Who gains from imported technology?

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Large aggregate gains from trade

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In absence of randomized control trials for trade policy, we can rely on natural experiments, in which trading opportunities changed suddenly, while tastes and technologies remained the same.

1. Jeffersonian self embargo of U.S. trade (1808-09)
2. Meiji restoration in Japan (1859-75)
3. Closure of the Suez Canal (1967-75)
4. The age of aviation (1960-95)

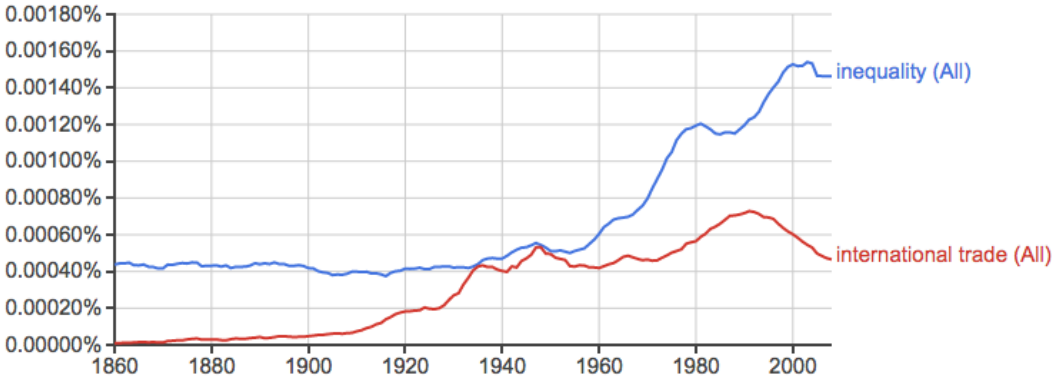
Aggregate loss from halving trade

Period	Geography	Percentage GDP loss from halving trade
1808–09	USA	2–3%
1854–75	Japan	3–5%
1967–75	Europe–Asia	10–16%
1960–95	World	25–35%

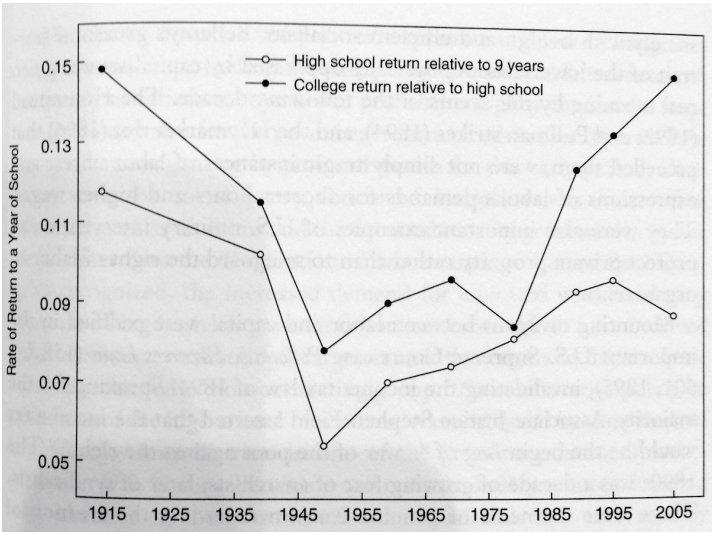
Based on Irwin (2005), Bernhofen and Brown (2004, 2005), Feyrer (2009a, b).

Note: Reduced-form estimates are much bigger than model-based estimates (Alvarez and Lucas, 2007; Arkolakis, Costinot, Rodriguez-Clare, 2010: 0.5–1%).

Interest in inequality is increasing (Google Books)

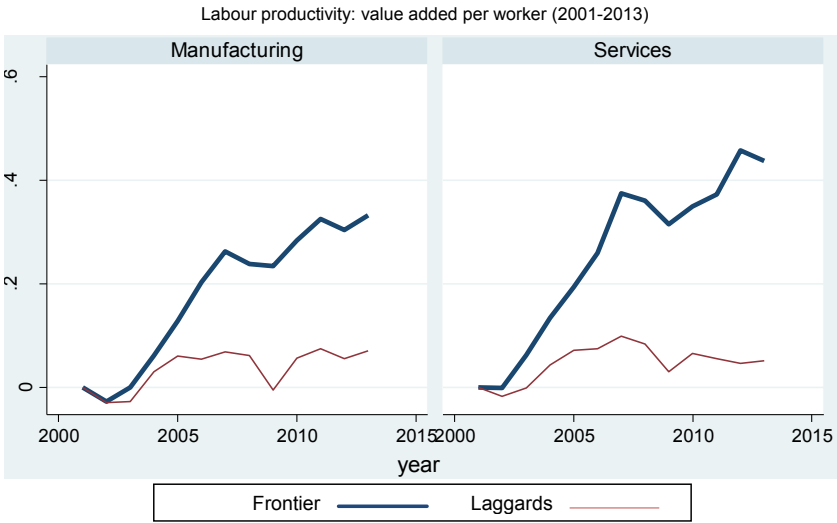


High-school and college wage premia have increased (Goldin and Katz, 2008)

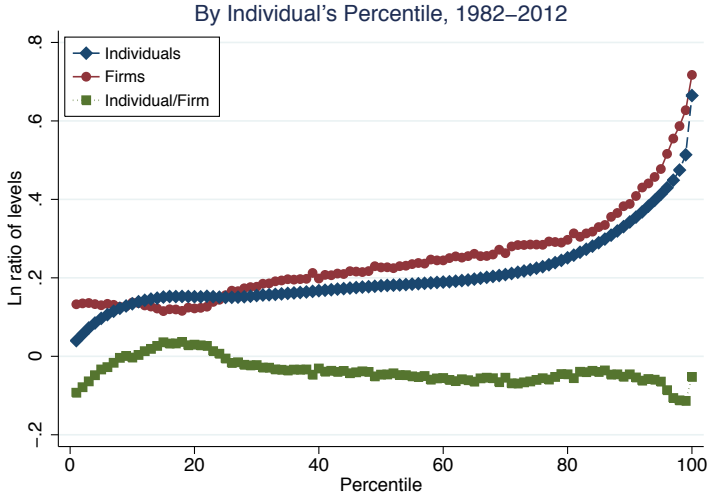


Share of top 10% in U.S. market income (Bourguignon, 2015)

The gap between frontier and laggard firms is widening (Andrews, Criscuolo and Gal, 2016)



Wage inequality increased between, not within firms (Song et al, 2015)



Is it exports or imports?

$$Y = C + I + G + X - M$$

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but

$$Y = F(K, L, M)$$

Outline

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1. Motivation: trade improves GDP
   - focus on supply side (imports)
   - focus on unequal gains
   - focus on firms
2. Three effects of imports
   - intermediate inputs
   - technology embodied in capital
   - technological diversification
3. Open questions

Three effects of imports

1. Imported intermediate inputs (Halpern, Koren and Szeidl, 2015)
2. Technology embodied in imported machines (Halpern, Hornok, Koren and Szeidl, 2018; Koren, Csillag and Köllő, 2018)
3. Technological diversification (Koren and Tenreyro, 2013; Caselli, Koren, Lisicky and Tenreyro, 2018)

Imported intermediate inputs

How do imported inputs affect productivity?

- Different (price-adjusted) quality ($A > 1$).
- Imperfect substitution with domestic inputs ($\theta < \infty$).

$$X_{ji} = \left[(AX_{jiF})^{\frac{\theta-1}{\theta}} + X_{jiH}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

$$a = \frac{\log\left[1 + A^{\theta-1}\right]}{\theta - 1}$$

Combining bundles of different products

$$Q_j = \Omega_j K_j^{\alpha} L_j^{\beta} \prod_{i=1}^{N} X_{ji}^{\gamma_i},$$

$$q_j = \alpha k_j + \beta l_j + \gamma(m_j - \rho) + a\gamma G(n_j) + \omega_j \qquad (1)$$

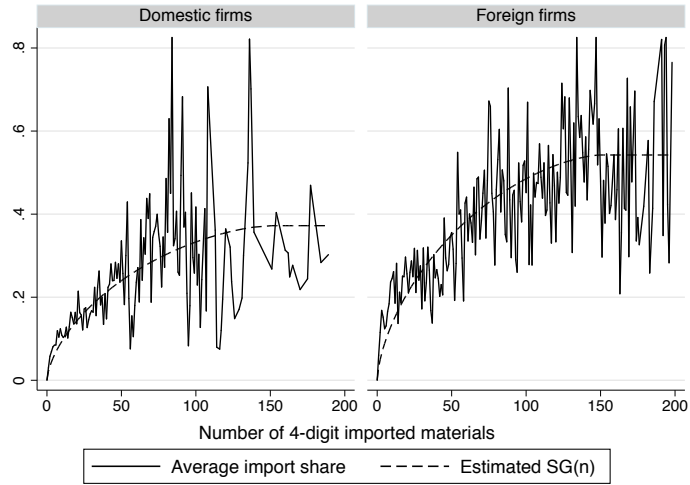
- n_j: number of products the firm imports, $G()$: increasing, concave function
- Estimate (1) in Hungarian manufacturing data 1992–2003.
- Conduct counterfactual simulations.

All firms gain from importing, but foreign firms gain more

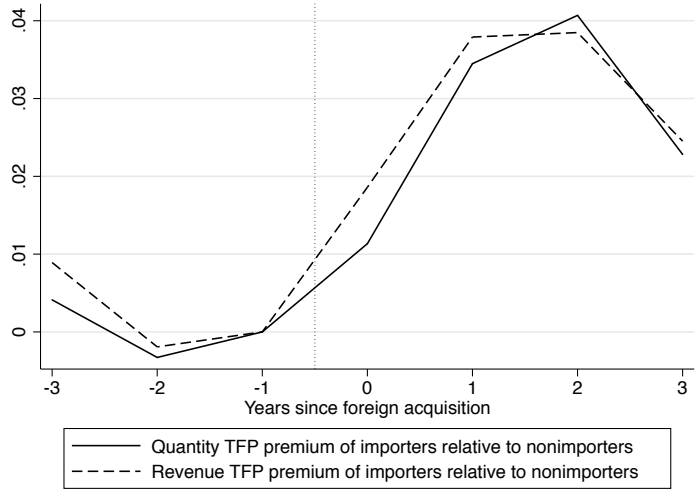
	Baseline		Conditioning on exporter	
	(1)		(2)	
Dependent variable: log sales	Domestic	Foreign	Domestic	Foreign
Per-product import gain (a)	0.271 (0.063)	0.390 (0.068)	0.213 (0.057)	0.314 (0.063)
Import share (S)	0.490 (0.052)	0.621 (0.042)	0.486 (0.052)	0.625 (0.045)
Efficiency of imports (A)	0.984 (0.083)	1.220 (0.072)	0.982 (0.066)	1.178 (0.061)
Elasticity of substitution (θ)	3.484 [2.753;5.004]		4.118 [3.135;6.712]	
Foreign owned	0.066 (0.015)		0.061 (0.014)	
Exporter			0.045 (0.006)	
Observations	127,472		127,472	

Notes: All specifications use the structural estimation procedure of Section 4. Bootstrapped standard errors clustered by firm are in parenthesis. For the elasticity of substitution (theta) we report a 95 percent confidence interval computed the same way in brackets.

Foreign firms spend more on imported inputs



After foreign acquisition, importers become even more productive



Trade liberalization increases aggregate TFP by 0.8–2.9 percent

Panel A

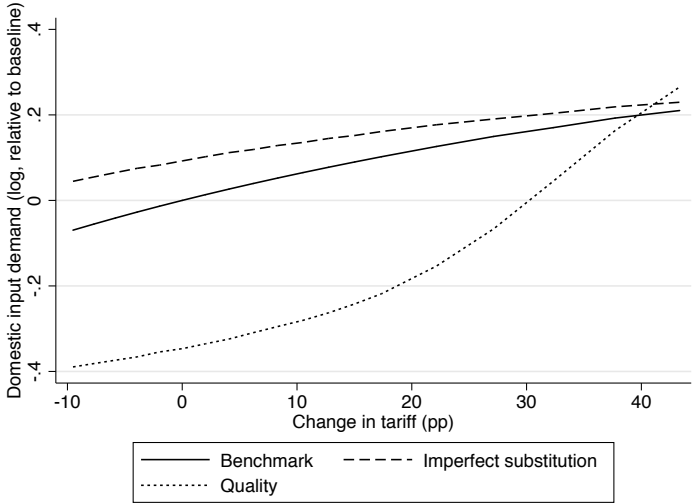
Tariff reduction (percent)	No firms foreign (percent)	Baseline (percent)	All firms foreign (percent)
40 to 30	0.8	1.3	1.6
10 to 0	1.6	2.5	2.9

Panel B

Tariff reduction (percent)	High fixed cost (percent)	Baseline (percent)	Low fixed cost (percent)
40 to 30	1.2	1.3	1.5
10 to 0	2.2	2.5	2.7

Notes: Table reports changes in aggregate TFP in our simulated economy in response to a 10 percentage point tariff reduction under various scenarios. High fixed costs are 3 times the baseline and low fixed costs are 1/3 of the baseline for each firm in the simulated economy.

Domestic suppliers do not lose much from trade liberalization



Technology embodied in capital

Questions

1. Are firms importing capital more productive?
2. Is foreign R&D embodied in capital imports?

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Coe and Helpman (1995) at the firm level.

Technology

- Production function is Cobb–Douglas in stock of R&D and labor:

$$Y_{it} = \Omega_{it} R_{it}^{\alpha} L_{it}^{\beta}.$$

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1. Ω_{it} is TFP independent of importing decision.
2. R_{it} captures
   - domestic capital,
   - imported capital,
   - and their R&D content.

Measuring R&D content

- What is the R&D content of a machine?
- We take each machine to be representative of the machinery industry in *their source country*.
- Use industry-level R&D data from OECD countries (Acharya and Keller, 2008).
  - Expenditure on R&D in the machinery sector,
  - divided by total revenue in the same.

R&D expenditure ratio of various countries

		import share	R&D intensity			import share	R&D intensity
1.	Sweden	1.0	23.0	17.	Norway	0.1	8.8
2.	United States	3.8	18.2	18.	Australia	0.0	7.8
3.	France	3.4	17.8	19.	Italy	5.5	6.3
4.	Israel	0.1	17.3	20.	Ireland	0.3	5.9
5.	Estonia	0.2	15.0	21.	Czech Republic	0.9	5.4
6.	Finland	0.6	14.9	22.	Slovenia	0.2	5.0
7.	Japan	7.6	14.6	23.	Spain	1.4	4.7
8.	Netherlands	1.4	14.4	24.	Greece	0.0	3.9
9.	Germany	35.9	12.1	25.	Switzerland	1.1	3.8
10.	Austria	8.8	12.1	26.	Romania	0.3	3.4
11.	South Korea	1.8	11.5	27.	New Zealand	0.0	3.0
12.	Canada	0.3	10.5	28.	Poland	0.8	2.6
13.	United Kingdom	2.5	10.0	29.	Turkey	0.1	2.2
14.	Belgium	1.8	9.6	30.	Slovakia	0.6	2.2
15.	Iceland	0.0	9.4	31.	Portugal	0.5	2.1
16.	Denmark	0.3	9.1	32.	Mexico	0.8	0.4

Source: OECD, Eurostat and authors' calculation. R&D intensity is business R&D expenditure over value added in 1992-2003 and industries NACE 29-35. Countries sorted by R&D intensity.

R&D expenditure is correlated with unit value of machines

Dependent variable: log value per quantity unit		
R&D intensity (32 countries)	0.0364***	
	(0.0012)	
R&D intensity (all countries)		0.0512***
		(0.0015)
6-digit product effects	yes	yes
Year effects	yes	yes
Adj.R^2	0.4645	0.4615
N	2,648,509	2,914,621

Notes: Log import value per unit quantity is regressed on the R&D intensity of source country's machinery sector by OLS with 6-digit product and year dummies. Sample is machinery imports of Hungarian manufacturing firms in years 1992-2003. Robust standard errors with product clusters in brackets.

Flow of R&D

- Measure R&D expenditure per sales in country c, λ_c.
- The flow of R&D:

$$F_{it} = \sum_c \lambda_c M_{ict}.$$

- This reflects total imports, as well as its country composition.
- Note: foreign and domestic capital are perfect substitutes (for now).

Stock of R&D

- Cumulate R&D flow using the perpetual inventory method.

$$R_{it} = (1 - \delta)R_{it-1} + F_{it}$$

- The R&D content of capital

$$\Lambda_{it} = \frac{R_{it}}{K_{it}},$$

  is a weighted average of country-level λ_cs.

Descriptives

1. Between 40-50% of firms have any imported capital. This has increased over time.
2. Among those that do, import accounts for around 25% of their fixed assets. Stable over time.
3. The mean R&D content of imported capital is around 3%. Stable over time.

Estimating equation

- Production function can be written as

$$Y_{it} = \Omega_{it} \Lambda_{it}^{\alpha} K_{it}^{\alpha} L_{it}^{\beta}.$$

- Conditional on the *book value of capital*, K_{it}, productivity is increasing in R&D content.
- This leads to the following estimating equation

$$y_{it} = \alpha_1 \lambda_{it} + \alpha_2 k_{it} + \beta l_{it} + \omega_{it}.$$

- We estimate this by firm fixed effects (for now).

Imported R&D improves productivity

	(1)	(2)	(3)
Dependent variable: log value added			
R&D content of capital		0.100***	0.086***
		(0.011)	(0.011)
Capital stock	0.172***	0.176***	0.170***
	(0.005)	(0.005)	(0.005)
Employment	0.667***	0.664***	0.648***
	(0.010)	(0.010)	(0.010)
Firm has foreign owner	0.027	0.022	0.014
	(0.021)	(0.021)	(0.021)
Firm imports materials			0.120***
			(0.010)
Firm is an exporter			0.123***
			(0.011)
Observations	99.816	99.816	99.816
Number of firms	24.316	24.316	24.316
Within R-squared	0.283	0.285	0.289

Standard errors (in parentheses) are clustered by firm. All specifications include firm fixed effects and common time dummies. *** p<0.01, ** p<0.05, * p<0.1

Complementarity with other inputs

- But imported capital may be complementary with other inputs of production.
  - intermediate inputs
  - workers
- Complementarity may magnify inequality (Jones 2011).

Capital importers buy more intermediate inputs from the same country

Dependent variable: Firm imports material dummy	(1)	(2)	(3)
After capital imports	0.051***	0.047***	0.037***
	(0.002)	(0.002)	(0.003)
After x Top 10 R&D		0.010***	
		(0.004)	
After x Top 20 R&D			0.022***
			(0.003)
Observations	363,371	363,371	363,371
Number of groups	39,424	39,424	39,424
Within R-squared	0.088	0.088	0.088

Notes: Firm-country fixed effects and common time dummies included. Additional regressors: employment (log), foreign dummy, exporter dummy. Sample includes firms that became capital importers between 1992-2003. Robust standard errors (in parentheses) are clustered by firm-country groups.
*** p¡0.01, ** p¡0.05, * p¡0.1

Data on workers

- Linked employer-employee data for Hungary, 1992–2004.
  - rapid trade liberalization
  - only 7 percent sample
- Import data: 290 specialized manufacturing machines (1/3 of imported capital).
- Worker data: 53 machine operators occupations (1/10 of employment).
  - hand matching on classification

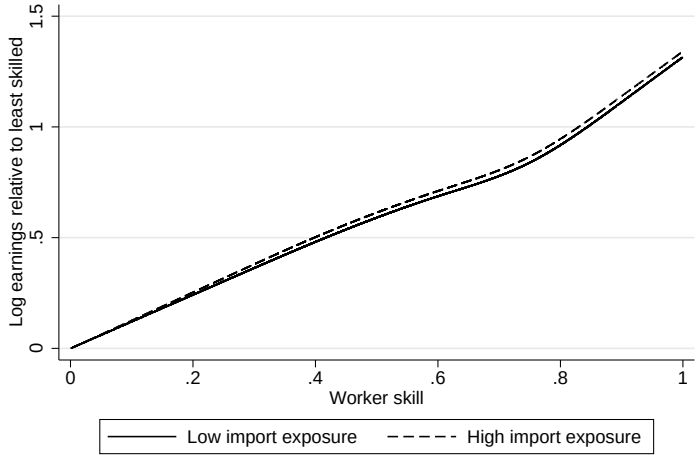
Tags used for machines and occupations

agriculture, *assembly*, *basic metals*, *beverage*, *cement and concrete*, *ceramics*, *chemicals*, *cleaning*, *construction*, *electric*, *fabricated metals*, *food*, *glass*, *heating and cooling*, *leather*, *mining*, *moving*, *oil and gas*, *other*, *packaging*, *paper*, *pharmaceuticals*, *plastic*, *power*, *printing*, *radiation*, *rubber*, *stone and minerals*, *textile*, *tobacco*, *vehicle*, *vessel*, *water*, *wood*

Operators exposed to imported machines earn more

	(1) Baseline	(2) Skill controls	(3) Firm controls	(4) IV
Worker exposed to imported machine (dummy)	0.055***	0.035***	0.021**	0.321***
	(0.016)	(0.010)	(0.011)	(0.066)
Firm is an importer (dummy)	0.019	0.011		-0.056
	(0.017)	(0.011)		(0.144)
Firm is foreign owned (dummy)	0.127***	0.075***		0.095**
	(0.017)	(0.011)		(0.024)
Book value of machinery (log)	0.086***	0.049***		0.072***
	(0.006)	(0.005)		(0.012)
R^2	0.517	0.715	0.863	0.496
Number of observations	61,173	61,173	61,173	61,173

Returns to skill increase with availability of imports



Graph shows wages as a cubic spline in worker skill, conditional on firm obversables, occupation and year fixed effects.

Summary

- Imported R&D has *large* effect on productivity.
- Buying all machines from Sweden (R&D content 8%) rather than Hungary (R&D content 0.5%) raises productivity by 30%.
- Preliminary evidence for complementarities.
- Needed: a model of imported machines with machine-material, machine-worker complementarities.

Technological diversification

Questions

1. Why are some firms more volatile than others?
2. Can technology choices affect volatility?

Technological diversification

- Larger firms tend to be more productive and less volatile (Hymer and Pashigian, 1962; Hall, 1987; Sutton, 2002)
- Possibly because they use many different types of inputs (Koren and Tenreyro, 2013)

$$y = A\left[\sum_{i=1}^{n} l_i^{1-1/\theta}\right]^{\theta/(\theta-1)} = Aln^{1/(\theta-1)}$$

- Model choice of multiple inputs, innovation (adding inputs): growth, firm-size distribution, volatility in spirit of Klette and Kortum (2004).

Diversification and volatility

$$\frac{\mathsf{Var}(dn/n)}{dt} = \frac{\lambda + \gamma}{n}$$

$$\frac{\mathsf{Var}(dY/Y)}{dt} = \gamma \sum_{k=1}^{\infty} s_k^2$$

Model yields plausible patterns of volatility over development (also across firms)

	Poisson parameter γ				Data	
	0.05	0.10	0.15	0.20	Maddison sample	All countries
Cross-sectional slope of volatility on development	−0.272 (0.101)	−0.262 (0.036)	−0.213 (0.033)	−0.169 (0.032)	−0.270 (0.056)	−0.205 (0.032)
Time-series slope of volatility on development	−0.487 (0.054)	−0.455 (0.056)	−0.402 (0.060)	−0.355 (0.066)	−0.421 (0.105)	−0.496 (0.073)
SD of log-GDP per capita in 1960	0.894 (0.436)	0.729 (0.069)	0.688 (0.058)	0.648 (0.053)	0.977	0.970
Percent variation in volatility due to a 1-SD increase in log GDP per capita	−24.4%	−19.1%	−14.6%	−10.9%	−26.4%	−19.9%

Diversification through trade

- The same should hold for imported inputs (remember, $\theta < \infty$).
- As firms diversify across supplier countries, volatility (may) go down.
- No closed-form solutions, simulate the world economy.
- On average, trade has reduced volatility between 1972 and 2007 by 33 percent. (But: small increases for Colombia, Greece, Italy, Japan.)

Conclusions

Open questions

1. Complementarity between trade and technology
2. New research designs based on new data

Complementarity between trade and technology

- Most studies focus on the competitive effect of trade: prices adjust, firms expand/shrink, worker income adjusts.
- In these explanations, trade liberalization and technical progress are alternative competitive forces.
- New approaches suggest complementarities between the two:
  - trading as an activity, quality needed to export (Hallak and Sivadasan, 2013, Boler, Moxnes and Ulltveit-Moe, 2015)
  - using imported technology (Koren, Csillag and Köllő, 2018, Halpern, Hornok, Koren and Szeidl, 2018)
- We need models to capture the precise nature of complementarities.

New research designs based on new data

- To study the heterogeneous effects of policy, micro data is needed on firms and workers.
- These are often collected outside traditional statistical agencies:
  - administrative data (social security, VAT filings)
  - business data (financials, transactions data, location tracking)
- Useful to analyze
  - full impact of policy (earnings, job loss, transfers, job transitions)
  - international linkages
  - long-run effects
- Some great examples of cross-country harmonization, but more work needed.

Concluding remarks

1. Imports are great.
   - improve productivity
   - increase complementary operator wages
   - serve as technological insurance

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1. Imports are great.
   - improve productivity
   - increase complementary operator wages
   - serve as technological insurance
2. But some gain more than others.
   - large, productive firms
   - foreign firms
   - skilled workers in complementary occupations