer) countries import and export more.
- **Trade barriers matter!** Larger bilateral trade barriers $t_{ij}$ between any two countries $i$ and $j$ lower trade flows between $i$ and $j$.
- **Relative trade barriers matter!** Multilateral resistance of importer $j$ or exporter $i$ raise trade flows between them.
- Multilateral trade resistance depends on relative sizes and relative trade barriers $\Rightarrow$ three main implications…

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**Theoretical gravity equation**

$$x_{ij} = \frac{y_i y_j}{y_{world}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \text{ with } P_j^{1-\sigma} = \sum_i P_i^{-1} \theta_i t_{ij}^{1-\sigma}$$
2. The Gravity Equation: Theory taken seriously

2.3 Three main insights

**IMPLICATION 1**
Trade barriers reduce (size-adjusted) trade between large countries more than between small countries.

**IMPLICATION 2**
Trade barriers raise (size-adjusted) trade within small countries more than within large countries.

\[
x_{ij} = \frac{y_i y_j}{y_{World}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma}
\]

with \( P_j^{1-\sigma} = \sum_i P_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma} \)
2. The Gravity Equation: Theory taken seriously

2.3 Three main insights

**Large country**
- Most goods consumed are produced domestically
- Trade barriers affect imported goods = a small fraction
- Multilateral resistances are **hardly** affected

**Small country**
- Most goods consumed are imported goods
- Trade barriers affect imported goods = a high fraction
- Multilateral resistances are **much** affected
2. The Gravity Equation: Theory taken seriously
2.3 Three main insights

**IMPLICATION 1**
Trade barriers reduce (size-adjusted) trade \textit{between} large countries more than between small countries.

**IMPLICATION 2**
Trade barriers raise (size-adjusted) trade \textit{within} small countries more than within large countries.

**IMPLICATION 3**
Trade barriers raise the ratio of (size-adjusted) \textit{INTRA}national trade within country 1 relative to (size-adjusted) \textit{INTER}national trade between countries 1 and 2 by more the smaller is country 1 and the larger is country 2.

\[
x_{ij} = \frac{y_i y_j}{y_{world}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \text{ with } P_j^{1-\sigma} = \sum_i P_i^{\sigma^{-1}} \theta_i t_{ij}^{1-\sigma}
\]
3. Solving the Puzzle
3.1. Implication from the theoretical model

- **IMPLICATION 3** gives a founded explanation for McCallum’s high border effect

  ![Impact of borders on INTRAnational trade to INTERnational trade](image)

- For a **relatively small country** such as Canada, the ratio of INTRAnational Canadian trade relative to INTERnational US-Canadian trade is expected to be particularly high!

- Canada’s relatively **small size is part of reason** for high border effect, and thus for the Puzzle!

  …another reason lies in the regression model used by McCallum:
3. Solving the Puzzle
3.2. New regression model

\[ x_{ij} = \frac{y_i y_j}{y_{world}} \left( \frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \]
with \( P_j^{1-\sigma} = \sum_i P_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma} \)

Trade cost factor

\[ t_{ij} = b_{ij} d_{ij}^\rho \]

Border dummy \rightarrow Distance

Theoretical gravity equation

\[ \ln x_{ij} = k + \ln y_i + \ln y_j + (1-\sigma) \rho \ln d_{ij} + (1-\sigma) \ln b_{ij} - (1-\sigma) \ln P_i - (1-\sigma) \ln P_j + \varepsilon_{ij} \]

Neglecting \( P_i \) and \( P_j \) causes omitted variable bias since they are indirectly correlated with \( d_{ij} \) and \( b_{ij} \)

KEY DIFFERENCE TO McCALLUM’s EQUATION
3. Solving the Puzzle
3.2. New regression model

Results from the new regression model

- Larger multilateral resistances in small countries than in large countries → **Implications 1-3 strongly confirmed by data**

- Border reduces trade between US and Canada by 44% and increases interprovincial trade by factor 6 → **Ratio 10.6 vs. McCallum’s 22**

- Borders reduce trade by moderate amounts of 20-50%
3. Solving the Puzzle
3.3. Where did McCallum go wrong?

Two reasons for McCallum‘s large border effect

**Relative size of Canadian economy**
Small size leads to high increase in interprovincial Canadian trade with an introduction of trade barriers; McCallum‘s ratio is thus expected to be very high!

**Omitted variable bias**
Not including multilateral resistance terms implies endogeneity in the regression. Endogeneity causes biased estimators!
4. Conclusion

Commonly estimated gravity equations
- have a good fit to the data, but
- are not theoretically founded,
- lead to biased estimation and
- an incorrect comparative statics analysis.

Theoretically founded gravity equation
- can explain the enormous border effects previously found and thus provide a convincing solution to the Border Puzzle
- finds that borders reduce bilateral trade levels by plausible though substantial magnitudes.
Thank you.