

# Economic Complexity and trade

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This work is based on earlier collaboration with R. Myro and A. Segarra

# Is the world more complex than it used to be?

- “It’s not you — the world has become more complex” (McGrath, HBR 2011)
  - “Complex systems are unforgiving places for companies, and people, who move slowly. “
  - The End of Competitive Advantage (Harvard Business Review Press)

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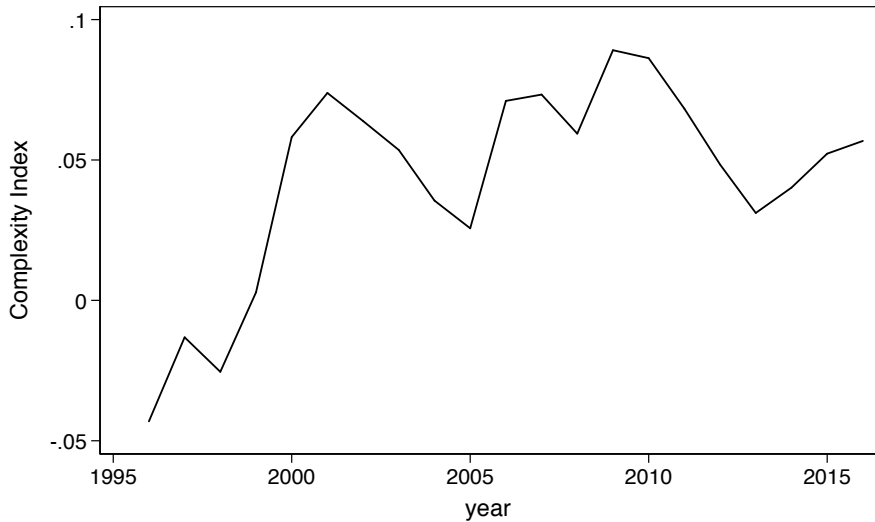
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## Frank and Ernest

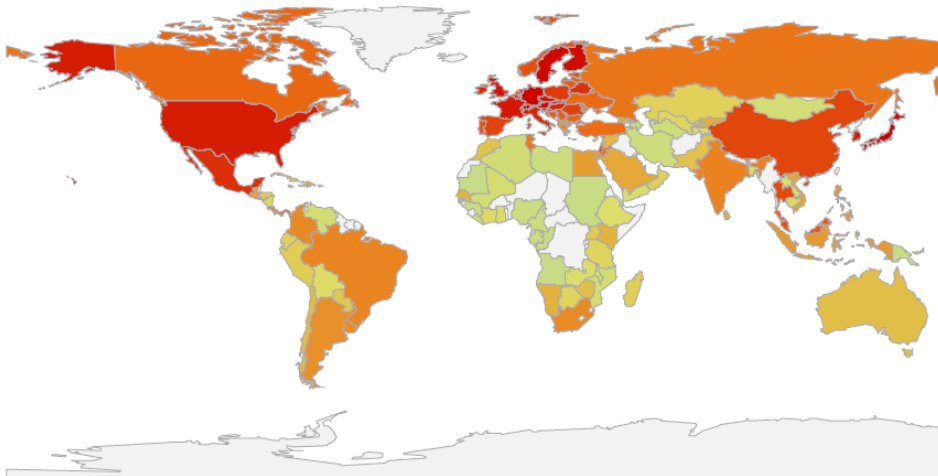


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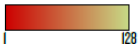
# The World is more Complex



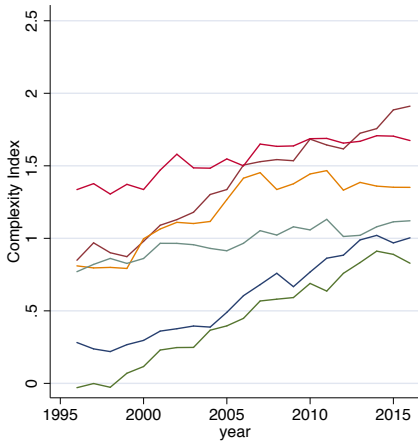
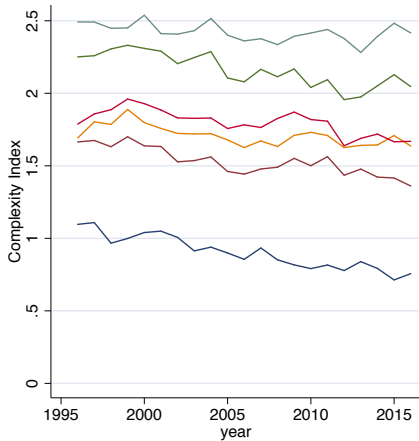
Map of the World colored according to ECI Ranking.



Rank



## Reversal of Complexities



# Outline

- 1 Motivation
  - Contributions
- 2 Background
  - Measuring Complexity
  - Literature
- 3 The model
  - Setup
  - Theoretical results
- 4 Data & Empirics
  - Gold Standard Gravity
- 5 Results: PE Effects
  - Trade Effects
- 6 GE Counterfactuals
  - Reversal of Fortunes
  - Back to the Future
  - MAGA
  - Bring Back Jobs (from China)
- 7 Conclusions
  - Lessons learned

# What do I do?

- My aim today:
  - Share (complex) ideas
  - Present burning results & estimates
- I study the partial and general equilibrium effects of complexity on trade
  - 1 I develop a model that delivers sharp predictions on the effects of increasing and shifting shifting complexity on trade and GDP
  - 2 I estimate partial effects with structural gravity
  - 3 I obtain trade-induced welfare quantifications with distributional implications

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# Economic Complexity index

- The Economic Complexity Index (ECI), defined by Hausmann and Hidalgo (2007), Hidalgo (2009), Hidalgo and Hausmann, 2009 and Hausman et al. (2014) is derived from an integration of two other measures:
  - Diversification by product of the exports in which a country exhibits Revealed Comparative Advantage (RCA)

$$\text{Diversity} \equiv k_{c,o} = \sum_p M_{cp}$$

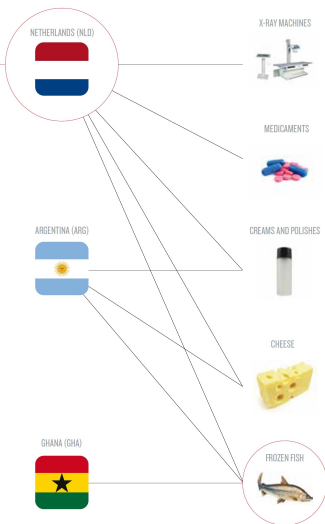
- average ubiquity of these same products

$$\text{Ubiquity} \equiv k_{p,o} = \sum_c M_{cp}$$

# Economic Complexity index: Diversification and Ubiquity

## DIVERSITY ( $k_{c,o}$ ):

Diversity is related to the number of products that a country is connected to. This is equal to the number of links that this country has in the network. In this example, using a subset of the 2009 data, the diversity of Netherlands is 5, that of Argentina is 3, and that of Ghana is 1.



## UBIQUITY ( $k_{p,o}$ ):

Ubiquity is related to the number of countries that a product is connected to. This is equal to the number of links that this product has in the network. In this example, using a subset of the 2009 data, the ubiquity of Cheese is 2, that of Fish is 3 and that of Medicaments is 1.

## Economic Complexity Index: Intuition

### ECI combines diversity and ubiquity recursively.

A country is more complex if it exports:

- many products;
- products that few other countries export;
- products exported mainly by other diversified countries.

### Method of Reflections:

*Are the products exported by this country also exported by many simple countries, or mainly by other diversified countries?*

Rare does not always mean complex: raw diamonds may be rare, but not necessarily capability-intensive.

The ECI comes from this recursive country–product structure and is standardized around zero:

- $ECI > 0$ : above-average complexity;
- $ECI < 0$ : below-average complexity.

# ECI: Eigenvector & Eigenvalues

The Method of Reflections repeatedly corrects diversity by ubiquity, and ubiquity by diversity:

$$k_{c,n} = \frac{1}{k_{c,0}} \sum_p M_{cp} k_{p,n-1}, \quad k_{p,n} = \frac{1}{k_{p,0}} \sum_c M_{cp} k_{c,n-1}$$

**Intuition:**

- Start with diversity and ubiquity.
- Ask whether a country exports rare products.
- Then ask whether those products are exported by diversified countries.
- Repeat until the information settles into a stable ranking.

That stable ranking is the eigenvector:

$$\tilde{M}K = \lambda K$$

- $K$ : country complexity scores.
- $\lambda$ : strength of that pattern in the country-product network.
- The second eigenvector is used because the first is the “all countries equal” solution.

Finally, standardize the scores:

$$ECI_c = \frac{K_c - \langle K \rangle}{sd(K)}$$

## ECI and Bilateral Trade: No Mechanical Link

ECI should measure **productive capabilities**, not bilateral trade intensity.

In structural gravity, bilateral exports can be written as:

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

- $Y_i$ : exporter size or production capacity.
- $E_j$ : importer expenditure.
- $\tau_{ij}$ : bilateral trade costs.
- $\Pi_i, P_j$ : multilateral resistance terms.

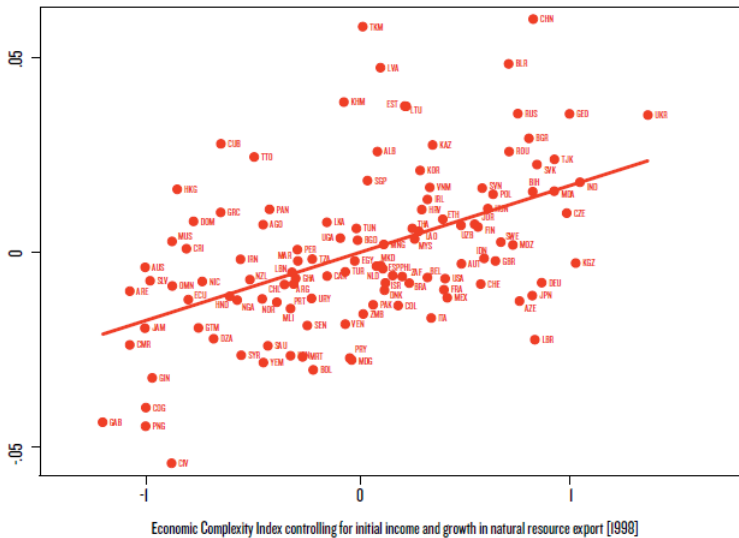
Bilateral trade depends on distance, size, borders, language, trade agreements, and relative trade costs.

ECI is instead constructed from the **country–product RCA matrix**, not from  $X_{ij}$ .

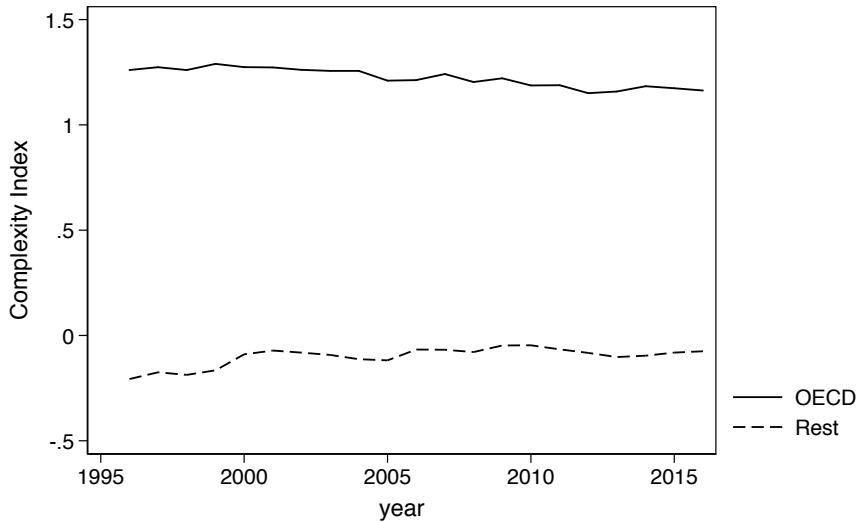
**Therefore:** ECI is independent of bilateral trade volumes by construction, avoiding mechanical circularity when ECI is later used to explain bilateral



Growth in per capita GDP, controlling for initial income and growth in natural resource exports [1998-2008]



## Complexity in the West and the Rest



# Complexity shifting from the West to the Rest

- ¿Does complexity shifting=Offshoring reduce welfare in the West?
- Samuelson (2004): YES, if it implies technology transfer from West to the rest. West loses rents from initial technological stance
  - Reduction of complexity for developed countries would negatively affect their exports of goods, the contrary of what would happen for developing countries (quasi-Rybczynski effect). (Romalis 2004 AER; Morrow, 2010 JIE).
- New Trade Theory: NO, West react by altering their specializations over intra and inter industrial bases in three main ways:
  - Deeper horizontal intra-industry specialization within each manufacturing industry, multiplying the number of varieties of each product.
  - A shift to deeper vertical ITT, with an improvement in the quality of their products – in those cases where greater complexity does not imply higher quality
  - A move to services intensive in knowledge would be expected.

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  - Myburgh & Paniagua (2016 JL&E)
- “Does FDI boost production complexity in host countries?” (Javorcik et al., 2018 EJ)
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# The model in 68 words

- We develop a stylized Ricardian model in line with Acemoglu et al., (2015), Rodriguez-Clare (2010) and Krugman (1979)
- Our model simplifies(\*) and extends(\*\*) Acemoglu et al., (2015)
  - Two countries, one final good, many intermediates, one type of worker(\*)
  - Workers in the West have positive production spillovers(\*\*)
  - Trade(\*\*)
- Results:
  - Complexity shifting increases welfare (up to a threshold)
  - Increasing complexity in the West increases welfare (+ changes threshold)
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# Consumers

- The world consists of two countries, the West and the Rest(\*). The West is populated by  $L$  units of workers and the East by  $L^*$  workers, both fixed in supply. The two countries differ in the technological stance to produce existing intermediates. New technologies are introduced in the West and can be transferred to the West after a paying an offshoring cost (Krugman 1979).
- Households supply labor inelastically and derive utility from consuming a unique final good. Preferences are identical and logarithmic. A representative household in this economy has preferences at time  $t = 0$  given by:

$$U = \int_0^{\infty} e^{-\rho t} \ln C_t dt,$$

where  $\rho > 0$  is the discount rate (impatience).

- Consumption satisfies standard Euler equation of  $\dot{C}_t/C_t = r_t - \rho$  and the transversality condition of  $\lim_{t \rightarrow \infty} [\exp(-\int_0^t r_s ds) W_t]$ , where  $W_t$  is the wealth of consumers that comes from the ownerships of firms.

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# The final good

- The final good  $Y$  is used both for consumption and investment and  $P_Y = 1$ ,
- The production of the good requires intermediates, which are produced by workers following the CES Dixit-Stiglitz production function:

$$Y = (A)^{\frac{2\alpha-1}{\alpha}} \left( \int_0^A x_i^\alpha di \right)^{1/\alpha}, \quad (1)$$

where  $x_i$ : quantity of intermediate  $i \in [0, A]$  and  $\sigma \equiv 1/(1 - \alpha) > 1$  is the elasticity of substitution between them.  $A$  represents the the state of the world's technology and grows endogenously over time (as in Romer, 1990).

# The firm's problem

- After resolving the profit maximization problem of

$$\max_{x_i} \left\{ (A)^{\frac{2\alpha-1}{\alpha}} \left( \int_0^A x_i^\alpha di \right)^{1/\alpha} - \int_0^A p_i x_i di \right\},$$

the price of an intermediate is given by:

$$p_i = A^{2\alpha-1} Y^{1-\alpha} x_i^{\alpha-1}.$$

- Intermediates are produced in monopolistic competition with a constant returns to scale technology using labor as the only input:

$$x_i^* = l_i^*, \text{ and } x = \eta^{\frac{1-\alpha}{\alpha}} l_i$$

where  $\eta = \eta(ECI)$  is a positive production externality of workers in the West, that depends monotonically on the ECI level.

- Monopolists charges a markup of  $1/\alpha$  over the marginal cost (wages).
  - Prices:  $p_i = \omega/\alpha$ , and in the Rest  $p_i^* = \omega^*/\alpha$  where  $\omega$  is the wages
  - Profits:  $\pi_i = (1 - \alpha)p_i x_i$ .

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# Equilibrium

- As in Krugman (1979), we assume that the West could potentially produce all products, and Rest can produce only a subset of intermediates  $\kappa A$ .
  - The subset of intermediaries that rest can produce depends monotonically on their complexity index  $\kappa = \kappa(ECI^*)$ .
- Imposing labor market clearing with homogeneous firms, the quantities produced in each country are:

$$x^* = \frac{L^*/A}{\kappa} \text{ and } x = \frac{\eta^{\frac{1-\alpha}{\alpha}} L/A}{(1-\kappa)}.$$

- $\kappa = \kappa(ECI^*)$ : Complexity shifting
- Complexity in the Rest =(RCA)
- Complexity in the West=(RCA+spillover)

## Shifting and increasing complexity

Result 1: Production increases in  $\kappa$  up to  $\bar{\kappa}$

Result 2: Production increases in  $\eta$

- World's production:

$$Y^\alpha = A^\alpha \left[ (\kappa)^{1-\alpha} (L^*)^\alpha + (\eta(1-\kappa))^{1-\alpha} L^\alpha \right]. \quad (2)$$

- Effect of complexity shifting

$$\frac{\partial Y^\alpha}{\partial \kappa} = (1-\alpha)A^\alpha \left[ \left( \frac{L^*}{\kappa} \right)^\alpha - \eta \left( \frac{L}{1-\kappa} \right)^\alpha \right] > 0.$$

if  $\kappa$  is below the limit of (which ensures that  $w > w^*$ ):

$$\kappa < \bar{\kappa} = \frac{L^*}{\xi^{\frac{1}{\alpha}} L + L^*}$$

- Effect of increasing complexity in the West:

$$\frac{\partial Y^\alpha}{\partial \eta} = A^\alpha \left[ \left( \frac{1-\kappa}{\eta^{\alpha/(1-\alpha)}} \right)^{1-\alpha} L^\alpha \right] > 0$$

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# Ideas & skills

Result 3:  $\bar{\kappa}$  decreases with  $\eta$  and in  $\sigma$

- This is easily shown by:

$$\lim_{\eta \rightarrow \infty} \bar{\kappa} = 0 \text{ and } \lim_{\sigma \rightarrow 1} \bar{\kappa} = 0.$$

- If workers in the West generate high spillovers (productivity, ideas) or products are not easily substitutable, the limit to profitable complexity shifting ( $\bar{\kappa}$ ) decreases.
- $\eta$  increases world output and reduces profitable complexity shifting

# Trade effects

Result 4: Trade increases in  $\kappa$  up to  $\bar{\kappa}$  and in  $\eta$

- Now if we want to determine the frictionless trade between the two countries, we plug the production shares into the standard gravity equation:

$$X_{ij} = \frac{Y Y^*}{Y} = A^2 (\eta \kappa (1 - \kappa))^{\frac{1-\alpha}{\alpha}} (L L^*). \quad (3)$$

- Effect of shifting complexity:

$$\frac{\partial X_{ij}}{\partial \kappa} > 0 \text{ if } \kappa < \bar{\kappa}$$

- Effect of increasing complexity in the West

$$\frac{\partial X_{ij}}{\partial \eta} > 0$$

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- Effect of increasing complexity in the West

$$\frac{\partial X_{ij}}{\partial \eta} > 0$$

# The mystery of the shrinking tables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnGDPi	1.180 (0.006)***	1.180 (0.006)***	1.175 (0.006)***	1.172 (0.006)***				
lnGDPj	0.892 (0.006)***	0.891 (0.006)***	0.887 (0.006)***	0.882 (0.006)***				
LnDist	-1.128 (0.017)***	-1.128 (0.017)***	-1.116 (0.017)***	-1.122 (0.017)***				
Contiguity	0.503 (0.081)***	0.502 (0.081)***	0.526 (0.081)***	0.516 (0.081)***				
Colony	1.283 (0.097)***	1.284 (0.097)***	1.248 (0.097)***	1.281 (0.097)***				
Language	0.597 (0.033)***	0.597 (0.033)***	0.615 (0.033)***	0.602 (0.033)***				
Island	0.463 (0.028)***	0.462 (0.028)***	0.423 (0.028)***	0.448 (0.028)***				
Landlocked	-0.418 (0.025)***	-0.419 (0.025)***	-0.432 (0.025)***	-0.431 (0.025)***				
ComCurr	1.060 (0.088)***	1.061 (0.088)***	1.035 (0.088)***	1.060 (0.087)***	0.315 (0.026)***	0.315 (0.026)***	0.311 (0.026)***	0.315 (0.026)***
RTAs	1.109 (0.035)***	1.108 (0.035)***	1.048 (0.035)***	1.095 (0.035)***	0.387 (0.010)***	0.387 (0.010)***	0.382 (0.010)***	0.387 (0.010)***
AML	-0.037 (0.038)				0.035 (0.015)**			
CML		0.755 (0.159)***				0.045 (0.074)		
HC			0.347 (0.029)***				0.081 (0.013)***	
NYC				0.176 (0.023)***				0.001 (0.012)
Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country*year FE	No	No	No	No	Yes	Yes	Yes	Yes
Country-pair FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	635,137	635,137	635,137	635,137	729,932	729,932	729,932	729,932

# The mystery of the shrinking tables

	(1)	(2)	(3)	(4)
ComCurr	0.315 (0.026)***	0.315 (0.026)***	0.311 (0.026)***	0.315 (0.026)***
RTAs	0.387 (0.010)***	0.387 (0.010)***	0.382 (0.010)***	0.387 (0.010)***
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# Structural Gravity

- Structural gravity is the new “Gold Standard” in gravity models

$$X_{ij} = T_{ij} \frac{Y_i E_j}{\Pi_i P_j}$$

- $Y_i$  is the total value of production in  $i$ :  $Y_i = X_{ii} + \sum_{j \neq i} X_{ij}$
- $E_j$  is the expenditure in country  $j$ :  $E_j = X_{jj} + \sum_{i \neq j} X_{ij}$
- $\Pi_i$  and  $P_j$  are structural outward and inward multilateral resistance terms (Anderson & van Wincoop, 2003).
- Structural gravity forces account for 100% of variation in product/importer/time and product/exporter/time fixed effects estimated from empirical gravity equations with PPML (Fally 2015)

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# Structural Gravity

- Structural gravity is the new “Gold Standard” in gravity models

$$X_{ij} = T_{ij} \frac{Y_i E_j}{\Pi_i P_j}$$

- $Y_i$  is the total value of production in  $i$ :  $Y_i = X_{ii} + \sum_{j \neq i} X_{ij}$
- $E_j$  is the expenditure in country  $j$ :  $E_j = X_{jj} + \sum_{i \neq j} X_{ij}$
- $\Pi_i$  and  $P_j$  are structural outward and inward multilateral resistance terms (Anderson & van Wincoop, 2003).
- Structural gravity forces account for 100% of variation in product/importer/time and product/exporter/time fixed effects estimated from empirical gravity equations with PPML (Fally 2015)

# Structural Gravity

## Recommendations for Estimating Structural Gravity (Piermartini & Yotov 2016)

- **Recommendation 1:** *Use Panel Data.*
  - Estimation efficiency and pair-fixed-effects methods for endogeneity
- **Recommendation 2:** *Allow for Adjustment in Trade Flows?*
  - adjustment in bilateral trade flows in response to trade policy or not (Egger et al., 2020)
- **Recommendation 3:** *Include Intra-national Trade Flows.*
  - consistency with gravity theory & identification of the effects of bilateral trade policies
  - Identification of the effects of country-specific trade policies
    - The effects on international trade are measured relative to the effects on intra-national trade
- **Recommendation 4:** *Use Directional Time-varying Fixed Effects*
  - importer-time and exporter-time fixed effects
- **Recommendation 5:** *Employ Country-Pair Fixed Effects*
  - Endogeneity and all time-invariant bilateral trade costs
- **Recommendation 6:** Estimate Gravity with PPML
  - Heteroskedasticity, zero trade flows and ensures that the gravity fixed effects are identical to their corresponding structural terms)

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## 15+1 Reasons Why Gravity Should Be Estimated with Domestic Trade (Yotov, 2021)

- The use of domestic trade flows in gravity estimations is:
  - 1 consistent with trade theory of the intensive margin of trade,
  - 2 available and
    - 1 it does not matter much which to use! (Campos et al., 2021),
  - 3 consistent with trade theory of the extensive margin of trade.
- 4 The use of domestic trade flows allows:
  - for estimation of the effects of international borders and home biases,
- 5 for estimation of heterogeneous domestic and regional trade costs,
- 6 for a systematic analysis of the determinants of domestic trade costs,
- 7 for country-specific asymmetries in the vector of international trade costs,
- 8 for identification of the trade-diversion effects of bilateral trade policies,
- 9 for identification of the effects of non-discriminatory trade policies on bilateral trade flows,
- 10 for identification of the effects of country-specific characteristics on bilateral trade flows,
- 11 for identification of the country-specific effects of trade policies,
- 12 to a solution to “The Distance Puzzle of International Trade”,
- 13 for solving “The Missing Globalization Puzzle”,
- 14 for solving the puzzle that “Larger Countries Should Be Richer than Smaller Countries”,
- 15 for solving the puzzle of “The Missing WTO Effects”.

# Structural Gravity

$$X_{ijt} = \exp \left( \begin{array}{c} \chi_{ijt} + (ECI_{it} \otimes ECI_{it}) \\ \lambda_{jt} + \lambda_{it} + \lambda_{ij} \end{array} \right) + e_{ijt}.$$

# Structural Gravity

$$X_{ijt} = \exp \left( \begin{matrix} \chi_{ijt} + ECI_{it} + ECI_{jt} \\ \lambda_{ij} \end{matrix} \right) + e_{ijt}.$$

# Structural Gravity

$$X_{ijt} = \exp \left( \begin{array}{c} \chi_{ijt} + \text{BRDR}_{ijt} + \text{ECI}_{jt} \times \text{BRDR}_{ij} \\ \lambda_{it} + \lambda_{jt} + \lambda_{ij} \end{array} \right) + e_{ijt}.$$

# Identifying country-specific effects in structural gravity

Heid et al (2020) & Beverelli et al (2018)

- $BRDR_{ij}$  is a dummy that identifies international flows
- $ECl_{jt} \times BRDR_{ij}$  is not collinear with MRT and can be used to identify the effect of ECI
  - More specifically the effect of the ECI on international relative to domestic trade flows

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## ITPD-E 2000-2018 w/o Domestic trade

	(1)	(2)	(3)	(4)	(5)
$(ECI_{it} \times ECI_{it})^{1/2}$	0.136*** (0.02)				
FTA	0.071*** (0.02)	0.076*** (0.02)	0.138*** (0.03)	0.149*** (0.03)	0.103*** (0.03)
$ ECI_{it} - ECI_{it} $		0.214*** (0.08)			
$ECI_{it}$			0.441*** (0.05)		0.435*** (0.05)
$ECI_{jt}$				0.328*** (0.04)	0.338*** (0.04)
Obs	324487	324487	536417	524515	324487
$R^2$	0.992	0.992	0.985	0.985	0.984
ImpxYearFE	Yes	Yes	No	No	No
ExpxYearFE	Yes	Yes	No	No	No
PairFE	Yes	Yes	Yes	Yes	Yes
Domestic	No	No	No	No	No
Global	No	No	No	No	No

Robust standard errors in (), clustered by country pair

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

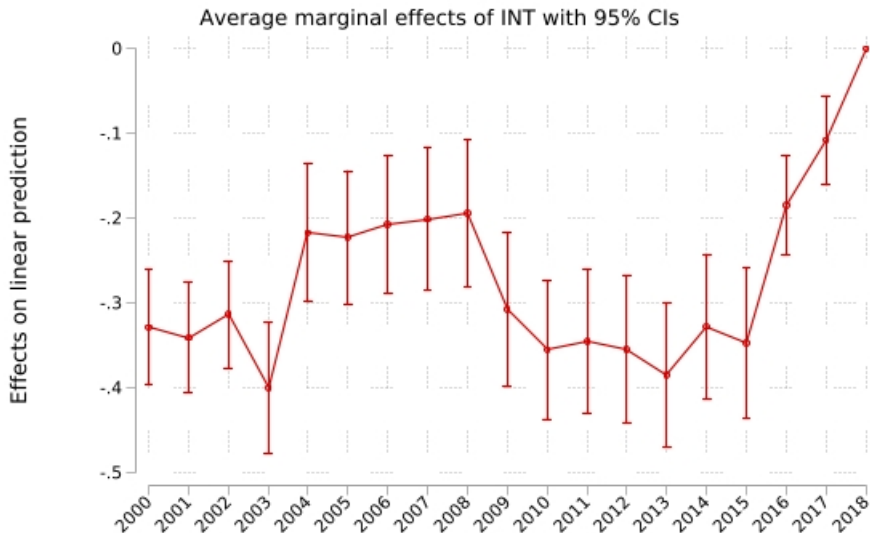
## ITPD-E 2000-2018 w/ Domestic trade

	(1)	(2)	(3)	(4)	(5)
$ECI_{jt} \times BRDR$	0.518*** (0.04)	0.534*** (0.04)	0.345*** (0.07)	0.516*** (0.07)	0.384*** (0.08)
BRDR	-4.035*** (0.15)				
FTA	0.206*** (0.07)	0.196*** (0.07)	0.216*** (0.04)	0.167*** (0.04)	0.157*** (0.04)
log DIST	-0.495*** (0.05)	-0.498*** (0.05)			
contiguity	0.404*** (0.08)	0.404*** (0.08)			
language	0.369*** (0.06)	0.371*** (0.06)			
Relig	0.724*** (0.11)	0.720*** (0.11)			
$ECI_{jt}^2 \times BRDR$					-0.018 (0.02)
Obs	484614	484614	538673	538673	538673
$R^2$	0.986	0.986	0.998	0.998	0.998
ImpxYearFE	Yes	Yes	Yes	Yes	Yes
ExpYearFE	Yes	Yes	Yes	Yes	Yes
PairFE	NO	NO	Yes	Yes	Yes
Domestic	Yes	Yes	Yes	Yes	Yes
Global	No	Yes	No	Yes	No

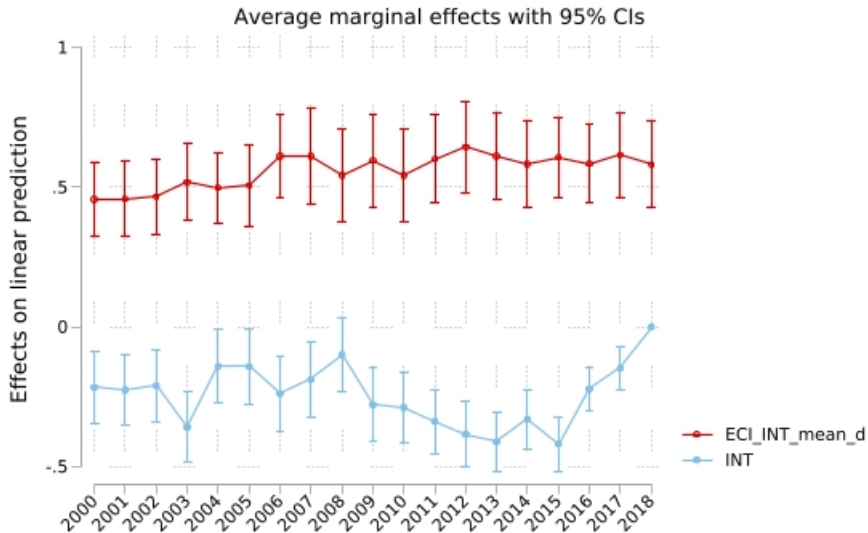
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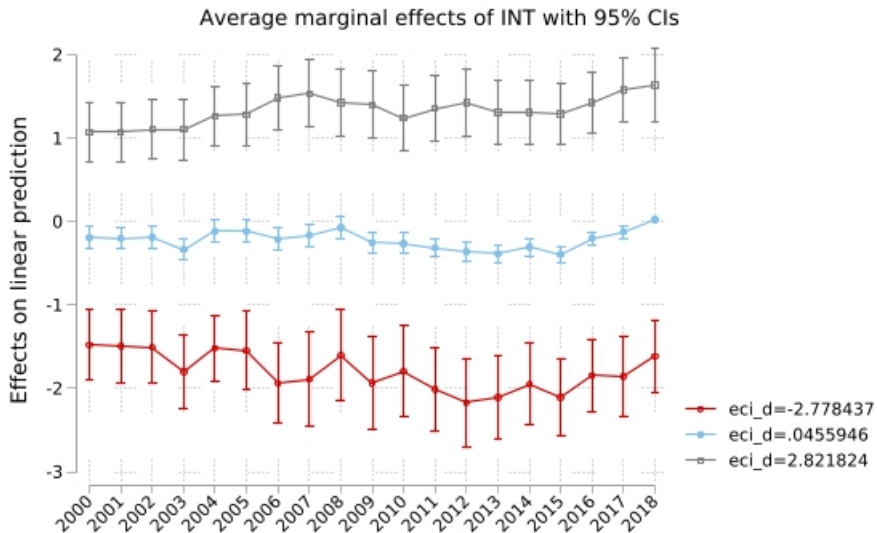
## Globalization



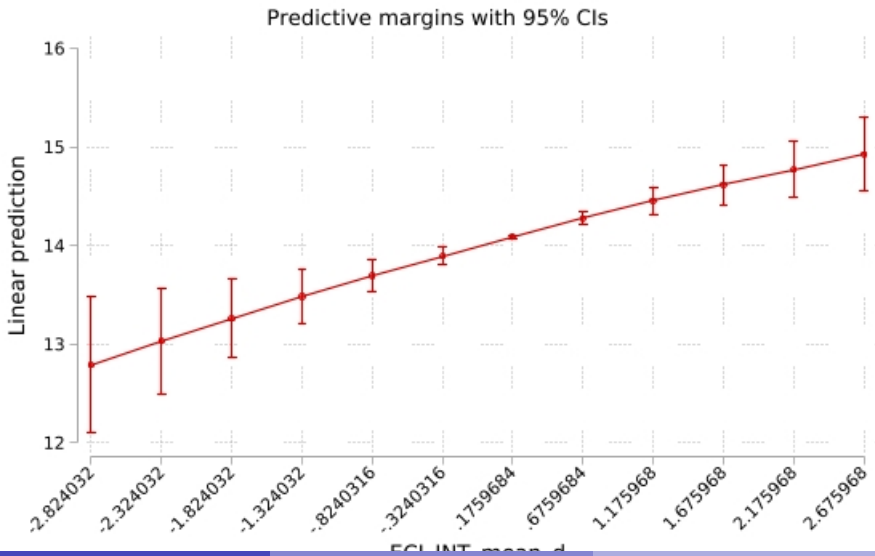
## Globalization &amp; average complexity



## Globalization by complexity levels



## Has complexity gone too far?



## IV using capital announcements as an instrument

Dep. Variable →	(1) First stage (OLS) $ECI_{jt} \times BRDR$	(2) Second stage (OLS) $\text{asinh}(\text{trade})$
$FDI_{i \neq jt} \times BRDR$	0.004*** (0.0002)	
$\hat{ECI}$		5.416** (0.01)
Observations	542575	4455
ImpxYearFE	Yes	Yes
ExpYearFE	Yes	Yes
PairFE	Yes	Yes
Global	Yes	Yes
Cragg-Donald Wald F	547	
Anderson LM statistic	585***	

Robust standard errors in parentheses, clustered by country pair

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

# General Equilibrium effects

GEPPML: Anderson et al (2018) » GE with Structural gravity

- GEPPML uses a useful property of PPML (Fally 2105) to recover consumer and producer prices from MRT
  - PPML translate the initial response of factory-gate prices into changes in the gravity fixed effects
  - Endogenizes the value of output to estimate a structural GE gravity counterfactuals
- GEMPPML needs internal trade data (for total output and expenditure)

# General Equilibrium effects

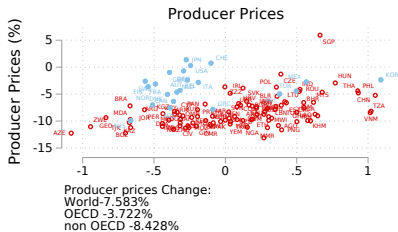
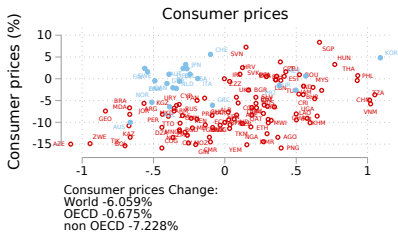
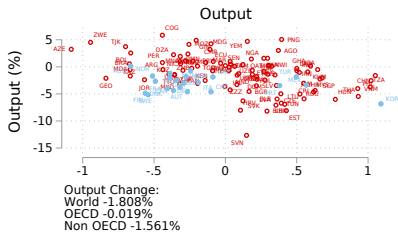
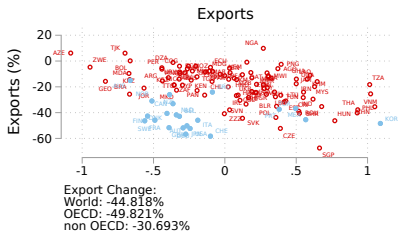
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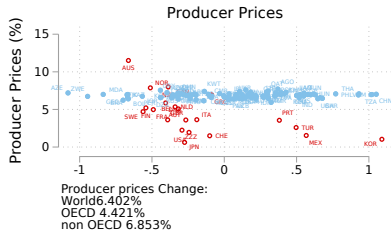
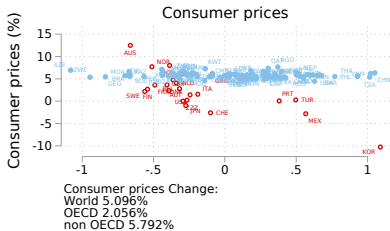
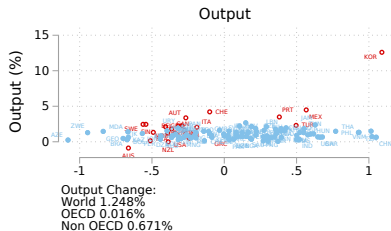
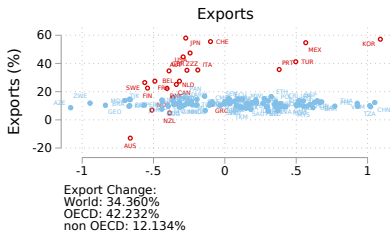
Reversal of Fortunes

Complexity in 1995 2018

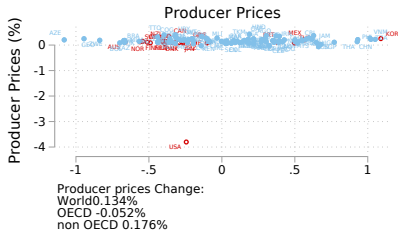
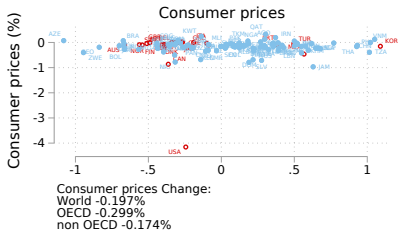
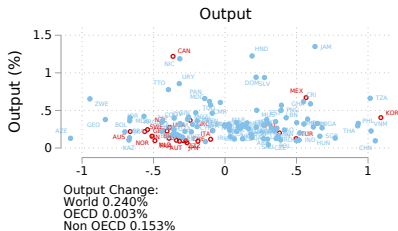
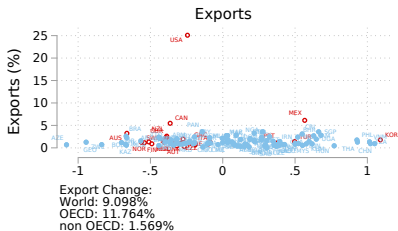


## Back to the future

## OECD Complexity in 1995 2018

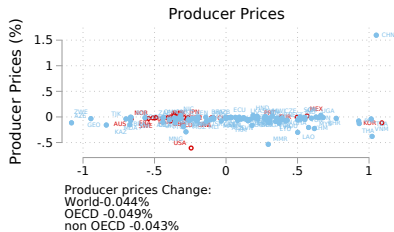
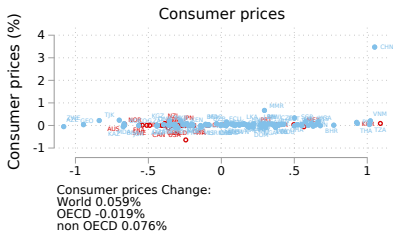
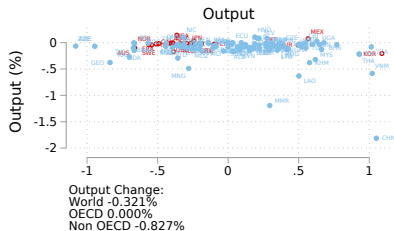
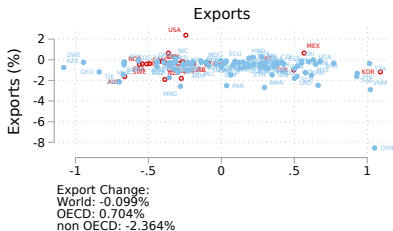


## USA Complexity in 1995 2018



## Bring Back Jobs (from China)

## USA &amp; CHN Complexity in 1995 2018



# Take-aways

- 1 **First course:** We can explain the effect of complexity on trade and output with a simple Ricardian model
  - 1 Complexity shifting increases output and trade up to a threshold
  - 2 Complexity increasing in the West increases output and trade, but changes the threshold
- 2 **Second course:** I use structural gravity to estimate the effects of increasing complexity on trade
  - 1 There seems to be room for more complexity shifting
- 3 **Dessert:** I use GE Counterfactuals to test the model predictions on output and prices
  - 1 Complexity shifting has increased world's GDP
  - 2 Increasing complexity in the west increases and tilt's world GDP
  - 3 Complexity shifting in USA and CHN comes at the expense of American consumers
- 4 **In the menu:** FDI, migration

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# Structural Gravity equation

▶ back

$$X_{ij} = \left( \frac{t_{ij}}{\pi_i P_j} \right)^{1-\sigma} Y_i E_j, \quad (4)$$

$$P_j^{1-\sigma} = \sum_i \left( \frac{t_{ij}}{\pi_i} \right)^{1-\sigma} Y_i, \quad (5)$$

$$\pi_i^{1-\sigma} = \sum_j \left( \frac{t_{ij}}{P_j} \right)^{1-\sigma} E_j, \quad (6)$$

$$P_j = \frac{Y_j^{\frac{1}{1-\sigma}}}{\chi_j \pi_j}. \quad (7)$$

where  $P_j$  is the CES consumer price index given by  $P_j = \left[ \sum_i (\chi_i P_{ij})^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$ .  
Empirically (3) becomes:

$$X_{ij} = \exp(\tau_{ij} + \pi_i + \chi_j) \times \varepsilon_{ij} \quad (8)$$

## GEPPML

▶ back

- For our counterfactual analysis, we rely on the structure of the theoretical model described above and PPML's property highlighted by Fally (2015 JIE) that the estimates of the fixed effects from gravity estimations are perfectly consistent with the structural gravity terms.
- The MRT  $\Pi_i^{1-\sigma}$  and  $P_j^{1-\sigma}$  can be recovered from the fixed effects as follows:

$$\widetilde{\Pi}_i^{1-\sigma} = E_0 Y_i \exp(-\widetilde{\pi}_i), \quad (9)$$

and

$$\widetilde{P}_j^{1-\sigma} = \frac{E_j}{E_0} \exp(-\widetilde{\chi}_j), \quad (10)$$

where  $\widetilde{\pi}_i$  and  $\widetilde{\chi}_j$  are the estimated fixed effects from Equation (8), and  $E_0$  denotes the expenditure of the country chosen as numéraire.

▶ back

- The three-step GEPPML procedure from Anderson et al., (2018), uses equations (4), (9) and (10) to calculate counterfactual effects by changing the trade cost vectors and then obtain counterfactual values for
  - output,  $Y_i^c = (p_i^c/p_i) Y_i$ ,
  - expenditures,  $E_i^c = (p_i^c/p_i) E_i$
  - trade flows,  $\tilde{X}_{ij}^c$ .
  - consumer and producer prices (  $(\widetilde{\Pi}_i^{1-\sigma})^c$  and  $(\widetilde{P}_j^{1-\sigma})^c$  )
- The reported results are then the percentage changes between baseline and counterfactual values, i.e., for output
 
$$\text{Output}\% = (Y_i^c - Y_i)/Y_i \times 100.$$