Quantifying the Impact of (Trade) Sanctions

Yoto Yotov

Selected presentation for the International Agricultural Trade Research Consortium's (IATRC's) 2023 Annual Meeting: The Future of (Ag-) Trade and Trade Governance in Times of Economic Sanctions and Declining Multilateralism, December 10-12, 2023, Clearwater Beach, FL.

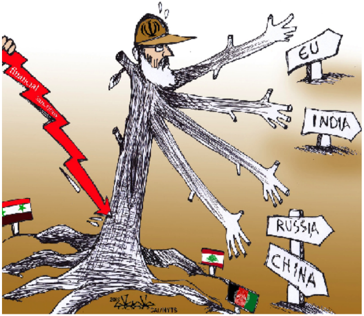
Quantifying the Impact of (Trade) Sanctions

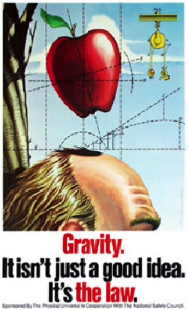
IATRC Annual Conference

Yoto V. Yotov

December 10, 2023

Quantifying the Impact of (Trade) Sanctions with New Quantitative Trade Models





IATRC Annual Conference

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Happy Birthday, Mom!!

Sanctions are important and popular

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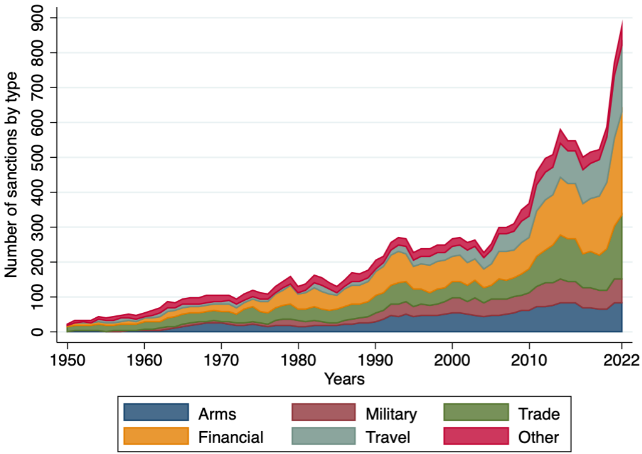
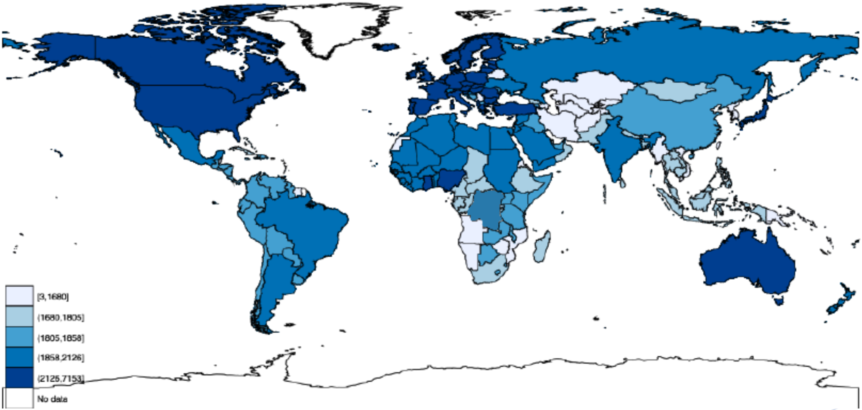
- **Findings are robust to searches at Yahoo and Bing.**

Sanctions are more popular than ever!



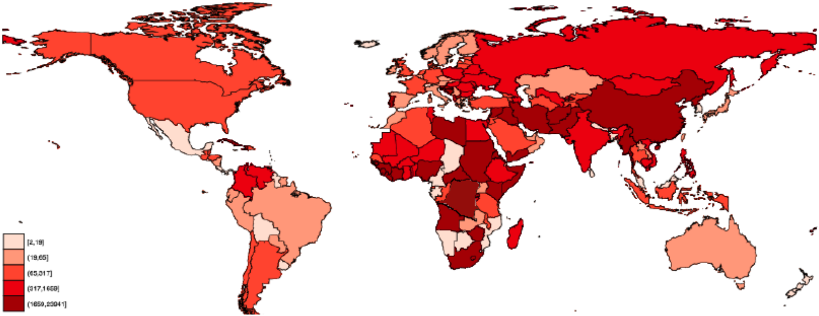
Source: The Global Sanctions Database - Revision 3 (GSDB-R3), Syropoulos et al. (2022).

Cumulative Sanctions: By Sender



Source: The Global Sanctions Database - Revision 3 (GSDB-R3), Author's calculation.

Cumulative Sanctions: By Target



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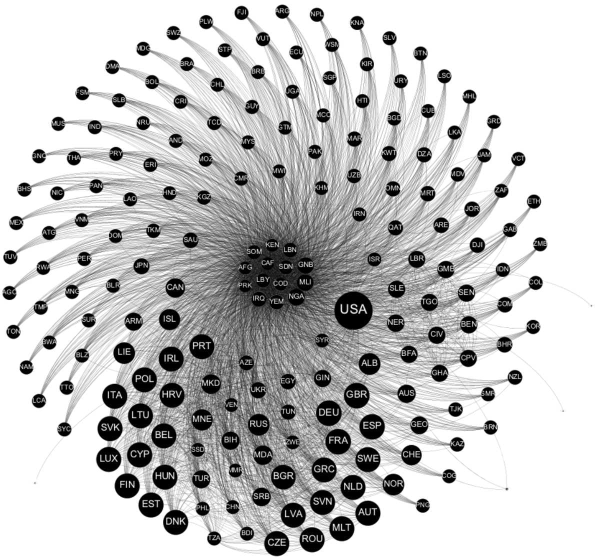
‘The Black Hole’ of Sanctions



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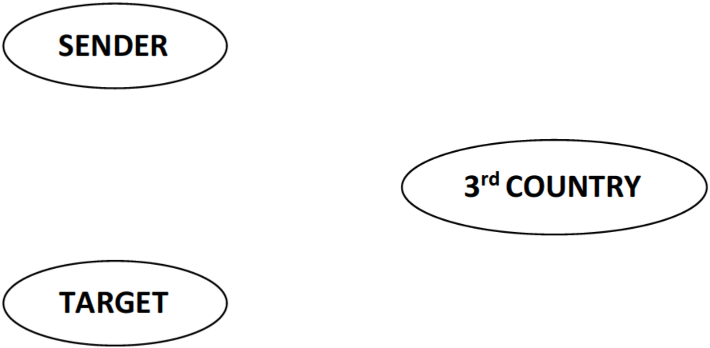
On the Effects of Trade Sanctions



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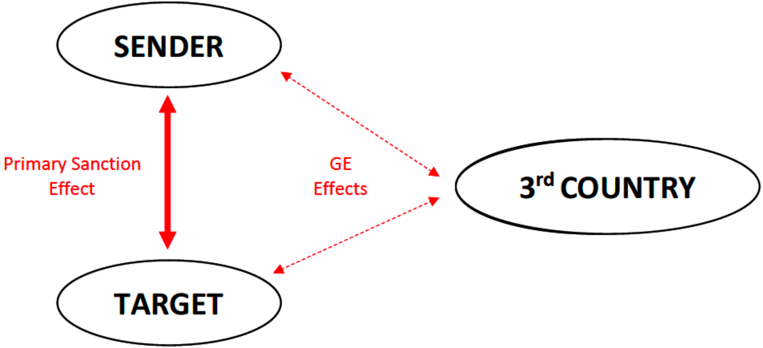

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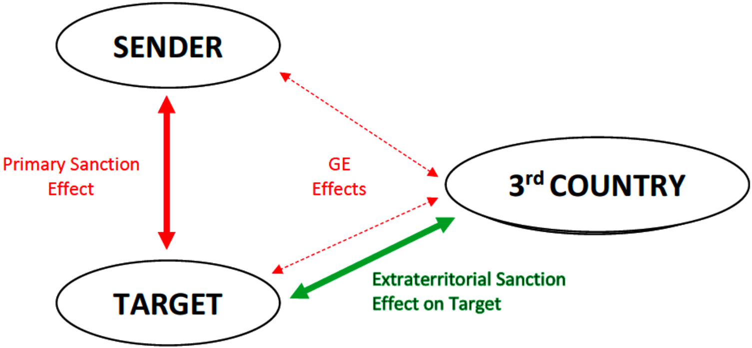

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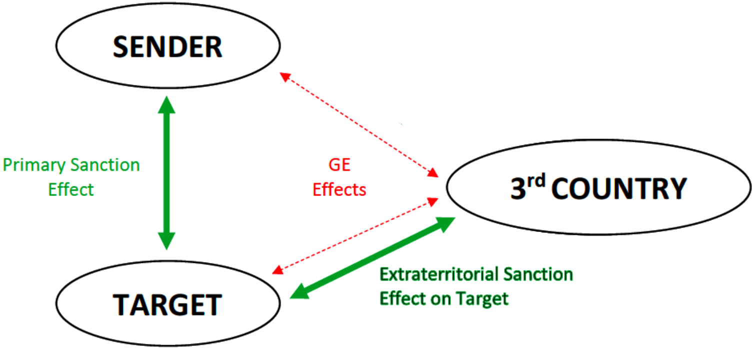

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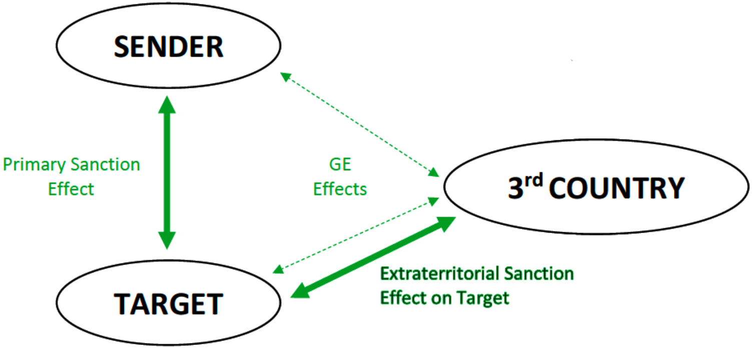
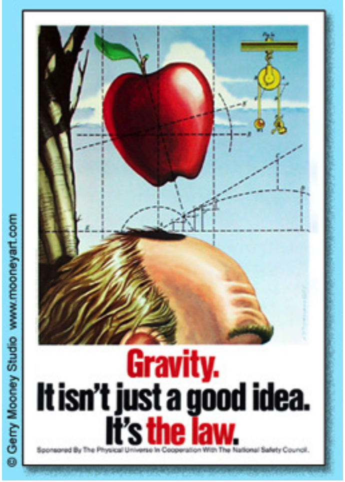
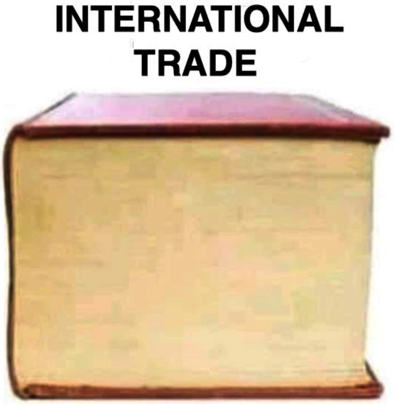


With the Structural Gravity Model



The Gravity equation is often regarded to as the most popular and the most successful framework in (international) economics.

A Literature Review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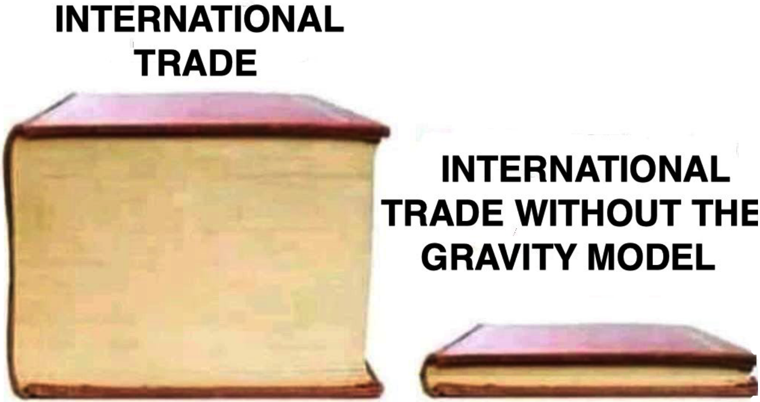
INTERNATIONAL
TRADE
INTERNATIONAL
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A Celebrity

FINANCIAL TIMES

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Merkel's comic error — Europe must fight for freedom of speech — GIDEON RACHMAN, PAGE 13

Problem child — Counting the global cost of El Niño — BIG READ, PAGE 11

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Three Treasury scenarios
Changes in UK GDP by 2030

WTO membership only: -9.5%

Negotiated bilateral agreement (like Canada): -6.2%

Membership of EEA (like Norway): -3.8%

...and the key equation

The Treasury's formula for calculating trade values between countries

$$\ln(T_{ijt}) = \alpha_{ij} + \gamma_t + \alpha_1 \ln(Y_{it} * Y_{jt}) + \alpha_2 \ln(POP_{it} * POP_{jt}) + \alpha_3 \ln(DIST_{ij}) + \alpha_4 COMLANG_{ij} + \alpha_5 COLONY_{ij} + \alpha_6 BORDER_{ij} + \varepsilon_{ijt}$$

Briefing

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Big UK companies are breaking with global peers and hiring more chiefs from outside than ever. Last year, 58 per cent came from another group, versus 25 per cent globally.— PAGE 17; LOMBARD, PAGE 22

Britons own 11% of world's superyachts
A survey has revealed that after a rise in demand in recent years, more than one in 10 superyachts are owned by Britons, the second-largest fleet in the world. The US accounts for 33 per cent.— PAGE 4

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Datawatch

Counterfeit and pirated goods
% of seized goods' value, 2011-2013

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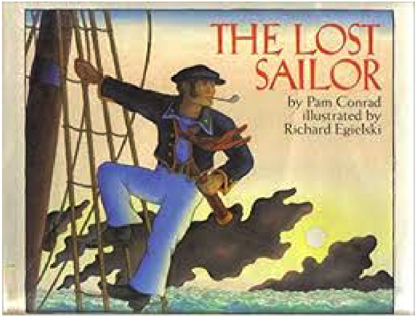


"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast."

Leonardo da Vinci

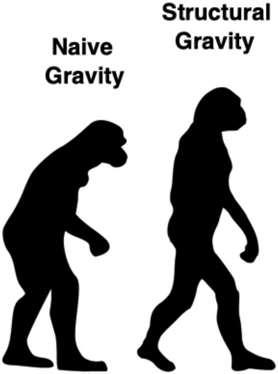
Objectives and Outline

With a focus on the effects of sanctions:

- Review the evolution of the gravity model and highlight many of its great features;
- Demonstrate the benefits of doing theory-consistent empirical and policy work;
- Discuss cutting-edge research, challenges, limitations, and directions for future work.

Outline: The Evolution of Gravity

Naive Gravity


Naive
Gravity
Structural
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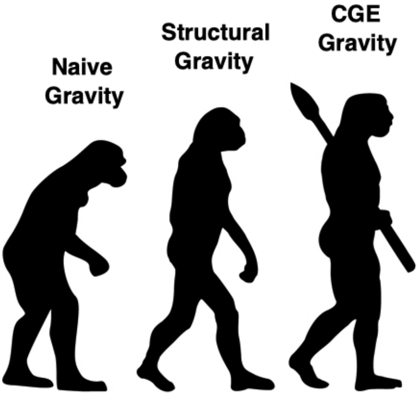
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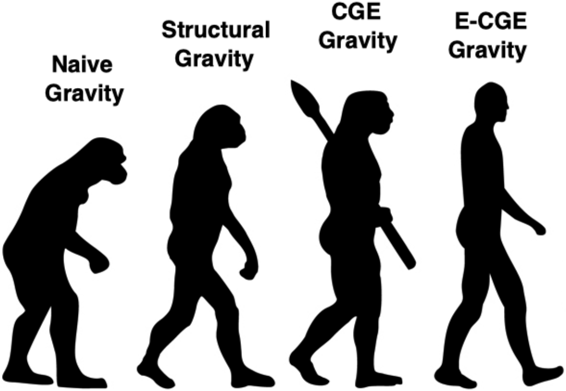
Outline: The Evolution of Gravity



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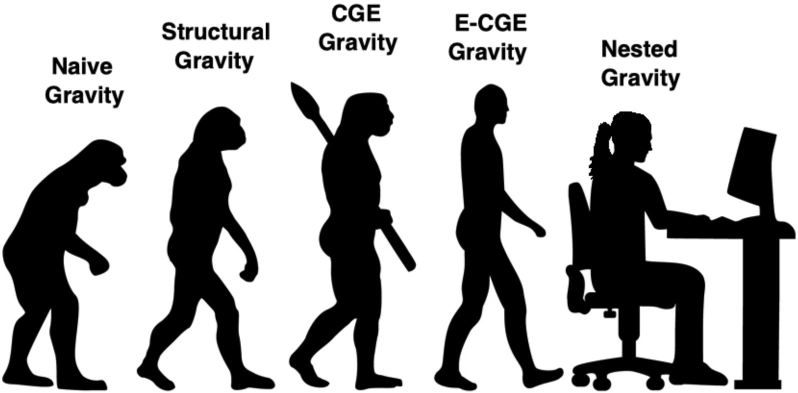
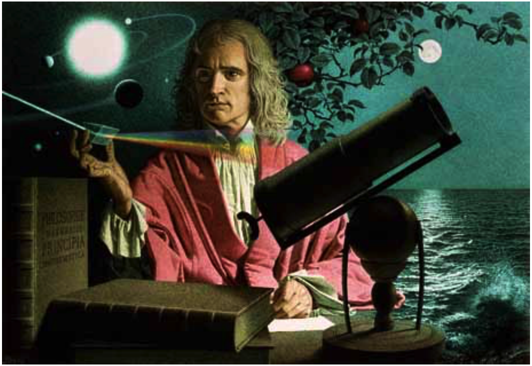


I. Naive Gravity: Why So Popular?



Turns out that Sir Newton's Law of Universal Gravitation,

$$F_{ij} = G\frac{M_i M_j}{D_{ij}^2},$$

applies 'equally' well to trade:

$$X_{ij} = \tilde{G}\frac{Y_i Y_j}{T_{ij}^{\theta}}.$$

- Trade (the gravitational force) between two countries (objects) is directly proportional to the product of their sizes (masses) and inversely proportional to the trade frictions (the square of distance) between them.

The gravity equation of trade consistently delivers a remarkable fit!

2. Unprecedented Predictive Power

The gravity equation of trade consistently delivers a remarkable fit!

Most studies offer estimates that demonstrate that gravity works with aggregate data.

Anderson and Yotov (2010) offer sectoral gravity estimates for trade of manufactured goods.

Anderson et al. (2015) demonstrate that gravity works very well with services sectoral data.

Borchert et al. (2020) estimate gravity for 170 sectors in agriculture, mining, manufacturing goods, and services.

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NOTE: Gravity delivers the same (!) great fit with and without fixed effects. Thus, the predictive power of the gravity model is unprecedented!

3. Very Flexible

Thousands of papers have used the gravity model to study the effects of various determinants of bilateral trade flows, including:

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- **More Exotic Determinants of Trade Flows:** Institutional Quality, Foreign Aid, Trust, Reputation for People, Covid, Export Promotion, Taxes, Mega Sporting Events (Olympic Games and World Cup), Embargoes and **Economic Sanctions**, Conflict and Wars, Piracy, Ice Cap Melting ...

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To study the impact of any determinant/policy on trade flows or via trade flows, one should probably rely on a 'Gravity Model'.

People like Gravity because

- It is very intuitive;
- It has great predictive power;
- It is very flexible.

A Naive Estimating Equation

A Naive Estimating Equation

... But ...

"The gravity model is NOT a structural model of trade ... The gravity equation is precisely what it is – an equation – but there's not much theory there."

Source: Referee Report, 2016

REVIEWER 2

Solid Theoretical Foundations

Many Theoretical Foundations

II. The Rise of Structural Gravity

(a.k.a. The New Quantitative Trade Models)

All Roads Lead to ...

Source: Yotov et al. (2016). Inspired by Arkolakis et al. (2012)

ARMINGTON-CES

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SECTORAL EK INTERMEDIATES

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HETEROGENEOUS FIRMS

RICARDIAN

Source: Yotov et al. (2016). Inspired by Arkolakis et al. (2012)

All Roads Lead to ...

ARMINGTON-CES

HECKSCHER-OHLIN

SECTORAL ARMINGTON-CES

MONOPOLISTIC COMPETITION

SECTORAL EK INTERMEDIATES

SECTORAL RICARDIAN

HETEROGENEOUS FIRMS

RICARDIAN

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All Roads Lead to ...

ARMINGTON-CES

DYNAMIC GRAVITY

HECKSCHER-OHLIN

SECTORAL ARMINGTON-CES

MONOPOLISTIC COMPETITION

SECTORAL EK INTERMEDIATES

SECTORAL RICARDIAN

HETEROGENEOUS FIRMS

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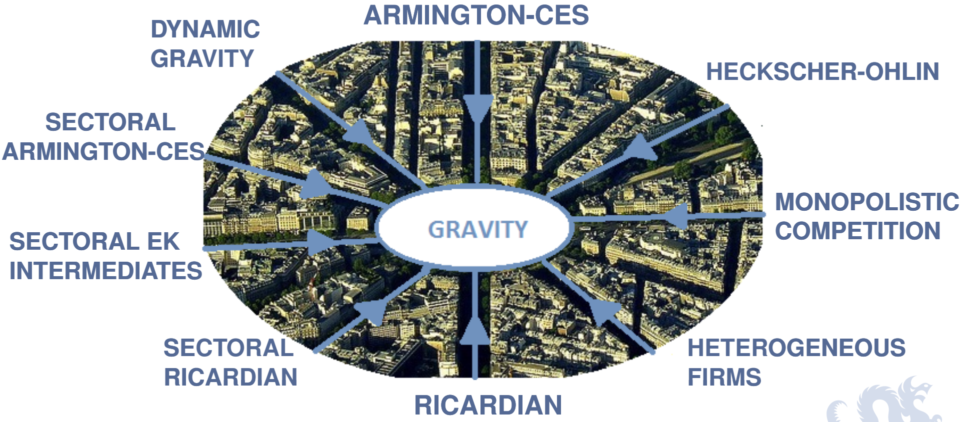
All Roads Lead to ...



Source: Yotov et al. (2016). Inspired by Arkolakis et al. (2012)

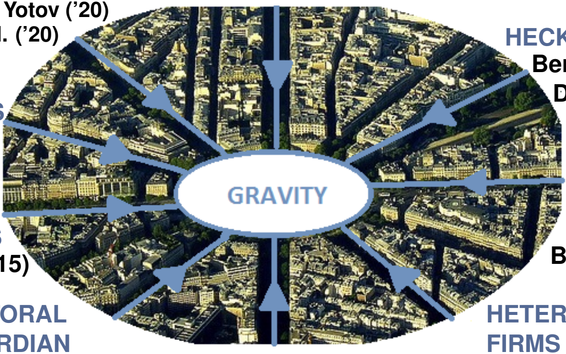
Contributions to Gravity Modeling

ARMINGTON-CES
Anderson ('79)
Bergstrand ('85)
Anderson-van Wincoop ('03)

DYNAMIC GRAVITY
Olivero and Yotov ('12)
Eaton et al. ('16)
Anderson and Yotov ('20)
Anderson et al. ('20)

HECKSCHER-OHLIN
Bergstrand ('85)
Deardorff ('98)

SECTORAL ARMINGTON-CES
Anderson and van Wincoop ('04)



MONOPOLISTIC COMPETITION
Krugman('80)
Bergstrand ('89)

SECTORAL EK INTERMEDIATES
Caliendo-Parro ('15)

SECTORAL RICARDIAN
Costinot et al. ('10)
Chor ('10)

RICARDIAN
Eaton-Kortum ('02)

HETEROGENEOUS FIRMS
Helpman et al. ('08)
Chaney ('08)
Redding ('14)
Egger et al. ('21)

Source: Yotov et al. (2016). Inspired by Arkolakis et al. (2012)

The Structural Gravity System

$$X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}$$

$$Y_i = \sum_j X_{ij}$$

The Structural Gravity Equation: $X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma}$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$$

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The Structural Gravity Equation: $X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma}$

Inward Multilateral Resistance: $P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$

Outward Multilateral Resistance: $\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}$

$$Y_i = \sum_j X_{ij}$$

The Structural Gravity Equation: $X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i}\right)^{1-\sigma}$

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Outward Multilateral Resistance: $\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y}$

The Market Clearing Condition: $Y_i = \sum_j X_{ij}$

Demand-side Gravity

$$X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}$$

$$Y_i = \sum_j X_{ij}$$

σ is the elasticity of substitution

Following: Anderson (1979) and Anderson and van Wincoop (2003)

$$X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{-\theta}$$

$$P_j^{-\theta} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{-\theta} \frac{Y_i}{Y}$$

$$\Pi_i^{-\theta} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{-\theta} \frac{E_j}{Y}$$

$$Y_i = \sum_j X_{ij}$$

θ is a Fréchet dispersion parameter

Following: Eaton and Kortum (2002)

Structural Gravity with Tariffs

$$X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma} \tau_{ij}^{-\sigma}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{\tau_{ij} t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$$

$$\Pi_i^{1-\sigma} = \sum_j \tau_{ij}^{-\sigma} \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}$$

$$Y_i = \sum_j X_{ij}$$

τ_{ij} is the *ad-valorem* tariff

Following: Larch and Yotov (2015)

Sectoral Gravity

$$X_{ij}^{k} = \frac{E_j^k Y_i^k}{Y^k} \left(\frac{t_{ij}^k}{P_j^k \Pi_i^k} \right)^{1-\sigma^k}$$

$${P_j^k}^{1-\sigma^k} = \sum_i \left(\frac{t_{ij}^k}{\Pi_i^k} \right)^{1-\sigma^k} \frac{Y_i^k}{Y^k}$$

$${\Pi_i^k}^{1-\sigma^k} = \sum_j \left(\frac{t_{ij}^k}{P_j^k} \right)^{1-\sigma^k} \frac{E_j^k}{Y^k}$$

$$Y_i^k = \sum_j X_{ij}^k$$

k denotes sector, industry, product, etc.

Following: Anderson and van Wincoop (2004) and Costinot et al. (2012)

Sectoral Gravity with Heterogeneous Firms

$$X_{ij}^k = \frac{E_j^k Y_i^k}{Y^k} \left(\frac{\tau_{ij}^k}{P_j^k \Pi_i^k} \right)^{-\gamma^k}$$

$$P_j^{k^{-\gamma^k}} = \sum_i \left(\frac{\tau_{ij}^k}{\Pi_i^k} \right)^{-\gamma^k} \frac{Y_i^k}{Y^k}$$

$$\Pi_i^{k^{-\gamma^k}} = \sum_j \left(\frac{\tau_{ij}^k}{P_j^k} \right)^{-\gamma^k} \frac{E_j^k}{Y^k}$$

$$Y_i^k = \sum_j X_{ij}^k$$

γ^k is Pareto dispersion parameter

τ_{ij}^k includes fixed costs f_{ij}^k

Following: Melitz (2003), Chaney (2008), Redding (2014), Egger et al., (2020)

$$X_{ij,t} = \frac{E_{j,t} Y_{i,t}}{Y_{,t}} \left(\frac{t_{ij,t}}{P_{j,t} \Pi_{i,t}} \right)^{1-\sigma}$$

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}} \right)^{1-\sigma} \frac{Y_{i,t}}{Y_t}$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{E_{j,t}}{Y_t}$$

$$Y_{i,t} = \sum_j X_{ij,t}$$

t denotes time

Following: Eaton et al. (2016) and Anderson et al. (2020)

Dynamic Gravity: Bilateral Dynamics

$$X_{ij,t} = \frac{E_{j,t} Y_{i,t}}{Y_{,t}} \left(\frac{\tau_{ij,t}}{P_{j,t} \Pi_{i,t}} \right)^{\rho(1-\sigma)}$$

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{\tau_{ij,t}}{\Pi_{i,t}} \right)^{\rho(1-\sigma)} \frac{Y_{i,t}}{Y_t}$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{\tau_{ij,t}}{P_{j,t}} \right)^{\rho(1-\sigma)} \frac{E_{j,t}}{Y_t}$$

$$Y_{i,t} = \sum_j X_{ij,t}$$

ρ is an incidence elasticity parameter

$\tau_{ij,t}$ includes dynamic trade cost components

Following: Anderson and Yotov (2020)

The Structural Gravity Equation: $X_{ij} = \frac{E_j Y_i}{Y} \left(\frac{t_{ij}}{P_j \Pi_i} \right)^{1-\sigma}$

Inward Multilateral Resistance: $P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y}$

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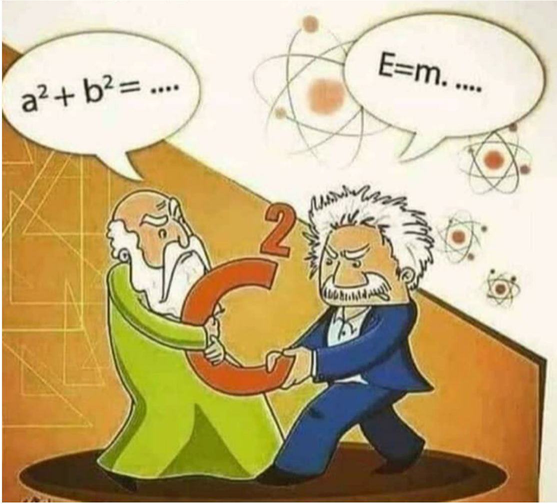
Trade Wars ... Academic Style



$a^2 + b^2 = ...$
E=m. ....
2
C

Estimating Gravity ... with Gravitas

$$X_{ij,t}^k = \left(\frac{t_{ij,t}^k}{\Pi_{i,t}^k P_{j,t}^k}\right)^{1-\sigma^k} \frac{Y_{i,t}^k \psi_{j,t}^k Y_{j,t}^k}{Y_t^k}$$

THE GRAVITY POLICE

Estimating Gravity, Larch and Yotov (2023)

$$X^k_{ij,t} = \left(\frac{t^k_{ij,t}}{\Pi^k_{i,t} P^k_{j,t}}\right)^{1-\sigma^k} \frac{Y^k_{i,t}\psi^k_{j,t}Y^k_{j,t}}{Y^k_t}$$

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THE GRAVITY POLICE

PPML Gravity Estimates of Trade Sanctions

	International	Domestic	Extraterritorial
Primary Effect	-0.429	-0.525	-0.728
	(0.091) **	(0.094) **	(0.114) **
Extraterritorial Effect			-0.231
			(0.044) **
Exporter-time FEs	Yes	Yes	Yes
Importer-time FEs	Yes	Yes	Yes
Country-pair FEs	Yes	Yes	Yes
Policy controls	Yes	Yes	Yes
N	99,321	102,121	102,121

Source: Author's calculations.

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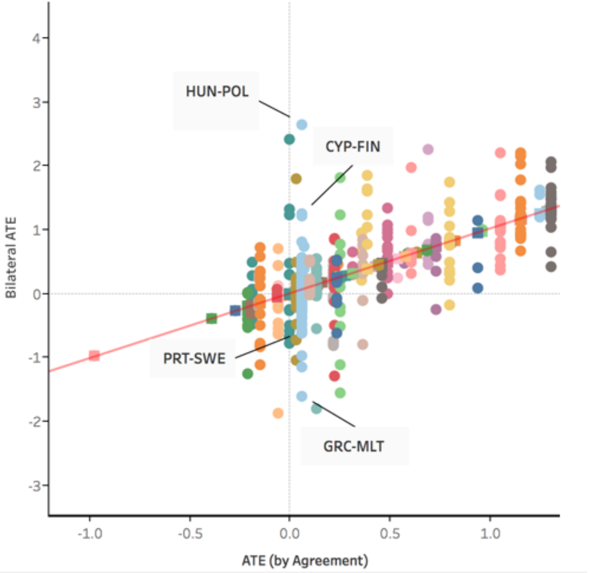
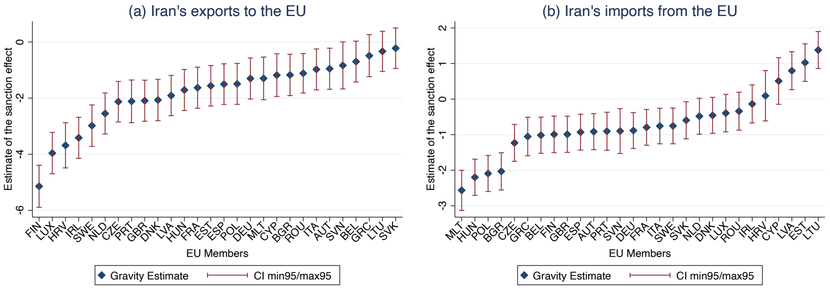
THE GRAVITY POLICE

Agreement-Pair FTA Estimates

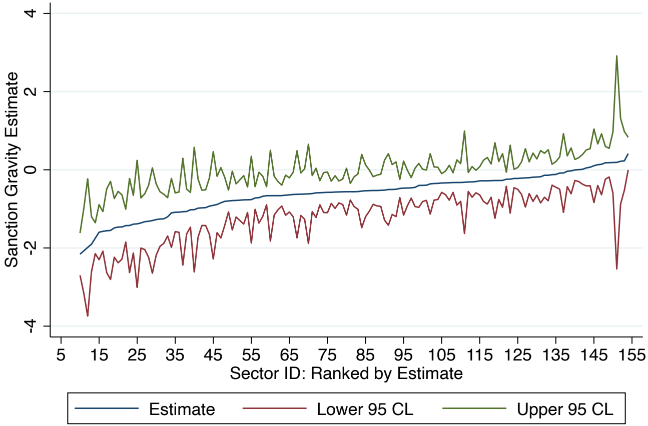


Source: Baier et al. (2019).

Impact of the EU Sanctions on Iran

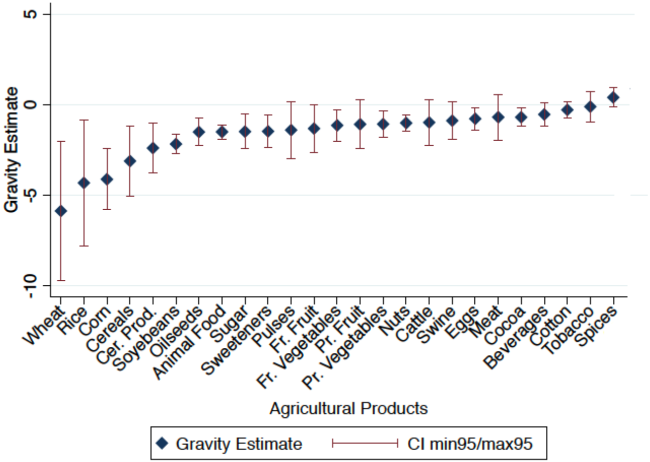


Source: Author's estimations,, following Felbermayr et al. (2023).



Source: Author's estimations,, following Felbermayr et al. (2023).

Sanction Effects: Agriculture



Source: Author's estimations„ following Luckstead et al. (2022).

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THE GRAVITY POLICE

$$X_{ij,t}^k = \left(\frac{t_{ij,t}^k}{\Pi_{i,t}^k P_{j,t}^k} \right)^{1-\sigma^k} \frac{Y_{i,t}^k \psi_{j,t}^k Y_{j,t}^k}{Y_t^k}$$

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THE GRAVITY POLICE

Estimating Gravity, Larch and Yotov (2023)

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THE GRAVITY POLICE

Estimating Gravity with Gravitas

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- $\pi_{\mathbf{i},\mathbf{t}}$ and $\chi_{j,t}$ are exporter-time and importer-time fixed effects, controlling for size and MRs (perfectly so with PPML).

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Estimating Gravity with Gravitas

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Estimating Gravity with Gravitas

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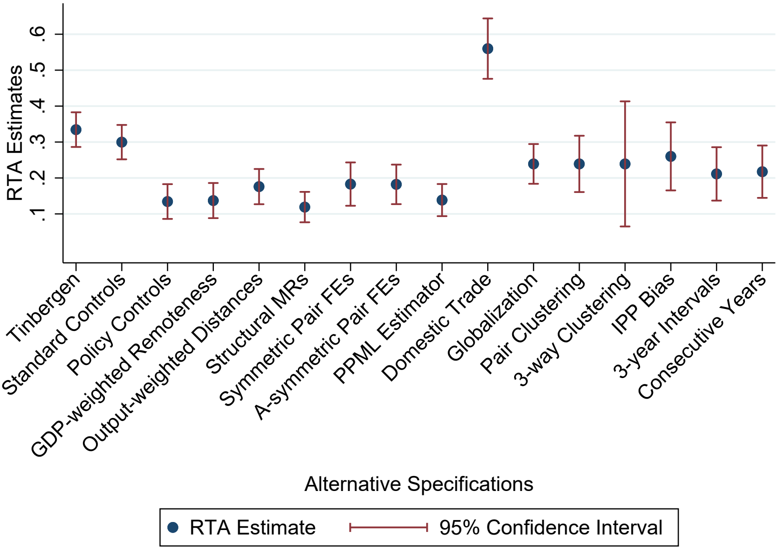
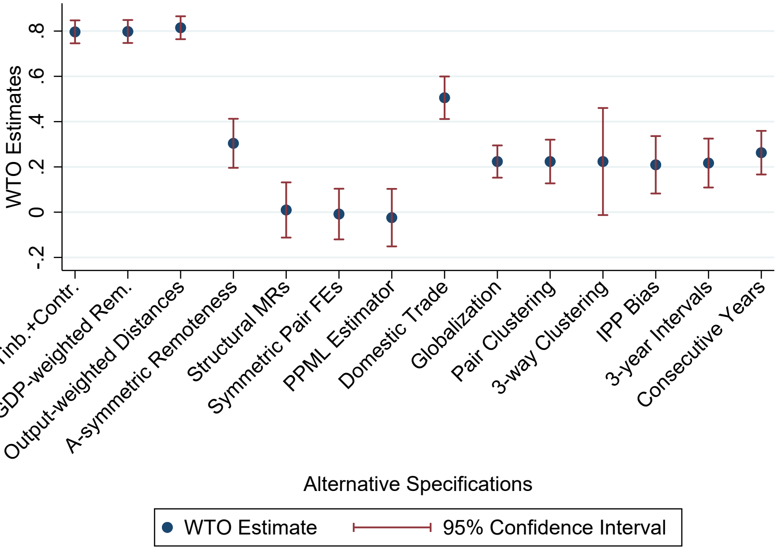
- $\mathbf{EXR_{ij,t}}$ is the exchange rate between *i* and *j* at *t*.

Evolution of RTA Gravity Estimates



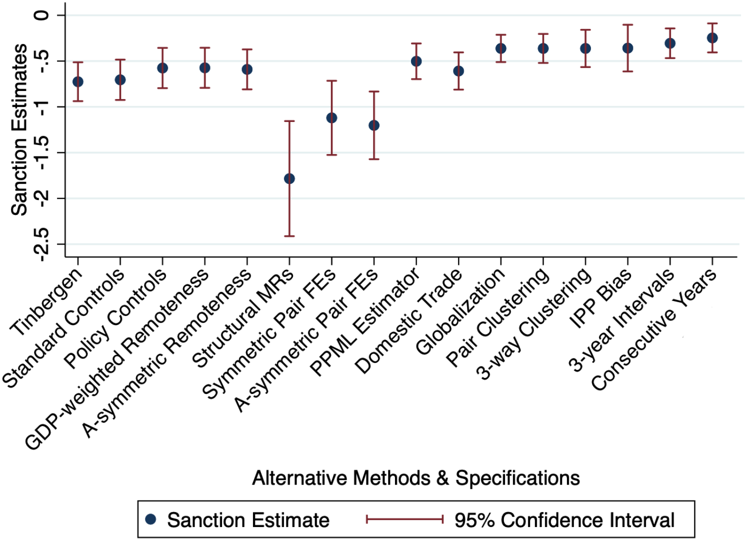
Source: Larch and Yotov (2022).

Evolution of WTO Gravity Estimates



Source: Larch and Yotov (2022).

Evolution of the Estimates of Sanctions



Source: Author's estimates.

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THE GRAVITY POLICE

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THE GRAVITY POLICE

Generalized PPML: Kwon et al. (2023)

- **Motivation:** The workhorse gravity estimator, PPML, assumes that:

$$\text{Var}(y|x) = h \cdot \mathbb{E}(y|x)^{\lambda}, \qquad \lambda = 1$$

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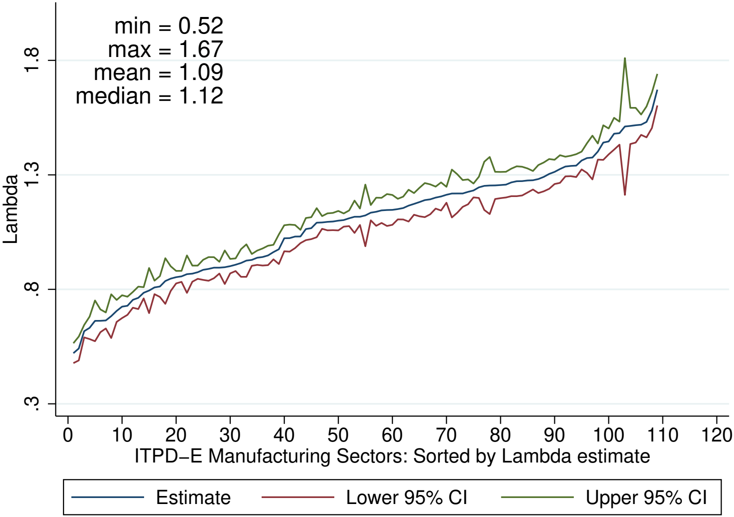
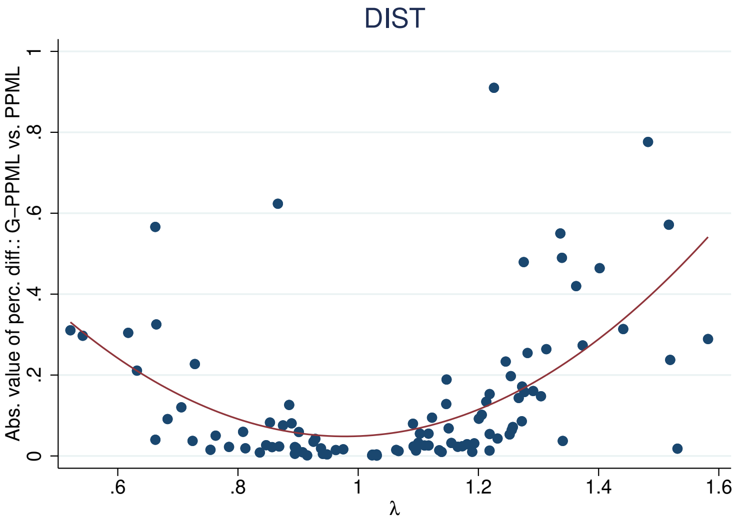
- **Contribution:** Estimate λ by the iterated GMM of Hansen and Lee (2021), and use it to implement a more efficient Generalized PPML (G-PPML), which inherits the nice properties of PPML.

λ Estimates and Confidence Intervals (ITPD-E-R2)



Source: Kwon et al. (2023).

Percentage Differences: PPML vs G-PPML



Source: Kwon et al. (2023).

Estimating Gravity, Larch and Yotov (2023)

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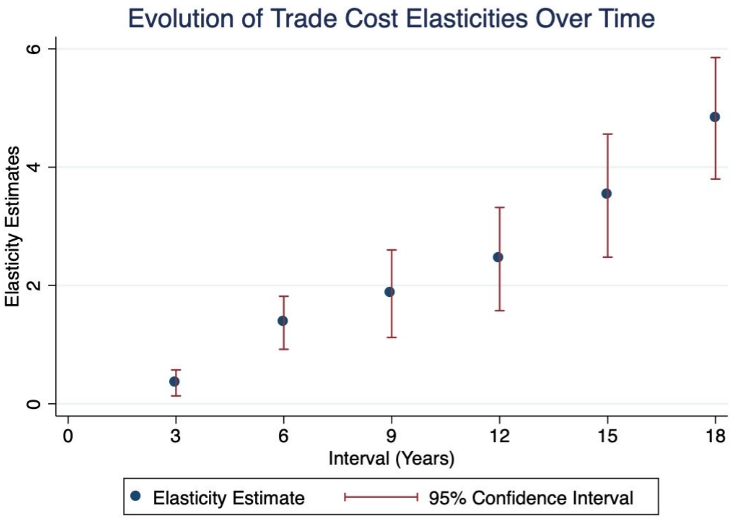
THE GRAVITY POLICE

Contribution: A theory and a simple econometric implementation to estimate gravity from the short to the long run:

$$X_{ij,t} = \exp[\beta_{1,\Delta t} FTA_{ij,t} + \beta_{2,\Delta t} LN\_TARIFF_{ij,t} + \pi_{i,t} + \chi_{j,t} + \gamma_{ij,\Delta t}] + \epsilon_{ij,t},$$

where:

- $\beta_{2\Delta t}$ captures the evolution of the trade elasticity
- $\beta_{1,\Delta t} = \beta_{2,\Delta t}\beta_{FTA}$ captures the evolution of the effects of FTAs.
- $\gamma_{ij,\Delta t}$ is a set of interval-country-pair fixed effects.

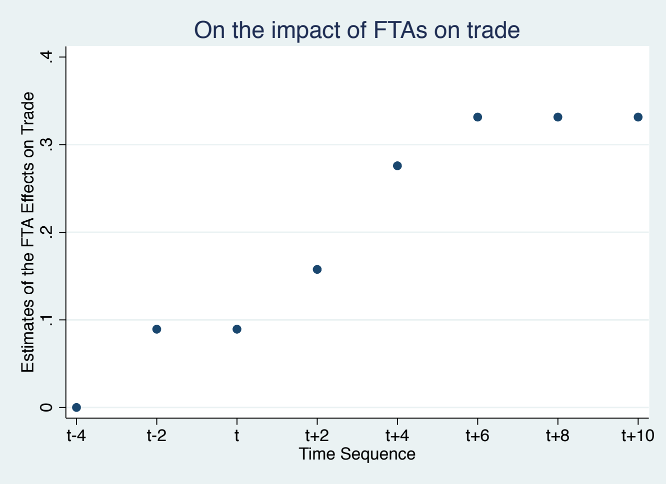


Source: Anderson and Yotov (2023).

Implications

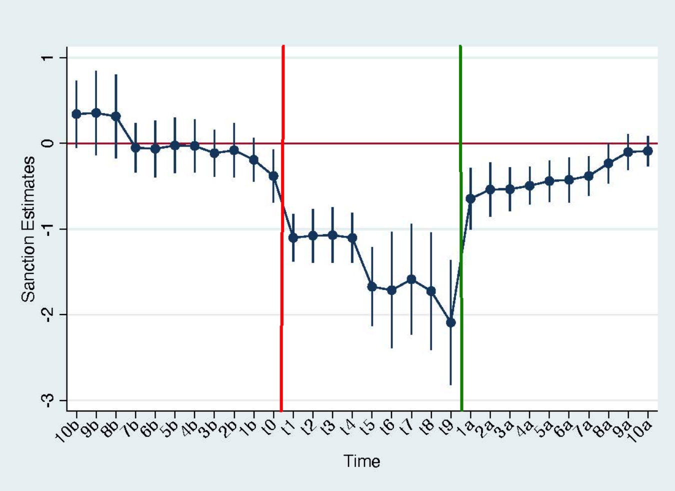
- A simple solution to the ‘International Elasticity Puzzle’.
- An explanation for tariff estimates that are smaller than one.
- How long is the ‘Long Run’ (in trade)? 16-17 years.
- Comparing trade elasticities should depend on time span.
- Time-varying/transitional general equilibrium analysis.
- An explanation for the evolution of the impact of FTAs.

Evolution of the FTA Effects



Source: Egger et al. (2022).

Evolution of the Sanction Effects



Source: Dai et al. (2021).

$$X_{ij,t}^{k} = \left(\frac{t_{ij,t}^{k}}{\Pi_{i,t}^{k} P_{j,t}^{k}} \right)^{1-\sigma^{k}} \frac{Y_{i,t}^{k} \psi_{j,t}^{k} Y_{j,t}^{k}}{Y_{t}^{k}}$$

- ***1. Use Panel Data (Borchert et al., 2021).***
- ***2. Use Directional Time-varying Fixed Effects (Hummels, 1999).***
- ***3. Employ Pair Fixed Effects (Baier and Bergstrand, 2007).***
- ***4. Include Domestic Trade Flows (Yotov, 2021).***
- ***5. Use Consecutive-year Data (Egger et al., 2022).***
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- ***10. Correct for IP Bias (Weidner and Zylkin, 2021).***
- ***11. Allow for general conditional variance (Kwon et al., 2023).***
- ***12. Allow for Adjustment in Trade Costs (Anderson & Yotov, 2023).***
- ***13. Gravity with Staggered DiD (Nagengast and Yotov, 2023).***

THE GRAVITY POLICE

Estimating Gravity, Larch and Yotov (2023)

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THE GRAVITY POLICE

Contribution: Adapt and nest the new (heterogeneity-robust) staggered difference-in-differences methods within an empirical panel gravity model.

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Benchmark gravity equation:

$$X_{ij,t} = \exp\left[\delta_{\text{TWFE}} RTA_{ij,t} + \pi_{i,t} + \chi_{j,t} + \mu_{ij} + \sum_t b_t BRDR_{ij,t}\right] \times \epsilon_{ij,t}.$$

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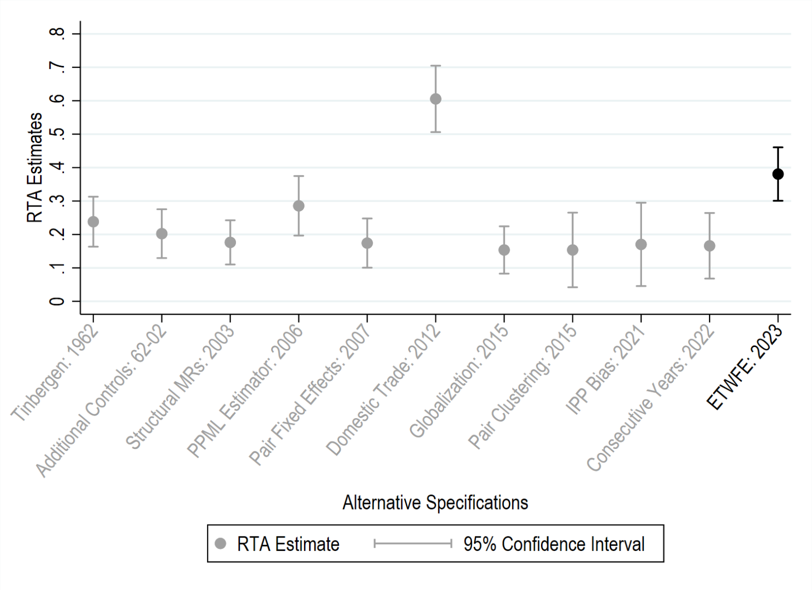
Staggered DiD specification:

$$Y_{ij,t} = \exp\left[\sum_{g=q}^{T}\sum_{s=g}^{T} \delta_{gs} D_{gs} + \pi_{i,t} + \chi_{j,t} + \mu_{ij} + \sum_t b_t BRDR_{ij,t}\right] \times \epsilon_{ij,t}.$$

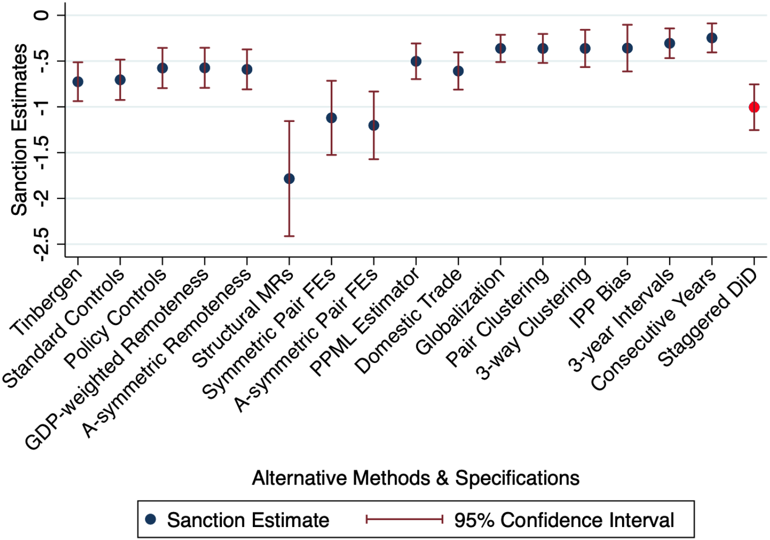
where:

- country-pair ij belongs to treatment cohort g if the RTA onset was in year g,
- D_{gs} is a time-varying treatment indicator equal to 1 for cohort g for $s = t$ in post-treatment years and 0 otherwise,
- δ_{gs} captures the cohort-year specific treatment effects.

Gravity with Staggered DiD: RTA Estimates



Source: Nagengast and Yotov (2023).



Source: Author's estimates.

- Has solid theoretical foundations, which:
  - Improves the fit of naive gravity;
  - Delivers better gravity estimates;
  - Solves prominent puzzles & mysteries;
  - Addresses certain estimation challenges.

Smart/Structural Gravity

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Smart/Structural Gravity

- Is very intuitive and flexible;
- Has remarkable predictive power;
- Has solid theoretical foundations, which:
  - Improves the fit of naive gravity;
  - Delivers better gravity estimates;
  - Solves prominent puzzles & mysteries;
  - Addresses certain estimation challenges.

A Naive Estimating Equation

A Structural Estimating Equation

... But ...

[redacted] 5:54

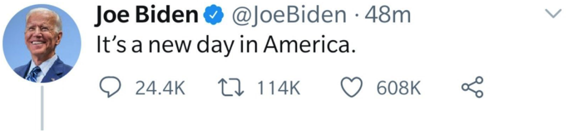
I want to evaluate the impact of the European Union–South Korea FTA. Should I use structural gravity or a CGE model?

Source: Seminar Question on Zoom Chat, 2021

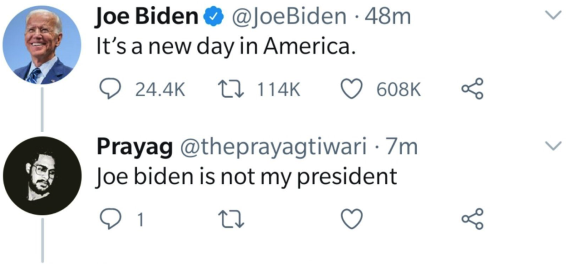
III. Gravity is a CGE Model

General Equilibrium vs. Partial Equilibrium

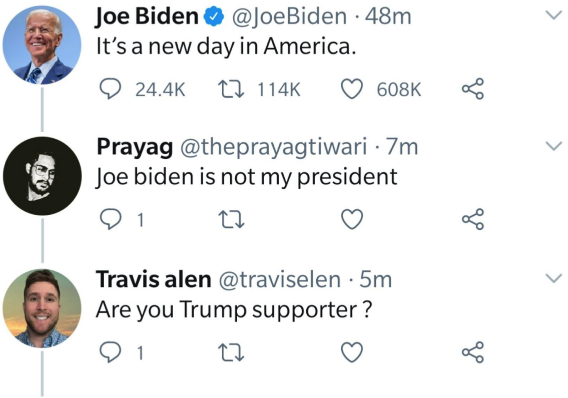
General Equilibrium vs. Partial Equilibrium



General Equilibrium vs. Partial Equilibrium



General Equilibrium vs. Partial Equilibrium



General Equilibrium vs. Partial Equilibrium

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The same first-order GE effects are often responsible for the limited success of economic sanctions.

Structural Gravity: $$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i E_j}{Y},$$

Inward Resistance: $$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y},$$

Outward Resistance: $$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y},$$

Market Clearing: $$Y_i = \sum_j X_{ij}.$$

CGE Gravity

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Expenditure & Output: $$E_j = \psi_j Y_j = \psi_j Q_j p_j.$$

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Market Clearing:	$p_j =$	$\frac{\left(Y_j/Y\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_j},$
Expenditure & Output:	$Y_j =$	$Q_j p_j.$

'Partial Equilibrium'	$\Big\{ X_{ij}$	$=$	$\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y}$,
Inward Resistance:	$P_j^{1-\sigma}$	$=$	$\sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y}$,
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Following: Anderson et al. (2020)

'Partial Equilibrium' $\left\{ X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y}, \right.$

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Following: Anderson et al. (2020)

On the Structural Effects of Sanctions

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On the Structural Effects of Sanctions

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Following: Anderson et al. (2020)

Gravity is a CGE Model

Structural Gravity: $X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y},$

Inward Resistance: $P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y},$

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Market Clearing: $p_j = \frac{(Y_j/Y)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_j},$

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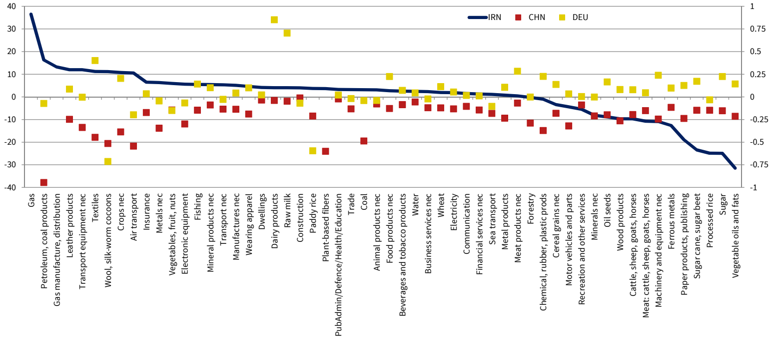
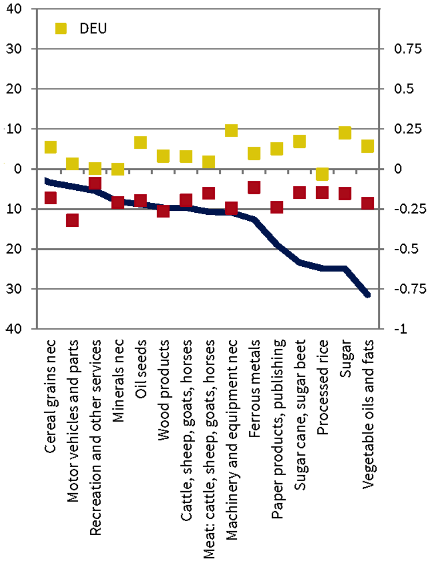
The GE Effects of the Sanctions on Iran



Source: Felbermayr et al. (2019).

The GE Effects of the Sanctions on Iran



Source: Felbermayr et al. (2019).

Gravity is a CGE model! Remarkably, it is also an Estimating CGE model!!

An Estimating CGE Model

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Market Clearing: $$p_i = \frac{(Y_i/Y)^{\frac{1}{1-\sigma}}}{\beta_i \Pi_i},$$

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Output Value: $$Y_i = Q_i p_i.$$

An Estimating CGE Model

Structural Gravity: $$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y},$$

Inward Resistance: $$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y},$$

Outward Resistance: $$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{\psi_j Y_j}{Y},$$

Market Clearing: $$p_i = \frac{(Y_i/Y)^{\frac{1}{1-\sigma}}}{\beta_i \Pi_i},$$

Output Value: $$Y_i = A_i L_i^{1-\alpha} K_i^{\alpha} p_i.$$

Structural Gravity: $X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y}$,

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Market Clearing: $p_i = \frac{(Y_i/Y)^{\frac{1}{1-\sigma}}}{\beta_i \Pi_i}$.

Output Value: $Y_i = A_i L_i^{1-\alpha} K_i^{\alpha} p_i$.

An Estimating CGE Model

Structural Gravity: $$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y},$$

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Outward Resistance: $$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{\psi_j Y_j}{Y},$$

Market Clearing: $$p_i = \frac{(Y_i/Y)^{\frac{1}{1-\sigma}}}{\beta_i \Pi_i}.$$

Output Value: $$Y_i = A_i L_i^{1-\alpha} K_i^{\alpha} p_i.$$

An **Estimating** CGE Model

Structural Gravity: $$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y},$$

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Outward Resistance: $$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{\psi_j Y_j}{Y},$$

Output Value: $$Y_i = \beta_i^{-\frac{1}{\sigma}} A_i^{\frac{1}{\sigma}} L_i^{\frac{1-\alpha}{\sigma}} K_i^{\frac{\alpha}{\sigma}} Y^{\frac{\sigma-1}{\sigma}} \Pi_i^{-\frac{1}{\sigma}}.$$

An **Estimating** CGE Model

Structural Gravity: $$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i \psi_j Y_j}{Y},$$

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An Estimating CGE Model

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An **Estimating** CGE Model

Trade:	$X_{ij,t} = \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \pi_{i,t}] \times \epsilon_{ij,t},$
Inward Resistance:	$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y},$
Outward Resistance:	$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{\psi_j Y_j}{Y},$
Output Value:	$Y_i = \beta_i^{-\frac{1}{\sigma}} A_i^{\frac{1}{\sigma}} L_i^{\frac{1-\alpha}{\sigma}} K_i^{\frac{\alpha}{\sigma}} Y^{\frac{\sigma-1}{\sigma}} \Pi_i^{-\frac{1}{\sigma}}.$

An Estimating CGE Model

Trade: $$X_{ij,t} = \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \pi_{i,t}] \times \epsilon_{ij,t},$$

IMR: $$\hat{P}_{j,t}^{1-\sigma} = \frac{E_{j,t}}{\exp(\hat{\chi}_{j,t})},$$

OMR: $$\hat{\Pi}_{i,t}^{1-\sigma} = \frac{Y_{i,t}}{\exp(\hat{\pi}_{i,t})},$$

Output Value: $$Y_i = \beta_i^{-\frac{1}{\sigma}} A_i^{\frac{1}{\sigma}} L_i^{\frac{1-\alpha}{\sigma}} K_i^{\frac{\alpha}{\sigma}} Y^{\frac{\sigma-1}{\sigma}} \Pi_i^{-\frac{1}{\sigma}}.$$

Following: **Anderson and Yotov (2012), Arvis and Shepherd (2013), and Fally (2015)**

An **Estimating** CGE Model

$$\text{Trade:} \quad X_{ij,t} = \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \pi_{i,t}] \times \epsilon_{ij,t},$$

$$\text{IMR:} \quad \hat{P}_{j,t}^{1-\sigma} = \frac{E_{j,t}}{\exp(\hat{\chi}_{j,t})},$$

$$\text{OMR:} \quad \hat{\Pi}_{i,t}^{1-\sigma} = \frac{Y_{i,t}}{\exp(\hat{\pi}_{i,t})},$$

$$\text{Output:} \quad \ln Y_{i,t} = \kappa_1 \ln L_{i,t} + \kappa_2 \ln K_{i,t} + \kappa_3 \ln\left(\frac{1}{\hat{\Pi}_{i,t}^{1-\sigma}}\right) + \nu_t + \omega_i + \varepsilon_{i,t}.$$

Following: **Anderson et al. (2020)**

An Estimating CGE Model

$$\text{Trade:} \quad X_{ij,t} = \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \pi_{i,t}] \times \epsilon_{ij,t},$$

$$\text{IMR:} \quad \hat{P}_{j,t}^{1-\sigma} = \frac{E_{j,t}}{\exp(\hat{\chi}_{j,t})},$$

$$\text{OMR:} \quad \hat{\Pi}_{i,t}^{1-\sigma} = \frac{Y_{i,t}}{\exp(\hat{\pi}_{i,t})},$$

$$\text{Output:} \quad \ln Y_{i,t} = \kappa_1 \ln L_{i,t} + \kappa_2 \ln K_{i,t} + \frac{1}{-\sigma} \ln\left(\frac{1}{\hat{\Pi}_{i,t}^{1-\sigma}}\right) + \nu_t + \omega_i + \varepsilon_{i,t}.$$

Following: Anderson et al. (2020)

The Full Effects of Country-specific Policies

$$
\begin{aligned}
\text{Trade:} \quad X_{ij,t} &= \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \pi_{i,t}] \times \epsilon_{ij,t}, \\
\text{IMR:} \quad \hat{P}_{j,t}^{1-\sigma} &= \frac{E_{j,t}}{\exp(\hat{\chi}_{j,t})}, \\
\text{OMR:} \quad \hat{\Pi}_{i,t}^{1-\sigma} &= \frac{Y_{i,t}}{\exp(\hat{\pi}_{i,t})}, \\
\text{Output:} \quad \ln Y_{i,t} &= \kappa_1 \ln L_{i,t} + \kappa_2 \ln K_{i,t} + \frac{1}{-\sigma} \ln\left(\frac{1}{\hat{\Pi}_{i,t}^{1-\sigma}}\right) + \nu_t + \omega_i + \varepsilon_{i,t}.
\end{aligned}
$$

Following: Freeman et al. (2021)

$$X_{ij,t} = \exp[\mathbf{GRAV_{ij,t}}\gamma + \chi_{j,t} + \nu_t + \omega_i + \kappa_1 \ln L_{i,t} + \kappa_2 \ln K_{i,t}] \times \exp\left[\kappa_3 \ln\left(\hat{\Pi}_{i,t}\right) + \mathbf{CNTRY_{i,t}}\kappa\right] \times \tilde{\epsilon}_{ij,t}$$

- where $\kappa_3 = \frac{\sigma(1-\sigma)+1}{(1-\sigma)\sigma}$;
- Implementation is a simple two-stage estimation procedure;
- Identifies **full** effects of country-specific policies within structural gravity;
- Recover estimates of the trade elasticity without price and/or tariff data;
  - Obtain estimates of the trade elasticity for services: $\sigma_{Services} \in [2.5; 5.36]$;

Following: Freeman et al. (2021)

- Has the nice properties of CGE models;
- Delivers key structural parameters;
- Uncovers new estimation opportunities.

E-CGE Gravity ... **is Very Powerful!**

- Has the nice properties of CGE models;
- Delivers key structural parameters;
- Uncovers new estimation opportunities.

E-CGE Gravity ... **is Very Powerful!**

- Has the nice properties of CGE models;
- Delivers key structural parameters;
- Uncovers new estimation opportunities.

The Gravity Model ...

- Is very intuitive and flexible;
- Has remarkable predictive power;
- Has solid theoretical foundations;
- Has the nice properties of CGE models;
- Delivers key structural parameters;
- Uncovers new estimation opportunities.

A Structural Estimating Equation

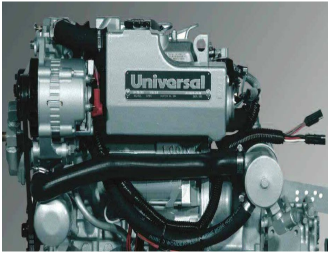
An Estimating CGE (E-CGE) Model

... But ...

"The structural gravity model is a small scale CGE model."

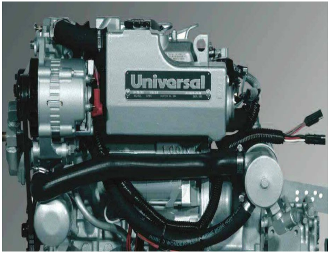
Source: Top CGE Economist

Universal Gravity

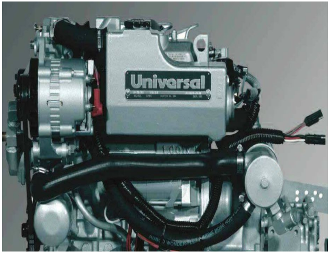


Universal Gravity

Policy
Trade & Other
($N^2 + N$) $\Rightarrow$



Policy
Trade & Other
($N^2 + N$) $\Rightarrow$

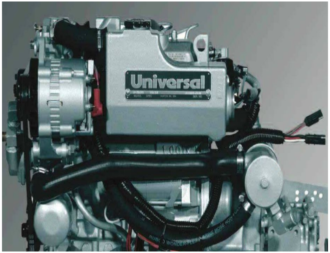


$\Rightarrow$ Consumers

$\Rightarrow$ Producers
(N^*2)

Policy
Trade & Other
($N^2 + N$)

$\Rightarrow$



$\Rightarrow$ Consumers

$\Rightarrow$ Producers
(N^*2)

$\Rightarrow$

Wages

Employment

Investment

Environment

Resources

NOTE: The Gravity Model can be conveniently integrated within a wide class of GE superstructures. While preserving tractability!

IV. Nested Gravity

Structural Gravity: $$X_{ij,t} = \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}}\right)^{1-\sigma} \frac{Y_{i,t}\psi_j Y_{j,t}}{Y_t},$$

Inward Resistance: $$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{Y_{i,t}}{Y_t},$$

Outward Resistance: $$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{\psi_j Y_{j,t}}{Y_t},$$

Market Clearing: $$p_{j,t} = \frac{\left(Y_{j,t}/Y_t\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_{j,t}},$$

Output Value: $$Y_{j,t} = A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} p_{j,t}.$$

Nested Gravity

Partial Equilibrium:

$$X_{ij,t} = \left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma} \frac{Y_{i,t}\psi_j Y_{j,t}}{Y_t},$$

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{Y_{i,t}}{Y_t},$$

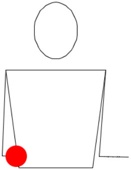
'Conditional' GE:

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{\psi_j Y_{j,t}}{Y_t},$$

$$p_{j,t} = \frac{\left(Y_{j,t}/Y_t\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_{j,t}},$$

Full Endowment GE:

$$Y_{j,t} = A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} p_{j,t}.$$



Following Anderson et al. (2018) can perform CGE analysis in Stata

Partial Equilibrium:

$$X_{ij,t} = \left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma} \frac{Y_{i,t}\psi_j Y_{j,t}}{Y_t},$$

'Conditional' GE:

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{Y_{i,t}}{Y_t},$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{\psi_j Y_{j,t}}{Y_t},$$

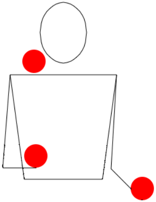
Full Endowment GE:

$$p_{j,t} = \frac{\left(Y_{j,t}/Y_t\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_{j,t}},$$

$$Y_{j,t} = A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} p_{j,t},$$

Dynamic GE:

$$K_{j,t+1} = \left[\frac{A_{j,t}L_{j,t}^{1-\alpha}\beta\alpha\delta p_{j,t}}{(1-\beta+\delta\beta)P_{j,t}}\right]^{\delta} K_{j,t}^{\alpha\delta+1-\delta}.$$



Following: Eaton et al. (2016) and Anderson et al. (2020)

Nested Gravity: Intermediates

Partial Equilibrium:

$$X_{ij,t} = \left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma} \frac{Y_{i,t}\psi_j Y_{j,t}}{Y_t},$$

'Conditional' GE:

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{Y_{i,t}}{Y_t},$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{\psi_j Y_{j,t}}{Y_t},$$

Full Endowment GE:

$$p_{j,t} = \frac{\left(Y_{j,t}/Y_t\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_{j,t}},$$

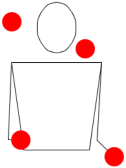
$$Y_{j,t} = p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi},$$

Dynamic GE:

$$K_{j,t+1} = \left[\frac{A_{j,t}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}\beta\alpha\delta p_{j,t}}{(1-\beta+\delta\beta)P_{j,t}}\right]^{\delta} K_{j,t}^{\alpha\delta+1}$$

Intermediates:

$$Q_{j,t} = [(1-\alpha-\xi)\frac{\phi_{j,t}p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}}{P_{j,t}}]^{\frac{1}{\alpha+\xi}}.$$



Following: Eaton and Kortum (2002) and Caliendo and Parro (2015)

Nested Gravity: Technology FDI

Partial Equilibrium:

$$X_{ij,t} = \left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma} \frac{Y_{i,t}\psi_j Y_{j,t}}{Y_t},$$

'Conditional' GE:

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{Y_{i,t}}{Y_t},$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{\psi_j Y_{j,t}}{Y_t},$$

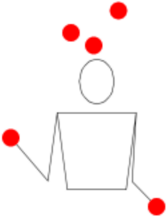
Full Endowment GE:

$$p_{j,t} = \frac{\left(Y_{j,t}/Y_t\right)^{\frac{1}{1-\sigma}}}{\beta_j \Pi_{j,t}},$$

$$Y_{j,t} = p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi-\phi}M_{j,t}^{\phi},$$

Dynamic GE:

$$K_{j,t+1} = \left[\frac{A_{j,t}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi-\phi}M_{j,t}^{\phi}\beta\alpha\delta p_{j,t}}{(1-\beta+\delta\beta)P_{j,t}}\right]^{\delta} K$$



Intermediates:

$$Q_{j,t} = [(1-\alpha-\xi-\phi)\frac{\phi_{j,t}p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}M_{j,t}^{\phi}}{P_{j,t}}]^{\frac{1}{\alpha+\xi+\phi}},$$

Technology FDI:

$$FDI_{ij,t} = \Gamma_i \frac{\omega_{ij,t}}{P_{i,t}} \frac{Y_{i,t}\psi_j Y_{j,t}}{M_{i,t}}.$$

Following: Anderson et al. (2018)

$$X^k_{ij,t} = \frac{Y^k_{i,t}E^k_{j,t}}{\sum_i Y^k_{i,t}} \left(\frac{t^k_{ij,t}}{\Pi^k_{i,t}P^k_{j,t}}\right)^{1-\sigma^k},$$

$$(\Pi^k_{i,t})^{1-\sigma_k} = \sum_j \left(\frac{t^k_{ij,t}}{P^k_{j,t}}\right)^{1-\sigma^k} \frac{E^k_{j,t}}{\sum_i Y^k_{i,t}},$$

$$(P^k_{j,t})^{1-\sigma_k} = \sum_i \left(\frac{t^k_{ij,t}}{\Pi^k_{i,t}}\right)^{1-\sigma^k} \frac{Y^k_{i,t}}{\sum_i Y^k_{i,t}},$$

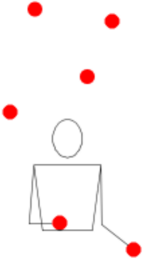
$$p^k_{i,t} = \left(\frac{Y^k_{i,t}}{\sum_i Y^k_{i,t}}\right)^{\frac{1}{1-\sigma^k}} \frac{1}{\psi^k_i \Pi^k_{i,t}},$$

$$Y^k_{j,t} = p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j}\prod_l \left(M^{l,k}_j\right)^{\gamma^{l,k}_j},$$

$$E^k_{i,t} = \alpha^k \phi_i \sum_k p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j}\prod_l \left(M^{l,k}_j\right)^{\gamma^{l,k}_j},$$

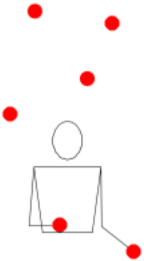
$$r_{j,t} = \sum_k \xi^k_j p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j-1}\prod_l \left(M^{l,k}_j\right)^{\gamma^{l,k}_j},$$

$$K_{j,t+1} = \left[\frac{\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}} + \frac{\beta\delta\phi_{j,t}r_{j,t}}{P_{j,t}} - \frac{\beta\delta\phi_{j,t}r_{j,t}}{P_{j,t}}\left(\frac{K^{1/\delta}_{j,t-1}\phi_{j,t-1}Y_{j,t-1}}{K^{1/\delta}_{j,t}P_{j,t-1}K_{j,t-1}}\right)}{1+(1-\delta)\beta\frac{K^{1/\delta}_{j,t-1}\phi_{j,t-1}Y_{j,t-1}}{K^{1/\delta}_{j,t}P_{j,t-1}K_{j,t-1}} - \beta(1-\delta)}\right]^{\delta} K_{j,t}$$



Nested Gravity

$$
\begin{aligned}
X^k_{ij,t} &= \frac{Y^k_{i,t}E^k_{j,t}}{\sum_i Y^k_{i,t}}\left(\frac{t^k_{ij,t}}{\Pi^k_{i,t}P^k_{j,t}}\right)^{1-\sigma^k}, \\
(\Pi^k_{i,t})^{1-\sigma_k} &= \sum_j \left(\frac{t^k_{ij,t}}{P^k_{j,t}}\right)^{1-\sigma^k} \frac{E^k_{j,t}}{\sum_i Y^k_{i,t}}, \\
(P^k_{j,t})^{1-\sigma_k} &= \sum_i \left(\frac{t^k_{ij,t}}{\Pi^k_{i,t}}\right)^{1-\sigma^k} \frac{Y^k_{i,t}}{\sum_i Y^k_{i,t}}, \\
p^k_{i,t} &= \left(\frac{Y^k_{i,t}}{\sum_i Y^k_{i,t}}\right)^{\frac{1}{1-\sigma^k}} \frac{1}{\psi^k_i \Pi^k_{i,t}}, \\
Y^k_{j,t} &= p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j}\prod_l\left(M^{l,k}_j\right)^{\gamma^{l,k}_j}, \\
E^k_{i,t} &= \alpha^k\phi_i\sum_k p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j}\prod_l\left(M^{l,k}_j\right)^{\gamma^{l,k}_j}, \\
r_{j,t} &= \sum_k \xi^k_j p^k_{j,t}A^k_{j,t}\left(L^k_{j,t}\right)^{\gamma^k_j}\left(K^k_{j,t}\right)^{\xi^k_j-1}\prod_l\left(M^{l,k}_j\right)^{\gamma^{l,k}_j}, \\
K_{j,t+1} &= \left[\frac{\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}} + \frac{\beta\delta\phi_{j,t}r_{j,t}}{P_{j,t}} - \frac{\beta\delta\phi_{j,t}r_{j,t}}{P_{j,t}}\left(\frac{K^{1/\delta}_{j,t-1}\phi_{j,t-1}Y_{j,t-1}}{K^{1/\delta}_{j,t}P_{j,t-1}K_{j,t-1}}\right)}{1+(1-\delta)\beta\frac{K^{1/\delta}_{j,t-1}\phi_{j,t-1}Y_{j,t-1}}{K^{1/\delta}_{j,t}P_{j,t-1}K_{j,t-1}} - \beta(1-\delta)}\right]^{\delta} K_{j,t}
\end{aligned}
$$



Nested Gravity

- The gravity model can be nested within many GE superstructures;
- The resulting system is still tractable and transparent;
- Often, the new GE equations can be estimated, which allows for:
  - Testing the causal impact of trade on various economic outcomes;
  - Recovery of the key structural parameters for CGE analysis.

Nested Gravity

- Is very intuitive and flexible;
- Has remarkable predictive power;
- Has solid theoretical foundations;
- Is an Estimating CGE (E-CGE) framework;
- The gravity model can be nested within many GE superstructures;
- The resulting system is still tractable and transparent;
- The resulting system can be estimated and allows for:
  - Testing the causal impact of trade on various economic outcomes;
  - Recovery of the key structural parameters for CGE analysis.

An Estimating CGE (E-CGE) Model

An Estimating CGE (E-CGE) Model

That Can Be Nested In Many GE Frameworks

The Green Giant

An Estimating CGE (E-CGE) Model

That Can Be Nested In Many GE Frameworks

“Gravity is Endless Fun!”

Peter Neary