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Gravity without Apology: The Science of Elasticities, Distance, and Trade

Hotel "Grand Villa Argentina"
Dubrovnik
June 14 – 16, 2019

Draft version
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Gravity without Apology: The Science of Elasticities, Distance, and Trade

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25th Dubrovnik Economic Conference
June 14, 2019
Gravity: The value of trade declines with distance

One of the great successes of modern economics

Gravity in trade is both fact and theory


Though this is not widely known by economists outside trade

And “anti-gravity” continues to have popular appeal
Introduction

Gravity in the News

FINANCIAL TIMES

TUESDAY 19 APRIL 2016
WORLD BUSINESS NEWSPAPER

Merkel's comic error
Problem child
Executive pay

Europe must fight for freedom of speech — Gideon Rachman, Page 11
Counting the global cost of El Niño - BIG READ, PAGE 11
The biggest block to trust in business — Andrew Hill, PAGE 14

Treasury’s grim forecasts spark fury from Tory Brexit rebels

Osborne seeks to demolish economic case for Out • Gove to launch stinging response

Three Treasury scenarios
Changes in UK GDP by 2020

WTO membership only

Negotiated bilateral agreement (like Canada)

Negotiated bilateral agreement (like Norway)

Membership of EEA (like Norway)

-9.5%

-6.2%

-3.8%

and the key numbers

The Treasury's forecast for changing trade values between countries

\[ \ln(T_{2020}) = \alpha + \gamma + \alpha \ln(Y_2020) + \alpha \ln(P_{2020}) + \alpha \ln(DIST) + \alpha \text{COMLANG} + \alpha \text{COLONY} + \alpha \text{BORDER} + \epsilon \]

Briefing

• Big companies look outside for a leader
• Big companies look outside for a leader
• UK companies are losing with global peers
• Big companies look outside for a leader
• Big companies look outside for a leader
• Big companies look outside for a leader

Watching the wings

The financial regulator has now cut its forecast for the economy to just 0.1 per cent in the first half of the year, down from 0.3 per cent, and has warned that it could fall further

• King quits Villa-based after two months
• Former governor of the Bank of England
• The Mark Carney resigns from the UK central bank's board of directors

Cuts dip but recovery after talks full

He can't have it all, but he's getting more of it

• Cameron is due to make
• Cameron is due to make
• Cameron is due to make

Breach of Swiss deal

Argentina's central bank has warned that the country's economy could contract by as much as 6 per cent this year

• Brezzil soldier charged over killing
• Brezzil soldier charged over killing
• Brezzil soldier charged over killing

CMN (Geneva and Oxford)

Gravity without Apology

DEC25: June 14, 2019 3 / 91
“Today, we stand on the verge of an unprecedented ability to liberate global trade for the benefit of our whole planet with technological advances dissolving away the barriers of time and distance. It is potentially the beginning of what I might call ‘post geography trading world’ where we are much less restricted in having to find partners who are physically close to us.”

– Liam Fox, UK Minister for International Trade, Sept. 2016
This Paper

- Review the evidence for gravity
- Introduce some simple ways of understanding CES gravity
- Note some problems with CES
- Sketch some alternatives

Background: Brexit ...

- 1973, January 1: UK joined EEC, later the European Union (EU)
- 2016, June 23: UK referendum: Vote to leave EU 51.89% to 48.11%
- 2017, March 29: UK invoked Article 50 of EU Treaty, starting a two-year process of withdrawal
- 2019, March 29: Deadline extended to October 31
- 2019, May 29: Still unclear whether UK will remain in EU, or leave, with or without a deal
Introduction

Economics of Brexit

- Many studies of the trade effects of Brexit
  - Predominantly using the gravity model
    - Dhingra et al. (2017), Sampson (2017)
    - Mayer, Vicard, and Zignago (2019)
  - We ignore work on other economic aspects of Brexit
    - Davies and Studnicka (2018): Stock-market response
    - Alabrese, Becker, Fetzer, and Novy (2019): Determinants of voting
    - O’Rourke (2019): Historical context
Professional consensus: Three Iron Laws of the Economics of Brexit

1. The only good Brexit is a dead Brexit
2. The harder the Brexit the higher the economic costs
3. Even a hard Brexit will not have “very” large costs
   - 2% of GDP if soft, 6+% of GDP if hard
   - Compare: UK spent 7.26% of GDP on NHS in 2016/17
Background


Outline

1. Gravity as Fact
2. Gravity as Theory
3. Gravity Anomalies
4. Subconvex Gravity
5. Conclusion
Outline

1. Gravity as Fact
2. Gravity as Theory
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The Gravity Equation: A Universal Tendency

- Overwhelming professional consensus that distance matters for trade
  - Head and Mayer (2014): review of 159 papers
    - Average preferred estimate of distance elasticity: $-1.1$
    - S.D. 0.41; median $-1.14$

- Not just geographical distance matters:
  - Common language, legal system, colonial origins, FTA membership, etc.

- Results below for distance elasticity of 2017 UK exports in line with the literature:
  - $-0.752 (0.098)$: OLS, simple regression, $n = 181$
  - $-1.441 (0.023)$: OLS, full controls, $n = 23,251$
  - $-0.735 (0.034)$: OLS, $\ln(1 + V_{jk})$ as depvar, full controls, $n = 42,230$
  - $-0.977 (0.021)$: PPML, full controls, $n = 42,230$
Gravity: Not Just for Trade in Goods

- Distance also matters (though less so on average) for:
  - Services trade: Kimura and Lee (2006)
  - FDI: Kleinert and Toubal (2010), Keller and Yeaple (2013)
  - Equities: Portes and Rey (2005)
  - eBay: Lendle, Olarreaga, Schropp, and Vézina (2016)
  - Google: Cowgill and Dorobantu (2012)

- And the distance coefficient for goods trade has not fallen over time
  - “The Mystery of the Missing Globalization”!
  - But: Not a mystery
  - Distance is relative

  [Yotov (2012)]
Data Sources, etc.

- **Survey:**
  - Head and Mayer (2014)

- **Data:** CEPII

- **UK trade policy:** UK Trade Policy Observatory
  - [http://blogs.sussex.ac.uk/uktpo/](http://blogs.sussex.ac.uk/uktpo/)

- **EU trade agreements**
UK Exports and Importer GDP, 2017

- **Slope**: 1.06
- **R²**: 0.826
Gravity as Fact

UK Exports/Importer GDP and Distance, 2017

- Slope: -0.75
- $R^2$: 0.246

CMN (Geneva and Oxford)
Gravity without Apology
DEC25: June 14, 2019
Gravity Weighted by Exports, UK, 2017

- Slope: -0.75
- R²: 0.246

UK Exports/Importer GDP (log) vs. Distance (log km)
Trade Agreements, UK, 2017

![Image of a scatter plot showing the relationship between UK exports/imports GDP (log) and distance (log km) for EU, EU-FTA, Non-EU, and Best Fit categories. The plot includes a red line indicating the best fit for the data.]
Trade Agreements and ex-Colonies, UK, 2017
Gravity, UK, 2017: $-0.752 (0.098)$
Gravity as Fact

Gravity, Ireland, 2017: $-1.123 (0.150)$

![Graph showing the relationship between distance (log km) and exports/importer GDP (log). The graph includes data points for various countries such as USA, CHN, JPN, DEU, GBR, IND, FRA, BRA, ITA, CAN, RUS, KOR, AUS, ESP, MEX, TUR, NLD, SAU, CHE, ARG, SWE, POL, BEL, AUT, NOR, ARE, NGA, ISR, ZAF, HKG, DNK, SGP, MYS, PHL, FIN, PRT, CZE, ROM, GRC, DZA, HUN, KWT, SVK, DZA. The red line indicates the regression line.](image_url)
Gravity, Switzerland, 2017: $-0.642 \pm 0.106$
Gravity as Fact

Gravity, China, 2017: $-0.437 \ (0.145)$

Distance (log km)

Exports/Importer GDP (log)

USA JPN DEU GBR IND

BRA ITA CAN RUS

KOR AUS FRA ESP MEX

IDN TUR NLD SAU CHE

ARG POL BEL THA IRN AUT

NOR ARE NGA ZAF

HKG SGP MYS COL PAK CHL BGD

MMR EGY VNM CZE PER NZL IRQ DZA

Gravity without Apology
Gravity as Fact

Gravity, Croatia, 2017: $-1.762 (0.178)$

![Graph showing distance in log kilometers on the x-axis and exports/importer GDP in log on the y-axis for various countries. The graph includes points for USA, CHN, JPN, DEU, GBR, FRA, ITA, RUS, ESP, TUR, NLD, CHE, SWE, POL, BEL, AUT, NOR, HKG, SGP, COL, EGY, PRT, CZE, ROM, HUN, SVK, BGR, SVN, BIH, MKD, SVN, with varying bubble sizes representing different magnitudes and a red line indicating the gravity equation.]
Outline

1 Gravity as Fact

2 Gravity as Theory
   - Structural Gravity
   - Comparative Statics for Structural Gravity
   - An Application: Brexit

3 Gravity Anomalies

4 Subconvex Gravity

5 Conclusion
“[I] have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power.”

– Isaac Newton (1713)

“The intent of this paper is to provide a theoretical explanation for the gravity equation applied to commodities.”

– Jim Anderson (1979)
Foundations of the Gravity Model

- A variety of different supply sides, all with CES preferences

- The gravity equation has been shown to be consistent with:
  - Armington (1969) model of pure exchange
  - Models of monopolistic competition such as Krugman (1980)
    - Bergstrand (1985) and Helpman (1987)
  - Heterogeneous-firms model of Melitz (2003)
    - Chaney (2008)
  - Multi-country Ricardian model
    - Eaton and Kortum (2002)
  - Synthesis: Arkolakis, Costinot, and Rodríguez-Clare (2012)

- All yield the same “structural gravity” model

- Here: We focus on the simplest Armington-based version
Start with CES Demands

- $n$ countries, each endowed with a unique good
- Common CES preferences: Each country consumes all goods:

\[ x_{jk} = \beta_j \left( \frac{p_{jk}}{P_k} \right)^{-\sigma} \frac{E_k}{P_k} \]

\[ \Rightarrow \quad V_{jk} = \beta_j \left( \frac{p_{jk}}{P_k} \right)^{1-\sigma} E_k \]

- $V_{jk} = p_{jk} x_{jk}$: Value of exports from $j$ to $k$
- $\beta_j$: Taste parameter for country $j$ good
- $p_{jk}$: Delivered price of $j$'s export in $k$
  - $p_{jk} = p_j t_{jk}$: Equals home price times an “iceberg” trade cost
- $P_k$: Importer price index:

\[ P_k = \left( \sum_h \beta_h P_{hk}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \]

- $\sigma$: Elasticity of substitution
- $E_k$: Country $k$’s expenditure on all goods
Total sales by country \( j \) sum to GDP in equilibrium:

\[
\sum_k V_{jk} = Y_j
\]

Substitute into this from CES demands:

\[
Y_j = \sum_k V_{jk} = (\beta_j p_j)^{1-\sigma} \sum_k \left( \frac{t_{jk}}{P_k} \right)^{1-\sigma} E_k
\]

Use this to eliminate \((\beta_j p_j)^{1-\sigma}\) from \(V_{jk}\) and \(P_k\)
Structural Gravity

- Structural gravity:

\[ V_{jk} = \left( \frac{t_{jk}}{\Pi_j P_k} \right)^{1-\sigma} \frac{Y_j E_k}{Y_W} \]

(1)

\[ (\Pi_j)^{1-\sigma} = \sum_h \left( \frac{t_{jh}}{P_h} \right)^{1-\sigma} \frac{E_h}{Y_W} \]

(2): Frictionless trade: \( Y_W \) is world income

(1): Trade costs relative to outward and inward “multilateral resistance”:

\[ (P_k)^{1-\sigma} = \sum_h \left( \frac{t_{hk}}{\Pi_h} \right)^{1-\sigma} \frac{Y_h}{Y_W} \]

- \( \Pi_j \): Index of outward trade costs
- \( P_k \): In equilibrium, price index is also an index of inward trade costs
- Dual to one another
Uses of Structural Gravity

- **Estimation**
  - Usually in log-linear form with importer and exporter fixed effects:
  \[
  \log V_{jk} = F_j + F_k + \beta \log t_{jk} + u_{jk}, \quad t_{jk} = \delta_{jk} \exp(\gamma' D_{jk})
  \]

- **Simulation**
  - Policy analysis, e.g. Brexit

- **Theoretical Analysis**
  - Not possible in levels
  - What about comparative statics for local changes?
Comparative Statics for Structural Gravity

- Allen, Arkolakis, and Takahashi (2019)
  - Dekle, Eaton and Kortum (2008)
- Baqae and Farhi (2017)
- Jones (1965)
  - Diewert and Woodland (1977), Jones and Scheinkman (1977)
Comparative Statics:

Define GDP and expenditure shares:

\[ \lambda_{jk} = \frac{V_{jk}}{Y_j} \quad \theta_{jk} = \frac{V_{jk}}{E_k} \]

Country \( j \) small: \( \lambda_{kj} \approx 0 \) and \( \theta_{jk} \approx 0, \forall k \neq j \)

Express changes in terms of these:

\[ \hat{Y}_j = \sum_k \lambda_{jk} \hat{V}_{jk} \Rightarrow 0 = \sum_k \lambda_{jk} (\hat{\tau}_{jk} + \hat{x}_{jk}) \]

\[ P_k = \left( \sum_j p_{jk}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \Rightarrow \hat{P}_k = \sum_j \theta_{jk} \hat{p}_{jk} \]
Gravity as Theory
Comparative Statics for Structural Gravity

Gravity at the Margin

Demands at the margin:

\[ \hat{x}_{jk} = -\sigma \hat{p}_{jk} + (\sigma - 1)\hat{P}_k + \hat{E}_k \]

- Own and cross-price derivatives:

\[ \frac{\partial \log x_{jk}}{\partial \log p_{jk}} = - (\sigma (1 - \theta_{jk}) + \theta_{jk}) \quad \frac{\partial \log x_{jk}}{\partial \log p_{hk}} \bigg|_{h\neq j} = (\sigma - 1)\theta_{hk} \]

- Gross substitutes:

\[ -\frac{\partial \log x_{jk}}{\partial \log p_{jk}} > \frac{\partial \log x_{jk}}{\partial \log p_{hk}} > 0 \]

Add:

- Trade costs: \( p_{jk} = p_j t_{jk} \Rightarrow \hat{p}_{jk} = \hat{p}_j + \hat{t}_{jk} \)

- Balanced trade: \( E_j = \kappa_j Y_j \Rightarrow \hat{E}_j = \hat{Y}_j \)

- Supply side: \( \left\{ \begin{array}{l} Y_j = p_j Q_j \\ w_j = p_j \end{array} \right\} \Rightarrow \hat{Y}_j = \hat{w}_j = \hat{p}_j \)
Specialize to 3 countries: $A$, $B$, and $E$

- $A$ and $E$ large
- Take country $A$’s good as numéraire, so $p_A = 1$
- Equilibrium: Market-clearing conditions for outputs of $B$ and $E$ ...
- ... determine equilibrium wages: $w_B = p_B$ and $w_E = p_E$
Goods-Market Equilibrium

Illustrate equilibrium in \( \{p_E, p_B\} \), i.e., \( \{w_E, w_B\} \) space
Goods-Market Equilibrium

- Initial equilibrium at $S$.
- Goods-market-equilibrium locus for good $B$?
Goods-market-equilibrium locus for good $B$:

- Higher $w_B$, i.e. $p_B$, leads to excess supply, lower to excess demand
Goods-Market Equilibrium

- Goods-market-equilibrium locus for good $B$:
  - Higher $w_B$, i.e. $p_B$, leads to excess supply, lower to excess demand
  - Conversely for $w_E$, though effect is weaker
    - Gross substitutes in each market, and so in all
Goods-market-equilibrium locus for good $B$:

- Higher $w_B$, i.e. $p_B$, leads to excess supply, lower to excess demand
- Conversely for $w_E$, though effect is weaker
  - Gross substitutes in each market, and so in all
- Uniformly higher $w_B$ and $w_E$ leads to excess supply
Goods-market-equilibrium locus for good $B$:

- Higher $w_B$, i.e. $p_B$, leads to excess supply, lower to excess demand
- Conversely for $w_E$, though effect is weaker
  - Gross substitutes in each market, and so in all
- Uniformly higher $w_B$ and $w_E$ leads to excess supply
- So market-clearing locus is upward-sloping as shown
Similarly for good $E$

- Close to vertical if $B$ is small
Intersection of the two determines equilibrium wages $w_B$ and $w_E$
Trade Cost Scenarios

- Decompose trade costs:

\[ t_{jk} = \delta_{jk} \tau_{jk} \]

\[ \begin{align*}
\delta_{jk} & : \text{“natural”} \\
\tau_{jk} & : \text{policy-induced}
\end{align*} \]

- Possible scenarios:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>( \delta_{BE} )</th>
<th>( \tau_{BE} )</th>
<th>( \delta_{BA} )</th>
<th>( \tau_{BA} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status quo</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>“Cake and Eat”</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>“Global Britain”</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>low</td>
</tr>
</tbody>
</table>

(1) All assumed to be bilaterally symmetric.
(2) Revenue from policy costs ignored.
“Cake and Eat”

Lower $\tau_{BA}$: ambiguous effect on demand for $Y_B$; assume for now it raises it

$$\frac{\partial \log X_B}{\partial \log \tau_{BA}} = -(\sigma - 1)(\lambda_{BA}(1 - \theta_{BA}) - \lambda_{BB}\theta_{AB})$$

(1) $> 0$

(2) $< 0$

1. Lower trade cost $B \rightarrow A$: raises export demand for good $B$

2. Lower trade cost $A \rightarrow B$: lowers home demand for good $B$
Lower $\tau_{BA}$ also lowers demand for $Y_E$, though not by much if $B$ is small

$$\frac{\partial \log X_E}{\partial \log \tau_{BA}} = (\sigma - 1)(\lambda_{EA} \theta_{BA} + \lambda_{EB} \theta_{AB})$$
**“Cake and Eat”**

- Net effect: Rise in $w_B$, ambiguous change in $w_E$
  - $w_B \uparrow \iff \hat{w}_B > \hat{w}_A$: Because $A$ is bigger
“Cake and Eat”: Wages in $B$ May Fall

What if lower $\tau_{BA}$ reduces demand for $Y_B$?

- This is because $\theta_{AB}$ is large enough that home demand for $B$ falls
- But in this case the price level also falls a lot
- When $B$ is small these effects exactly cancel, so effect of higher exports dominates: real wage in $B$ definitely rises
- This result holds for any number of countries
Complete symmetry between $A$ and $E$: No net effect

- $\tau_{BE} \uparrow$ exactly offsets the effect of $\tau_{BA} \downarrow$
“Global Britain”: Departures from Symmetry

- Depth of integration
  - Single market is a deeper trade agreement: \( \tau_{BE} \bigg|_S < \tau_{BA} \bigg|_{GB} \)

- Size
  - What matters is not absolute size, but size in initial UK trade
  - EU27 accounts for 40% of 2017 UK trade; but countries with EU trade agreements add another 15%

- Asymmetries between increases in low policy costs and decreases in high ones
  - This matters for discrete changes
  - Cost of 10\%-point increase in \( \tau_{BE} \) is greater than the gain from a 10\%-point decrease in \( \tau_{BA} \)

- Distance a fixed cost
  \[
  t_{jk} = \delta_{jk} + \tau_{jk} \quad \Rightarrow \quad \hat{t}_{jk} = (1 - \omega_{jk}) \hat{\tau}_{jk}, \quad \omega_{jk} \equiv \frac{\delta_{jk}}{t_{jk}}
  \]
“Global Britain”: Reality Bites

- Net effect: Higher trade costs with $E$ dominate
  - More than offset the (only slightly) lower trade costs with $A$
Outline

1. Gravity as Fact

2. Gravity as Theory

3. Gravity Anomalies
   - Gravity Anomalies: Markups and Pass-Through
   - Gravity Anomalies: Bilateral Trade Balances

4. Subconvex Gravity

5. Conclusion
Gravity Anomalies

Counter-factual implications of CES preferences:

1. Firm-level markups and pass-through
   - CES demands imply constant markups and 100% pass-through
   - But: Mounting firm-level empirical evidence to the contrary
   - Empirics: De Loecker et al. (2016); theory: Mrázová and Neary (2017)

2. Elasticities of import demand across markets
   - Evidence that they vary by market size and distance: Novy (2013)

3. Bilateral trade balances
   - CES gravity imposes very strong counter-factual restrictions
Firm-Level Evidence Against CES

- Inverse demand function:
  \[ p = p(x) \quad p' < 0 \]

- Two key demand parameters:
  1. Slope/Elasticity:
     \[ \varepsilon(x) \equiv -\frac{p(x)}{xp'(x)} > 0 \]
  2. Curvature/Convexity:
     \[ \rho(x) \equiv -\frac{xp''(x)}{p'(x)} \]
CES Demands

- In general, both $\varepsilon$ and $\rho$ vary with sales.

- Exception: CES/iso-elastic case:
  - $p = \beta x^{-1}/\sigma$
  - $\Rightarrow \varepsilon = \sigma$, $\rho = \frac{\sigma+1}{\sigma} > 1$
  - $\Rightarrow \varepsilon = \frac{1}{\rho-1}$
CES Demands

- In general, both $\varepsilon$ and $\rho$ vary with sales

- Exception: CES/iso-elastic case:
  - $p = \beta x^{-1}/\sigma$
  - $\Rightarrow \varepsilon = \sigma, \rho = \frac{\sigma+1}{\sigma} > 1$
  - $\Rightarrow \varepsilon = \frac{1}{\rho-1}$

- Cobb-Douglas: $\varepsilon = 1, \rho = 2$
Sub- and Superconvexity

\( p(x) \) is subconvex at \( x^0 \) IFF:

- \( \log p(x) \) is concave in \( \log x \)
- \( p(x) \) is less convex than a CES demand function with the same elasticity: \( \rho < \frac{\varepsilon+1}{\varepsilon} \)
Sub- and Superconvexity

\( p(x) \) is subconvex at \( x^0 \) IFF:

- \( \log p(x) \) is concave in \( \log x \)
- \( p(x) \) is less convex than a CES demand function with the same elasticity: \( \rho < \frac{\varepsilon+1}{\varepsilon} \)
- \( \varepsilon \) is decreasing in sales:
  \[ \varepsilon x = \frac{\varepsilon}{x} \left( \rho - \frac{\varepsilon+1}{\varepsilon} \right) \]

Subconvexity confirmed empirically, and theoretically plausible:

- Introspection: “Marshall’s 2nd Law of Demand”
- Dixit and Stiglitz (1977), Krugman (1979), etc.
Represent demand functions in \( \{\varepsilon, \rho\} \) space by their Demand Manifold

**Definition:** A curve in \( \{\varepsilon, \rho\} \) space corresponding to the demand function \( p(x) \)

**Existence:** A smooth manifold corresponds to every demand function
- Except for CES: Manifold is a point

**Invariance:** \( \varepsilon(x, \phi) \) and \( \rho(x, \phi) \Rightarrow \rho(\varepsilon) \)?
- Necessary and sufficient condition in Mrázová-Neary (2017)
- Holds for most widely-used demand functions
Manifolds for Some Common Demand Functions

- All manifold-invariant
Mrázová and Neary (2017) show that $\varepsilon$ and $\rho$ can be inferred from estimates of pass-through and markups (as in de Loecker et al. (2016))

CES lies outside the implied confidence regions
Gravity Anomalies 3: Bilateral Trade Balances

- Structural gravity predicts bilateral trade flows $V_{jk}$
- So it also predicts their ratios: bilateral trade balances $V_{jk}/V_{kj}$
  - Precedent for this: *Products* of trade flows widely used to infer trade costs and elasticity of trade
  - Precursors:
    - Davis and Weinstein (2002): “Mystery of the Excess Trade (Balances)”
Bilateral Trade Balances: The Simplest Case

- Assume (for now) symmetric bilateral trade costs and balanced trade:
  - *Divide* bilateral trades:
    \[ \frac{V_{jk}}{V_{kj}} = \left( \frac{\Pi_j}{P_j} \right)^{\sigma^{-1}} \bigg/ \left( \frac{\Pi_k}{P_k} \right)^{\sigma^{-1}} \]

- But: With symmetric bilateral trade costs, \( P_j = \lambda \Pi_j \)
  - Anderson and van Wincoop (2003)
  - They go further and set \( \lambda = 1 \): “an implicit normalization”
  - a.k.a. a choice of numéraire
  - Not advisable if another numéraire has already been chosen!
    [Baldwin and Taglioni (2007)]

- So: All trade balances are zero!
Bilateral Trade Balances: Robustness

- In logs:
  \[ v_{jk} - v_{kj} = \rho_j - \rho_k \]

- This continues to hold with unbalanced trade:
  \[ \Rightarrow \rho_j = \log \left( \frac{\Pi_j}{P_j} \right)^{\sigma^{-1}} + \log \left( \frac{I_j}{E_j} \right) \]

- And with quasi-symmetric bilateral trade costs:
  \[ t_{jk} = t_j^X \bar{t}_{jk} t_k^M, \quad \bar{t}_{jk} = \bar{t}_{kj} \]

  - Allows for home bias and border effects: Head and Ries (2001)
  \[ \Rightarrow \rho_j = \log \left( \frac{\Pi_j}{P_j} \right)^{\sigma^{-1}} + \log \left( \frac{I_j}{E_j} \right) + \log \left( \frac{t_j^X}{t_j^M} \right)^{1-\sigma} \]

  - i.e., relative multilateral resistance, adjusted for both overall trade surplus and border effects
Bilateral Trade Balances: Recap

- So:

\[ v_{jk} - v_{kj} = \rho_j - \rho_k \]

- \( \frac{1}{2}n(n-1) \) terms, \( v_{jk} - v_{kj} \), determined by \( n \) relative multilateral resistance terms \( \rho_j \)

- Conclusion:

- With unbalanced trade and quasi-symmetric trade costs, the bilateral trade balances between any country \( j \) and all other countries are independent of \( j \), except for a factor of proportionality.
Implications

- Yet another elegant implication of CES?
- Or: Yet another implausible prediction of CES?!
- To test it:

\[
\log V_{jk} - \log V_{kj} = \sum_{h=1}^{n-1} \beta_h D_h(j, k), \quad D_h(j, k) = \begin{cases} 
1 & \text{when } h = j \\
-1 & \text{when } h = k \\
0 & \text{when } h \neq j, k
\end{cases}
\]

- Same $n = 182$ countries, 2017
- All $n \ D_h(j, k)$ are perfectly collinear, so drop $D_{US}$
- Total number of observations: $182 \cdot 181/2 = 16,471$
- Country pairs with any zero dropped, leaving 9,314

- Results:
  - $R^2 = 0.340$
  - Hypothesis $\{H_0 : \beta_h = 0\}$ is rejected at 5% for 70% of the $\beta_h$
  - But: A very poor fit for the trade balances in levels
Predicted versus Actual Trade Balances, 2017

Supplementary Ask “figure à la Davis and Weinstein”

Sample: 182 countries in 2017 (same than for BigAsk#2). Number of observations should be $182 \times \frac{1}{2} = 16,471$ but only 9,314 due to zeroes for some country pairs.

In log (predicted and actual $V_{\text{export}} - V_{\text{import}}$) – reference lines at zero

In relative levels (predicted and actual $V_{\text{export}} / V_{\text{import}}$) – reference lines at 1

To see something I had to drop outliers, i.e, the 5% highest values of actual $V_{\text{export}} / V_{\text{import}}$ ($>850$)
Outline

1. Gravity as Fact
2. Gravity as Theory
3. Gravity Anomalies
4. Subconvex Gravity
5. Conclusion
Assume additively separable demands:

\[ u'(x_{jk}) = \lambda_k p_{jk} \implies x_{jk} = f(\lambda_k p_j t_{jk}) \]

\[ \Rightarrow \hat{V}_{jk} = -(\sigma_{jk} - 1)\hat{p}_j - \sigma_{jk}\hat{\lambda}_k - (\sigma_{jk} - 1)\hat{t}_{jk} \]

Subconvexity: \( \sigma_{jk} \equiv \sigma(x_{jk}) \), decreasing in \( x_{jk} \)

To estimate this, we use quantile regression:

- Order data by \( V_{jk} \)
- Estimate for each quantile \( q \):
  \[ \log V_{q,jk} = F_{q,j} + F_{q,k} + \beta_q \log t_{jk} + u_{q,jk} \]
- Estimation and bootstrapped confidence intervals:
  - Baltagi and Egger (2016), Machado and Santos Silva (2019)
Quantile Regression: Estimated Distance Coefficient

![Graph showing the relationship between Quantiles and Distance Coefficient with a line graph.](image)
Quantile Regression Results: Compared to OLS
## Quantile Regression Results: Tests

Significance Tests for Differences Between Quantile and OLS Estimates of Distance Coefficient

<table>
<thead>
<tr>
<th></th>
<th>$\beta_{OLS}$</th>
<th>$\beta_{Q10}$</th>
<th>$\beta_{Q20}$</th>
<th>$\beta_{Q30}$</th>
<th>$\beta_{Q40}$</th>
<th>$\beta_{Q50}$</th>
<th>$\beta_{Q60}$</th>
<th>$\beta_{Q70}$</th>
<th>$\beta_{Q80}$</th>
<th>$\beta_{Q90}$</th>
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<tr>
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<td>*</td>
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</tr>
<tr>
<td>$\beta_{Q80}$</td>
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<tr>
<td>$\beta_{Q90}$</td>
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<td>*</td>
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<td>n.s.</td>
<td>n.s.</td>
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</tr>
</tbody>
</table>

* Significantly different at 5% level
n.s. Not significant
Robustness: Interactive Dummies

- Robustness check in the spirit of Novy (2013):
  - Quantile dummies for intercept and interacted with all OLS coefficients
  - Quantile dummies computed on the *predicted* value of trade
    - i.e., \( \log \hat{V}_{jk} = F_j + F_k + \hat{\beta} \log t_{jk} \)
    - Estimated distance coefficient is not the same as in the QR case as different fixed effects are used: \( F_j + F_k + F_q \) instead of \( F_j + F_k \)

\[
\log V_{jk} = F_j + F_k + F_q + \beta_q F_q \log t_{jk} + u_{jk}
\]
Persuasive Evidence for Subconvexity
- Distance coefficient significantly decreasing (in absolute value) in trade
- Replication needed ...
- Chernozhukov, Fernandez-Val, and Weidner (2018) find the opposite with 1986 data

Implications for the Trade Balances Puzzle?
- Bilateral balances now depend on distance
- Provisional evidence confirming this

Implications for Brexit?
- With subconvexity, elasticities are higher in smaller markets
- Implications for estimated effects of Brexit unlikely to be major
Conclusion

- Gravity as Fact
  - Overwhelming evidence that trade tends to fall with distance

- Gravity as Theory
  - A simple general equilibrium system
  - New analytic tools for understanding it

- Gravity Anomalies
  - Constant Elasticity of Trade not the whole story

- Subconvex gravity a promising direction
  - Unlikely to change the Three Iron Laws of the Economics of Brexit
Thanks and Acknowledgements*

Thank you for listening. Comments welcome!

* Some of the research on which this lecture draws received funding from the European Research Council under the European Union’s Seventh Framework Programme (FP7/2007-2013), ERC grant agreement no. 295669.
Equilibrium in market for \( Y_B \):

\[
\hat{X}_B = \varepsilon_{BB}\hat{p}_B + \varepsilon_{BE}\hat{p}_E + \varepsilon_{BtE}\hat{t}_{BE} + \varepsilon_{BtA}\hat{t}_{BA} = 0
\]

where the elasticities of excess demand for \( Y_B \) are:

\[
\begin{align*}
\varepsilon_{BB} & : -(\sigma - 1)\lambda_{BB}(1 - \theta_{BB}) - \lambda_{BE}\{\sigma(1 - \theta_{BE}) + \theta_{BE}\} - \lambda_{BA}\{\sigma(1 - \theta_{BA}) + \theta_{BA}\} \\
\varepsilon_{BE} & : (\sigma - 1)\lambda_{BB}\theta_{EB} + \lambda_{BE}\{\sigma - 1}\theta_{EE} + 1\} + (\sigma - 1)\lambda_{BA}\theta_{EA} \\
\varepsilon_{BtE} & : -(\sigma - 1)\{\lambda_{BE}(1 - \theta_{BE}) - \lambda_{BB}\theta_{EB}\} \\
\varepsilon_{BtA} & : -(\sigma - 1)\{\lambda_{BA}(1 - \theta_{BA}) - \lambda_{BB}\theta_{AB}\}
\end{align*}
\]

Similarly in the market for \( Y_E \):

\[
\hat{X}_E = \varepsilon_{EB}\hat{p}_B + \varepsilon_{EE}\hat{p}_E + \varepsilon_{EtE}\hat{t}_{BE} = 0
\]

\[
\begin{align*}
\varepsilon_{EB} & : (\sigma - 1)\lambda_{BB}\theta_{EB} + \lambda_{BE}\{\sigma - 1}\theta_{EE} + 1\} + (\sigma - 1)\lambda_{BA}\theta_{EA} \\
\varepsilon_{EE} & : -(\sigma - 1)\lambda_{BB}(1 - \theta_{BB}) - \lambda_{BE}\{\sigma(1 - \theta_{BE}) + \theta_{BE}\} - \lambda_{BA}\{\sigma(1 - \theta_{BA}) + \theta_{BA}\} \\
\varepsilon_{EtE} & : -(\sigma - 1)\{\lambda_{BE}(1 - \theta_{BE}) - \lambda_{BB}\theta_{EB}\} \\
\varepsilon_{EtA} & : 0
\end{align*}
\]
Markups and pass-through in general:

\[
\frac{p - c}{c} = \frac{1}{\epsilon - 1} \quad \text{and} \quad \frac{d \log p}{d \log c} = \frac{\epsilon - 1}{\epsilon} \frac{1}{2 - \rho}
\]

CES demands imply constant markups and 100% pass-through:

\[
\frac{p - c}{c} = \frac{1}{\sigma - 1} \quad \text{and} \quad \frac{d \log p}{d \log c} = 1
\]

But: Mounting empirical evidence to the contrary

Mark-ups differ a lot across firms, even in narrowly-defined industries.
Higher markups. The results indicate that firms offset the beneficial cost reductions from improved access to imported inputs by raising markups. The overall effect, taking into account the average declines in input and output tariffs between 1989 and 1997, is that markups, on average, increased by 12.6 percent. This increase offsets almost half of the average decline in marginal costs, and as a result, the overall effect of the trade reform on prices is moderated.52

Although tempting, it is misleading to draw conclusions about the pro-competitive effects of the trade reform from the markup regressions in Column 3 of Table IX. The reason is that one needs to control for the impacts of

52These results are robust to controlling India's de-licensing policy reform; see Table A.I in the
Supplemental Material.

From: de Loecker, Goldberg, Khandelwal and Pavcnik (2016)
Empirical Evidence on Markups II

Markups for Bread, Wine and Jeans

From: Lamorgese, Linarello and Warzynski (2014)
CES-based models predict the same elasticity of import demand in all markets.

- Macro elasticity, not micro elasticity facing firms

By contrast, Novy (2013) finds that elasticities are systematically lower in larger and closer markets.
An Implication of Constant-Trade-Elasticity Gravity

- Inferring trade costs from trade volumes:
  [Head and Ries (2001), Jacks, Meissner, and Novy (2008)]

- Multiply bilateral trades and divide by domestic trades:
  $$\frac{V_{jk}V_{kj}}{V_{jj}V_{kk}} = \left(\frac{t_{jk}t_{kj}}{t_{jj}t_{kk}}\right)^{1-\sigma}$$

- Invert to solve for trade costs in terms of observables:
  $$\left(\frac{t_{jk}t_{kj}}{t_{jj}t_{kk}}\right)^{\frac{1}{2}} = \left(\frac{V_{jk}V_{kj}}{V_{jj}V_{kk}}\right)^{\frac{1}{2(1-\sigma)}}$$

- Even simpler with symmetric bilateral and zero internal trade costs:
  $$t_{jk} = \left(\frac{V_{jk}V_{kj}}{V_{jj}V_{kk}}\right)^{\frac{1}{2(1-\sigma)}}$$


References


References VII


