Comparative advantage in routine production

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Our starting point

- We want to understand why countries at a similar level of development and with similar factor endowments specialize in different types of goods
- We want to understand why countries with similar endowments appear to adjust very differently to the ongoing process of globalization and technological change
- Our approach:
  - → A key feature of both processes (trade integration & technological change) is that they trigger labor reallocation
  - → We know that labor reallocation is costly, our hypothesis is that the extent of barriers to worker mobility may be country-specific

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Main findings

- Theory:
  1. Comparative advantage predictions for countries that are identical in every respect, except for their ability to smooth labor reallocation
  2. Microfoundations for differential smoothing are in preparation
- Empirics:
  1. Characterizing industries by routine-intensity and countries by substitution elasticity passes 'sniff test'
  2. Countries differ starkly in the routine-intensity of their net exports
  3. Cultural or institutional differences predict this type of specialization

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  1. Institutional characteristics that facilitate labor market transitions may be a source of comparative advantage
  2. Workers benefit relatively more from technological change and trade integration in countries with flexible labor markets

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Roadmap

1. Literature review
2. The model
   - Nested CES production function
   - Equilibrium
   - Normalizing the CES
   - Comparative advantage predictions
   - Microfounding country-level differences in substitutability (to come)
3. Empirical evidence
   - Plausibility of parameter assumptions
   - Pattern of trade:
     Estimate country ranking in terms of routine-intensity of exports
   - Relate country ranking to country characteristics ('endowments')

Heckscher-Ohlin framework: importance of endowments

- Sectors differ in factor intensities (which are universal)
- Countries differ in endowments (which are fixed)
- Different relative autarky prices provide incentive for trade
  - Country endowed with a lot of X specializes in X-intensive good
- Most important sources of comparative advantage may be man-made
  - Porter (1990): Country with strong universities specializes in knowledge-intensive goods
  - Nunn (2007): Country with strong rule of law specializes in contract-intensive goods (which use a lot of differentiated inputs)
  - Costinot (2009): Country with high-quality workforce specializes in complex goods (which require a lot of training to master many tasks)

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Labor market perspective: importance of K-L substitution

- Labor literature on job polarization & technical change:
  - Technological change (innovation) leads to labor displacement from routine tasks (Autor, Levy, Murnane, 2003; Acemoglu & Autor, 2013)
  - Strong employment protection laws discourage firms from investing in high-risk, high-return projects (Bartelsman, Gauthier, De Wind 2016)
  - Dynamic: labor has comparative advantage in new tasks $\rightarrow$ opposite effects of automation and innovation (Acemoglu & Restrepo, 2016)
- Related applications:
  - Macro: high K-L substitutability becomes more valuable once countries have accumulated more K $\rightarrow$ leads to higher GDP per capita (Klump et al., 2000)
  - Trade: strength of financial institutions leads to investment in higher-risk, higher-return projects (Bonfiglioli et al., 2016)

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The structure of production

- We borrow two-tiered production function from the labor literature
- Production technology of final goods is Cobb-Douglas

$$Y_g = z\, A_g^{1-\beta} M_g^{\beta}$$

- Abstract tasks are carried out by non-routine labor $A_g = L_g^a$
- Routine tasks are produced with CES production function

$$M_g = Z \left[\alpha \left(K_g\right)^{\mu} + (1-\alpha)\left(L_g^m\right)^{\mu}\right]^{1/\mu}$$

- Standard assumptions:
  - Routine-intensity β is sector, but not country-specific $\rightarrow$ β_g
  - $\mu \in [0,1]$, such that elasticity of substitution $\sigma = (1-\mu)^{-1} > 1$

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Two-tiered production function

- Assumptions of sector-specific β_g and country-specific σ_i lead to

$$Y_{ig} = z^{\prime} \left(L_{ig}^{a}\right)^{1-\beta_g} \left[(1-\alpha)(L_{ig}^{m})^{\mu_i} + \alpha(K_{ig})^{\mu_i}\right]^{\frac{\beta_g}{\mu_i}}$$

- Solve in 2 steps

1. Assume existence of competitive routine input sector, $M_{i1} + M_{i2} = [\cdots]^{\frac{1}{\mu_i}}$. Get equilibrium factor-ratio, or equivalently, the L_i^m/M_i ratio as a function of endowments and the relative price.
2. Standard Heckscher-Ohlin in final goods markets: utility maximization & cost minimization allocates $L_i^a (= \bar{L} - L_i^m)$ and M_i over the two sectors

1. Competitive routine input sector

- price = cost of production factors

$$P_i^m = \frac{1}{Z_i}\left[\alpha_i^{-\frac{1}{1-\mu_i}} r_i^{-\frac{\mu_i}{1-\mu_i}} + (1-\alpha_i)^{\frac{1}{1-\mu_i}} w_i^{-\frac{\mu_i}{1-\mu_i}}\right]^{\frac{\mu_i-1}{\mu_i}}$$

$\rightarrow$ Can express equilibrium conditions in $\left(\frac{w}{P^m}\right)$ or in $\left(\frac{w}{r}\right)$

- Capital is only useful in routine production; can solve directly for the factor supply equation (production factors for the final good sectors)

$$\frac{L_i^a}{M_i} = \frac{\bar{L} - L_i^m}{M_i} = f\left(\frac{\bar{L}}{\bar{K}}, \frac{w}{r}\right) = \frac{\frac{\bar{L}}{\bar{K}} - \left[\frac{w_i/(1-\alpha_i)}{r_i/\alpha_i}\right]^{-\frac{1}{1-\mu_i}}}{Z_i \alpha_i^{\frac{1}{\mu_i}} \left\{1 + \frac{w_i}{r_i}\left[\frac{w_i/(1-\alpha_i)}{r_i/\alpha_i}\right]^{-\frac{1}{1-\mu_i}}\right\}^{\frac{1}{\mu_i}}}$$

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2. Final good sectors (omitting country subscript i)

- Solving the model only requires allocating L_1^a and M_1 (need 2 equations)
  - (with $L_2^a = L^a - L_1^a$ and $M_2 = M - M_1$)
- F.o.c. in utility maximization, assuming Cobb-Douglas utility (with θ_g)

$$\frac{Q_1}{Q_2} = \frac{\theta_1}{1-\theta_1}\frac{P_2}{P_1}$$

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$$\frac{M_g}{L_g^a} = \frac{\beta_g}{1-\beta_g}\frac{w}{P^m} \qquad \text{for } g = 1,\ 2$$

$\rightarrow$ with PFs can solve for conditional factor demands $L_1^a = f\left(Y_1, \frac{w}{P^m}, \beta\right)$,...

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- After some more algebra we find the (relative) factor demand equation

$$\frac{L_i^a}{M_i} = \frac{\sum_g \theta_g(1-\beta_g)}{\sum_g \theta_g \beta_g}\frac{P_i^m}{w_i}$$

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Price equilibrium

- Equating the factor demand and supply equations gives an implicit solution for the equilibrium factor price ratio $\omega_i^* = (w_i/r_i)^*$ as a function of endowments and parameters (preferences & technology)

$$\omega_i^* = c\left[\frac{\bar{L}}{\bar{K}} - (1+c)\left[\frac{1-\alpha_i}{\alpha_i}\right]^{\frac{1}{1-\mu_i}}(\omega_i^*)^{\frac{-1}{1-\mu_i}}\right]^{-1}$$

with $c = \frac{\sum_g \theta_g(1-\beta_g)}{\sum_g \theta_g \beta_g}$ and $\frac{\bar{L}}{\bar{K}}$ assumed not country-specific

Properties of CES function

- When predicting comparative advantage from comparative statics of $\frac{\partial(Y_1/Y_2)}{\partial\sigma}$ or $\frac{\partial(P_1/P_2)}{\partial\sigma}$, need to incorporate that $\frac{\partial\alpha}{\partial\sigma} \neq 0$
  - Note that equilibrium equation contained α_i

- CES is defined as production function with the following property:

$$\sigma = \frac{d\ln(K/L)}{d\ln(F_k/F_l)}$$

  - It can be re-written as second-order differential equation in $F(K, L)$; solution contains two integration constants
  - The elasticity of substitution is implicitly defined as a point elasticity, related to one particular point on one particular isoquant
  - Requiring a CES to go through one particular point, say $\{Y_0, K_0, L_0, w_0/r_0\}$, pins down the two integration constants: $\alpha_i(\sigma_i)$ & $Z_i(\sigma_i)$

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Work with normalized CES

- Klump, McAdam, Willman (2012):

(a) $$Y = Y_0 \left[(1 - s_0) \left(\frac{K}{K_0} \right)^{\mu} + s_0 \left(\frac{L^m}{L_0^m} \right)^{\mu} \right]^{\frac{1}{\mu}} \quad \text{with } s_0 = \frac{w_0 L_0^m}{Y_0}$$

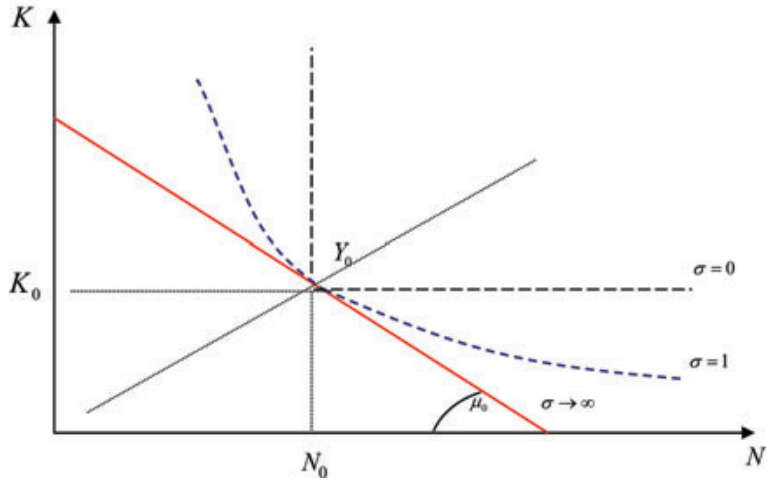

Figure 1. Isoquants of Normalized CES Production Functions.

(b) or substitute $\alpha(\sigma_i) = \dfrac{(K/L)^{1-\mu_i}}{(K/L)^{1-\mu_i} + \omega_i}$ and $Z(\sigma_i) = \ldots$

Comparative advantage predictions

- Comparative advantage depends on factor abundance
- σ in the CES is inherently a property about adjustment: it dampens the factor price reduction needed to fully employ the abundant factor

$$\frac{\partial w/r}{\partial \sigma} < 0 \quad \text{if } \frac{w/(1-\alpha)}{r/\alpha} > 1, \quad \text{i.e. if labor is expensive (scarce)}$$

$$\frac{\partial w/r}{\partial \sigma} > 0 \quad \text{if } \frac{w/(1-\alpha)}{r/\alpha} < 1, \quad \text{i.e. if labor is cheap (abundant)}$$

- If labor is scarce (in both countries), the high-σ country specializes in the non-routine intensive sector. It can fully employ capital, with a limited increase in the w/r ratio (decrease in r/w). Hence the P^M/w ratio falls less and abstract labor remains relatively affordable
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Implications

- Comparative statics on changes in w/r, imply changes in w/P^M that go in the same direction

$$L \text{ scarce} \quad \Rightarrow \quad \frac{\partial w/r}{\partial \sigma} < 0 \quad \Rightarrow \quad \frac{\partial w/P^M}{\partial \sigma} < 0 \quad \Rightarrow \quad \text{specialize in non-}M$$

- Capital deepening tilts comparative advantage in the high-σ country towards the non-routine intensive sector
  - If it had a comparative advantage there: it strengthens
  - If it had the reverse comparative advantage: scope for trade weakens
  - If it had no comparative advantage initially: capital deepening creates it

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Thought experiment

- Initially, two countries produce the same output bundle
  - Implicitly normalizes the CES function
  - No scope for trade between identical countries; prices have adjusted to support the allocation in consumption & production

- Add capital to both countries (or make capital more productive)
  - to clear K market: r falls, relative wage ω_i increases
  - change is most pronounced in the low-σ country

  $\rightarrow$ makes L relatively expensive in the low-σ country

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Intuition from labor adjustment

- Extra K can only be deployed in the production of routine tasks, freeing up labor to be redeployed in abstract tasks
  - $\Delta L^a = -\Delta L^m > 0$
  - ΔL^a is absorbed by shifting the output ratio towards the non-routine intensive sector
- This adjustment is easier and goes furthest in the high-σ country
  - that is the key property of σ in the CES production function: there is less of a productivity penalty if factor ratios move away from equality
- For product markets to clear, the relative price of the non-routine intensive good falls (or increases less), relative to the low-σ country
- The high-σ country becomes an exporter of the non-routine intensive good
  - the factor price ratio w/P^m equalizes through a divergence in the K/L ratio in routine production

Possible mechanisms to micro-found (low) σ

$$\text{Recall} \quad \sigma = \frac{d \ln(K/L)}{d \ln(F_k/F_l)}$$

- Simplest mechanism: Variation in severance pay incurred by the firm
- Labor market rigidities—e.g. mobility costs, rigid work practices, search costs—drive a wedge between average and marginal wages and reduce adjustments to shocks
- Legal obligation to retrain workers after termination to split burden of educating workers who transition from L^m to L^a between the firm and society at large (financed by taxes)
- In countries with low bargaining power for labor, workers can appropriate less of the returns to (K-biased) innovations and firms will choose more risky projects (as they can adjust K/L to take advantage of innovations)

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Two-tiered production function

- Assumptions of sector-specific β_g and country-specific σ_i lead to

$$Y_{igt} = z' \left(L^a_{igt}\right)^{1-\beta_g} \left[(1-\alpha)(L^m_{igt})^{\mu_i} + \alpha(K_{igt})^{\mu_i}\right]^{\frac{\beta_g}{\mu_i}}$$

- Verify whether there is empirical support for these assumptions
- Using EU-KLEMS data
  - For 20 countries, 33 sectors, 25 years
  - Assume high-skill workforce is L^a ($L^m = L - L^a$)
  - Calculate $\frac{L^a}{L^a+L^m}$ and ln $\left(\frac{K}{L^m}\right)$
  - Estimate β_{ig} and μ_{ig} exploiting only time-series variation
- ANOVA analysis provides support that
  - Country FE have most explanatory power for variation in ln $\left(\frac{K}{L^m}\right)$ & μ_{ig}
  - Sector FE have most explanatory power for variation in $\frac{L^a}{L^a+L^m}$ & β_{ig}

ANOVA

	Sum of squares				F-statistic (N,1)		
	Dep.Var.	Sector (33)	Country (20)	Year (25)	Sector (33)	Country (20)	Year (25)
(a) Observable variables							
$\frac{\overline{L^a}}{L^a+L^m}$	9.98	5.41	2.84		62.03	53.69	
		(54.2%)	(28.5%)		(0.00)	(0.00)	
$\ln\left(\frac{K}{L^m}\right)$	3843	466	789	1118	114.73	320.63	363.49
		(12.1%)	(20.5%)	(29.1%)	(0.00)	(0.00)	(0.00)
(b) Estimated parameters							
β_{ig}	25.52	5.30	2.67		6.03	5.01	
		(20.8%)	(10.5%)		(0.00)	(0.00)	
σ_{ig}	1636	191	217		1.03	1.93	
(if < 20)		(11.7%)	(13.3%)		(0.43)	(0.01)	

Reduced form evidence in two-step analysis

- We follow the 2-step approach of Costinot (2009):

Step 1: Retrieve pattern of specialization, i.e. ranking of countries in terms of routine versus non-routine intensity of (net) exports

Step 2: Explain country rankings using country characteristics that proxy for σ (institutional, cultural, organizational, labor-market features,...)

- Could do it in 1 step: regress exports on '$\text{sector}_g \times \sigma_i$-proxy'
  - Useful to gauge quantitative importance of this channel relative to other HO-inspired channels from the literature
  - E.g. Nunn (2007) and Chor (2010)

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Step 1: retrieve routine intensity of exports

- Estimate on two separate samples
  - 43 largest exporters i and all importers j (small countries are grouped)
  - Within EU trade
- Key explanatory variable: industry ranking w.r.t. routine intensity r_g
  - Using task codifiability ranking of Autor, Levy, Murnane (2003)
  - 140 US census industries, 77 in manufacturing
  - Correlated positively with skill intensity, but not identical ($\rho = -0.62$)
  - Matched to HS 4-digit trade data and aggregated to industry
- We run the following regression:

$$\ln EXP_{gij} = \tau_{ij} + \tau_{gj} + \gamma_i r_g + \epsilon_{gij}$$

  - ↪ Estimated separately for 1995, 2005, 2015 to see whether patterns are stable (using 2-year average exports to smooth outliers)
  - ↪ τ_{ij} captures bilateral barriers and exporter characteristics
  - ↪ τ_{gj} captures variation in import barriers and preferences
- CA pattern is given by ranking of exporter fixed effects: γ_i

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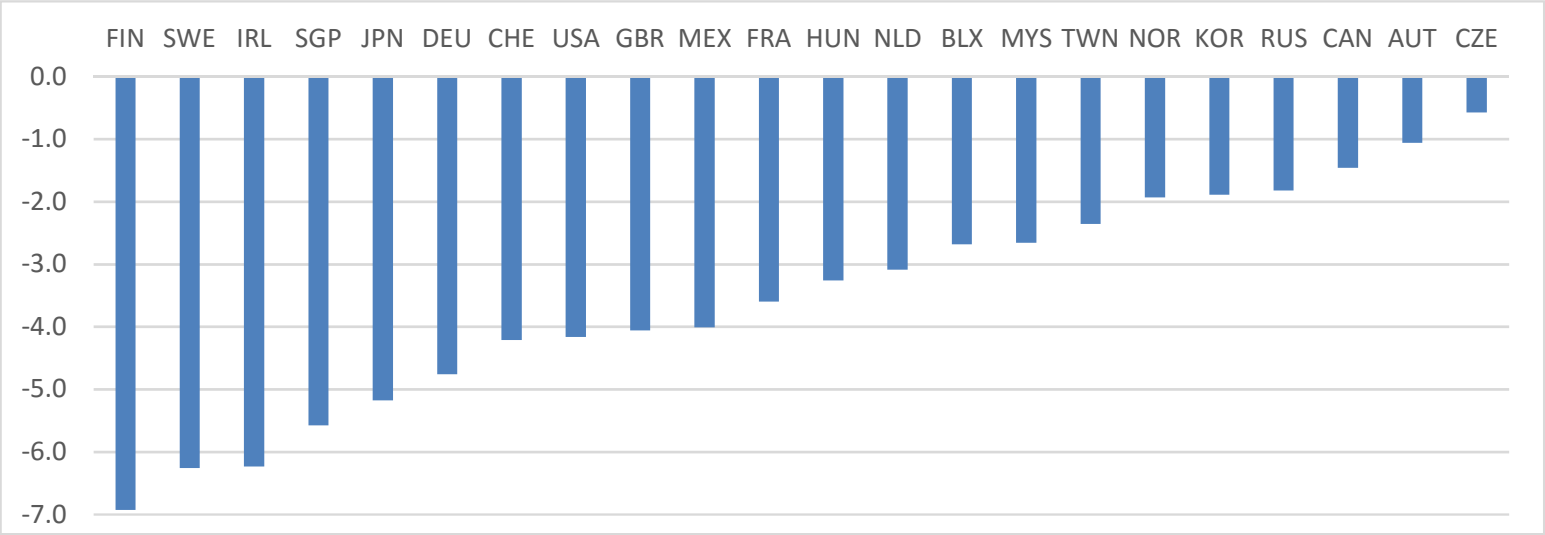
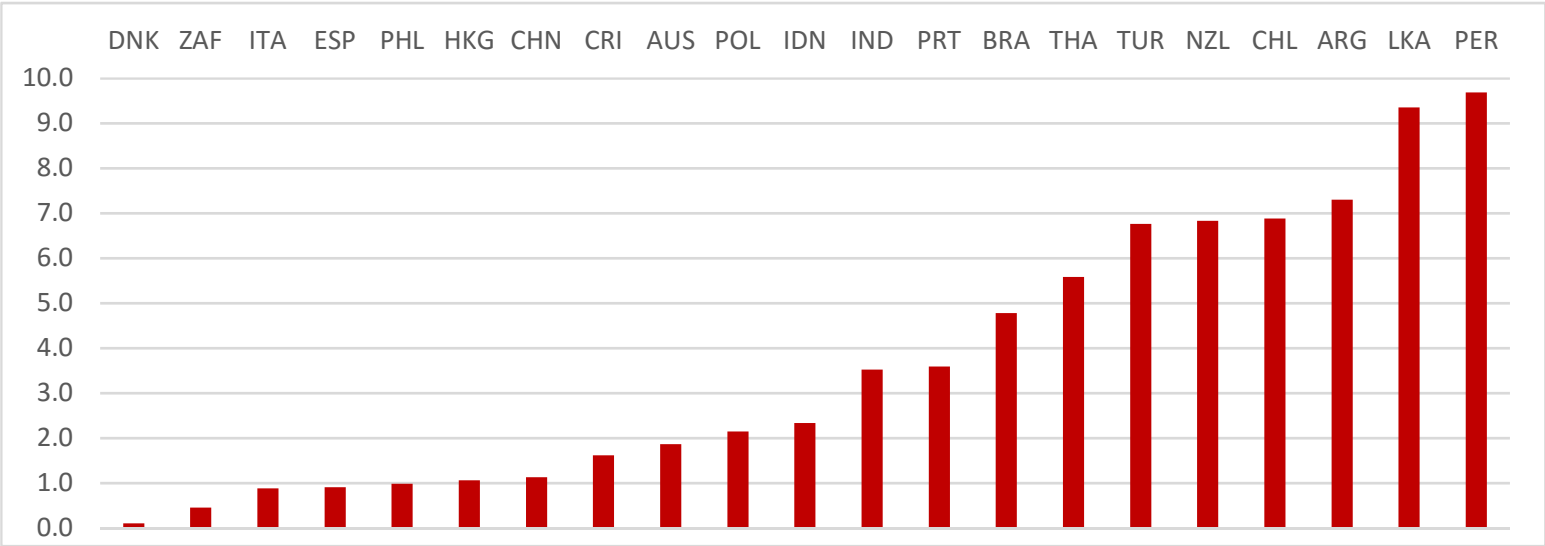
Country ranking in terms of routineness (γ_i) for 2005

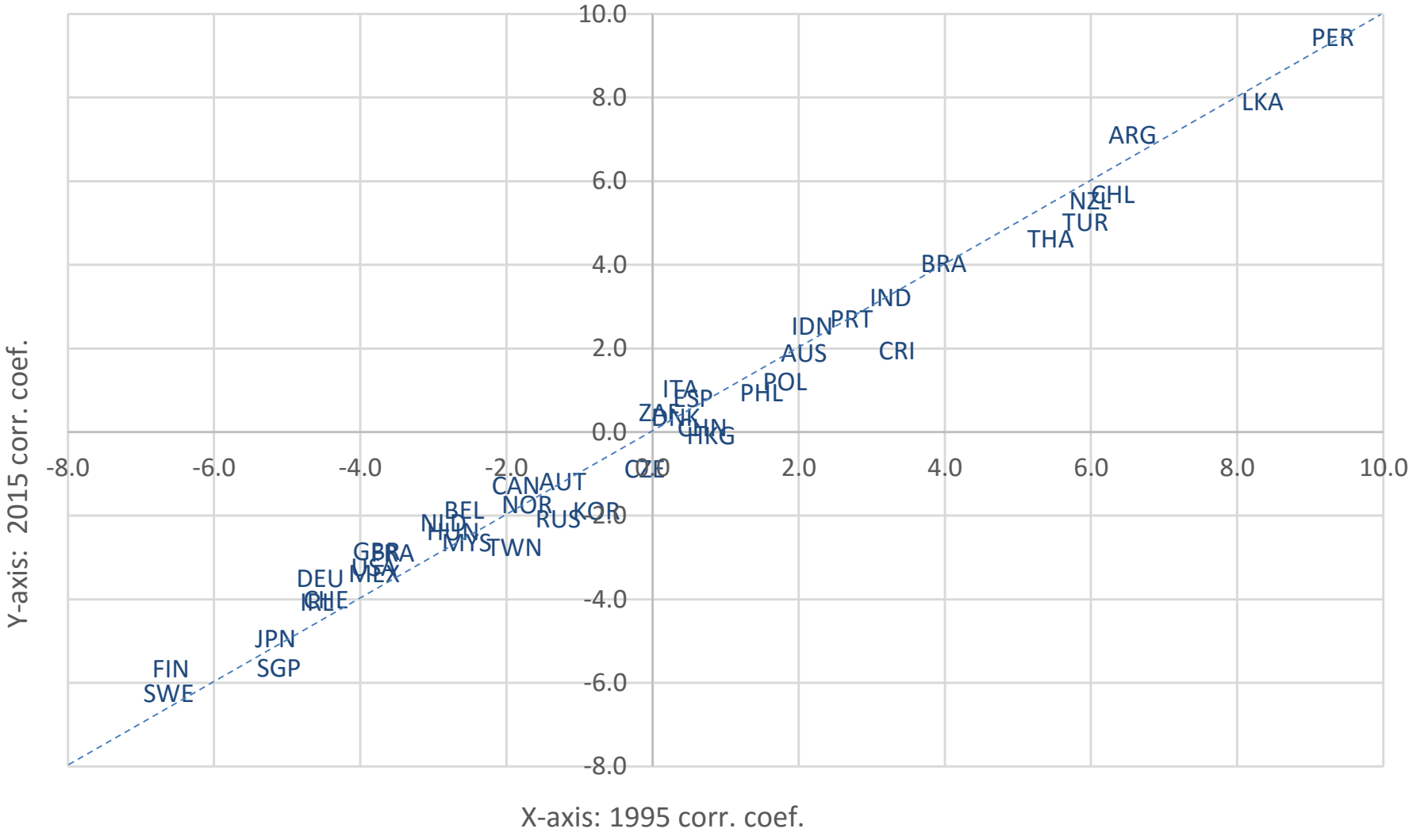
(a) Countries with negative correlation -- specializing in non-routine intensive industries



(b) Countries with positive correlation -- specializing in routine intensive industries

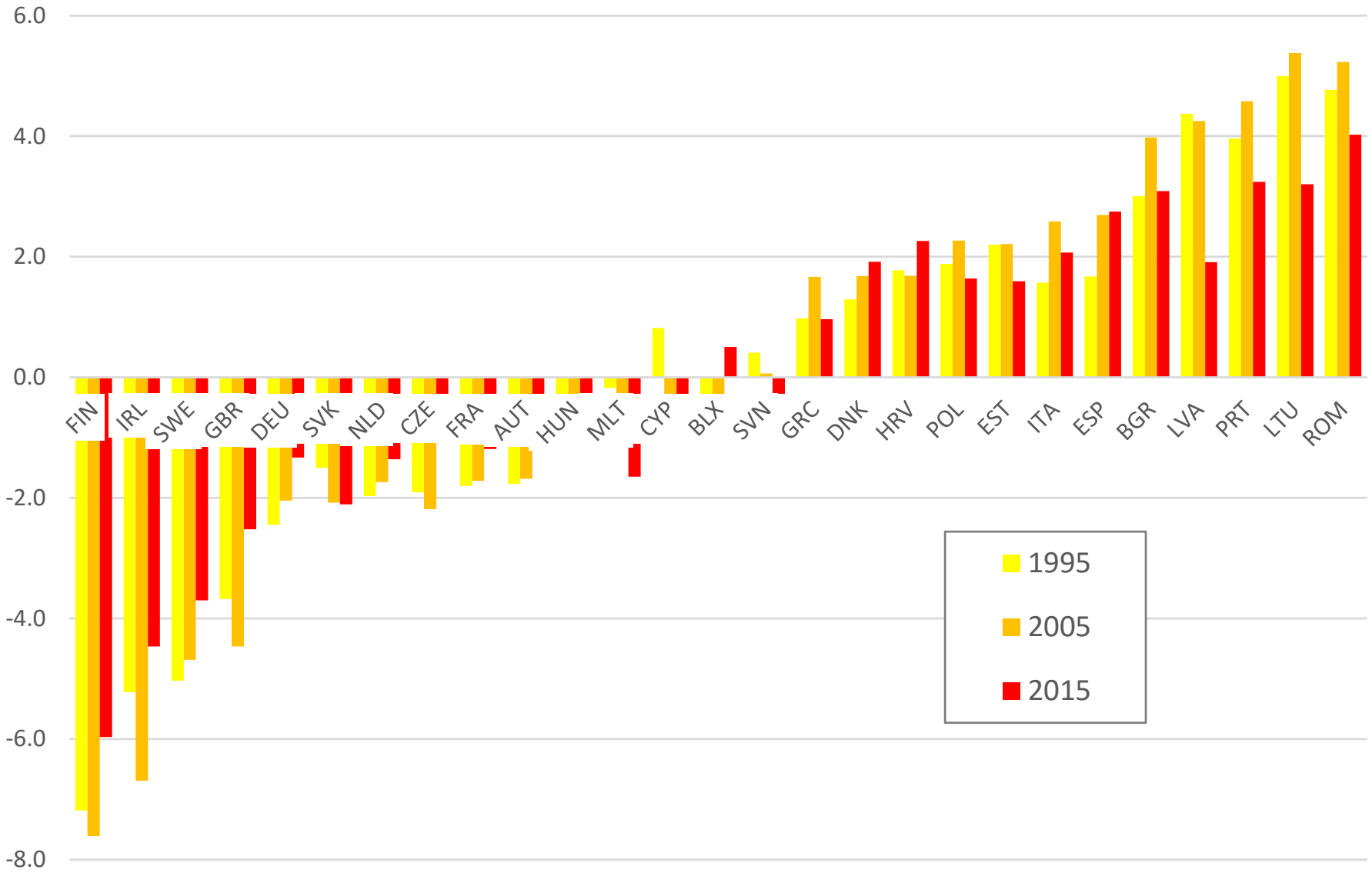


Evolution of routineness ranking (1995 versus 2015)



(Slight convergence or weakening of routiness-based comparative advantage)

Within EU ranking by routineness (γ_i)



(Large differences, but shrinking over time)

Step 2: connect pattern of CA to country characteristics

- Which institutional or cultural dimensions explain the cross-country variation in the routine-intensity of exports?
- We test the following dimensions (I_i)
  1. Quality of institutions: 'Rule of law'
  2. Quality of the workforce: 'Ability to perform' (Costinot, 2009)
  3. Cultural traits: LT orientation; 1/uncertainty avoidance (Hofstede, '80)
  4. Lack of frictions in other domain: 'Internal migration' (mobility)
  5. Labor market regulations: strictness of employment protection (OECD)
- We run the following regression:

$$\ln \hat{\gamma}_i \quad = \quad \delta_0 + \delta_1 I_i + \epsilon_i$$

↪ Recall that $\hat{\gamma}_i$ increases in routine-intensity of exports: expect $\delta_1 < 0$

Country characteristics that explain $\hat{\gamma}_i$ in full sample

	(1)	(2)	(3)	(4)	(5)
log(GDP/capita)	-0.619***	-0.168	-0.482***	-0.553***	-0.372*
	(2.7)	(0.8)	(4.0)	(3.3)	(1.7)
Rule of law	0.009				
	(0.1)				
Quality of workforce		-0.538***			
		(2.6)			
Hofstede/culture			-0.375***		
			(3.1)		
Internal migration				-0.195	
				(1.2)	
Strictness of EPL					-0.149
					(0.7)
Observations	43	43	42	26	26
Adjusted R^2	0.34	0.44	0.44	0.30	0.15

- Coefficients are standardized β coeff. that measure effects in SE, t-stats in brackets
- Without GDP/capita control, coefficient on 'Rule of law' is -0.512***
- Results similar in 1995/2015; using 1/SE as weights; controlling for Rule of law

Country characteristics that explain $\hat{\gamma}_i$ within EU

	(1)	(2)	(3)	(4)	(5)
log(GDP/capita)	-0.330	0.027	-0.632***	-0.264	-0.317*
	(1.1)	(0.1)	(4.1)	(1.2)	(1.8)
Rule of law	-0.384				
	(1.3)				
Quality of workforce		-0.569			
		(1.3)			
Hofstede/culture			-0.190		
			(1.2)		
Internal migration				-0.365	
				(1.6)	
Strictness of EPL					0.607***
					(3.4)
Observations	27	16	26	18	18
Adjusted R^2	0.43	0.19	0.43	0.18	0.45

- Coefficients are standardized β coeff. that measure effects in SE, t-stats in brackets
- Without GDP/capita control, all coefficients become (strongly) significant
- Except for 'Strictness of EPL' most magnitudes are similar to full sample results

What do we learn?

- We learn that institutions which facilitate labor reallocation across tasks may be a source of comparative advantage
  1. Countries that adjust more smoothly to technological change (e.g. better K) specialize in production of non-routine-intensive goods
  2. Workers in such countries benefit more from opening up to trade
- Way forward: connect σ to the magnitude of adjustment costs
  1. Current approach is reduced form: countries differ in K-L substitutability, but this is a feature of the production function
  2. Microfoundation of σ: worker- or employer-side friction that reduces the sensitivity of K/L ratio to changes in w/r
  3. If this changes the incentives for automation or K accumulation, the mechanism would be re-enforcing

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