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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**Implications:**
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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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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  - Cuñat & Melitz (2012): Country with flexible labor market specializes in volatile sectors
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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 → opposite effects of automation and innovation (Acemoglu & Restrepo, 2016)

- Related applications:
  - Macro: high \( K-L \) substitutability becomes more valuable once countries have accumulated more \( K \) → 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:

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

- Standard assumptions:
  - Routine-intensity \( \beta \) is sector, but not country-specific \( \rightarrow \beta_g \).
  - \( \mu \in [0, 1] \), such that elasticity of substitution \( \sigma = (1 - \mu)^{-1} > 1 \).
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- Novel assumptions:
  - Countries have the same efficiency \( (z, Z) \) and endowments \( (K/L) \)
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Two-tiered production function

- Assumptions of sector-specific $\beta_g$ and country-specific $\sigma_i$ lead to

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

- Solve in 2 steps

1. Assume existence of competitive routine input sector,
   \[M_{i1} + M_{i2} = [\cdots]^{1 \mu_i}.\] Get equilibrium factor-ratio, or equivalently, the \[L^m_i / M_i\] ratio as a function of endowments and the relative price.

2. Standard Heckscher-Ohlin in final goods markets: utility maximization & cost minimization allocates \[L^a_i (= \bar{L} - L^m_i)\] and \[M_i\] over the two sectors.
1. Competitive routine input sector

- price = cost of production factors

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

→ Can express equilibrium conditions in \((\frac{w}{Pm})\) or in \((\frac{w}{r})\)

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

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

\[ Z_i \alpha_i^{\frac{1}{\mu_i}} \left\{ 1 + \frac{w_i}{r_i} \left[ \frac{w_i/(1-\alpha_i)}{r_i/\alpha_i} \right]^{-\frac{1}{1-\mu_i}} \right\}^{\frac{1}{\mu_i}} \]
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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 \( \theta_g \))
  
  \[
  \frac{Q_1}{Q_2} = \frac{\theta_1}{1 - \theta_1} \frac{P_2}{P_1}
  \]

  \[
  \rightarrow \text{ with some algebra we can replace } P_1/P_2 \text{ by a function of } w/P^m
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- F.o.c. in cost minimization, assuming CD production fct. (with $\beta_g$)
  \[
  \frac{M_g}{L_g^a} = \frac{\beta_g}{1 - \beta_g} \frac{w}{Pm}
  \text{ for } g = 1, 2
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  $\rightarrow$ with PFs can solve for conditional factor demands $L_1^a = f(Y_1, \frac{w}{Pm}, \beta),...$
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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) P_i^m}{\sum_g \theta_g \beta_g 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 \( \alpha_i \)

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

\[
\sigma = \frac{d \ln(K/L)}{d \ln(F_k/F_l)}
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- 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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2. The model

Work with normalized CES

- Klump, McAdam, Willman (2012):

\[ Y = Y_0 \left[ (1 - s_0) \left( \frac{K}{K_0} \right)^\mu + s_0 \left( \frac{L^m}{L^m_0} \right)^\mu \right]^{\frac{1}{\mu}} \]

with \( s_0 = \frac{w_0 L^m_0}{Y_0} \)

\[ \alpha(\sigma_i) = \frac{(K/L)^{1-\mu_i}}{(K/L)^{1-\mu_i} + \omega_i} \text{ and } Z(\sigma_i) = ... \]
Comparative advantage predictions

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

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

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

- If labor is scarce (in both countries), the high-$\sigma$ 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

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

- Capital deepening tilts comparative advantage in the high-$\sigma$ 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 $\omega_i$ increases
  - change is most pronounced in the low-$\sigma$ country
    → makes $L$ relatively expensive in the low-$\sigma$ country
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- HO-type predictions for trade patterns: countries export the good that uses its abundant factor more intensively (which is cheap)
  - high-$\sigma$ country has become relatively labor abundant
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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
  - $\Delta L^a = -\Delta L^m > 0$
  - $\Delta L^a$ is absorbed by shifting the output ratio towards the non-routine intensive sector

- This adjustment is easier and goes furthest in the high-$\sigma$ country
  - that is the key property of $\sigma$ 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-$\sigma$ country

- The high-$\sigma$ 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) $\sigma$

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

- **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 $\beta_g$ and country-specific $\sigma_i$ lead to

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

- 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 $\beta_{ig}$ and $\mu_{ig}$ exploiting only time-series variation

- ANOVA analysis provides support that
  - Country FE have most explanatory power for variation in $\ln \left( \frac{K}{L^m} \right)$ & $\mu_{ig}$
  - Sector FE have most explanatory power for variation in $\frac{L^a}{L^a+L^m}$ & $\beta_{ig}$
### ANOVA

<table>
<thead>
<tr>
<th>Sum of squares</th>
<th>F-statistic (N,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep. Var.</td>
<td>Sector</td>
</tr>
<tr>
<td></td>
<td>(33)</td>
</tr>
<tr>
<td>(a) Observable variables</td>
<td></td>
</tr>
<tr>
<td>( \frac{L^a}{L^a + L^m} ) &amp; 9.98 &amp; 5.41 &amp; 2.84 &amp; 62.03 &amp; 53.69</td>
<td>(54.2%) &amp; (28.5%) &amp; (0.00) &amp; (0.00) &amp; (0.00)</td>
</tr>
<tr>
<td>( \ln \left( \frac{K}{L^m} \right) ) &amp; 3843 &amp; 466 &amp; 789 &amp; 1118 &amp; 114.73 &amp; 320.63 &amp; 363.49</td>
<td>(12.1%) &amp; (20.5%) &amp; (29.1%) &amp; (0.00) &amp; (0.00) &amp; (0.00)</td>
</tr>
<tr>
<td>(b) Estimated parameters</td>
<td></td>
</tr>
<tr>
<td>( \beta_{ig} ) &amp; 25.52 &amp; 5.30 &amp; 2.67 &amp; 6.03 &amp; 5.01</td>
<td>(20.8%) &amp; (10.5%) &amp; (0.00) &amp; (0.00) &amp; (0.00)</td>
</tr>
<tr>
<td>( \sigma_{ig} ) (if &lt; 20) &amp; 1636 &amp; 191 &amp; 217 &amp; 1.03 &amp; 1.93</td>
<td>(11.7%) &amp; (13.3%) &amp; (0.43) &amp; (0.01) &amp; (0.01)</td>
</tr>
</tbody>
</table>
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 $\sigma$ (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
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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 $r_g$
  - 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)
- $\tau_{ij}$ captures bilateral barriers and exporter characteristics
- $\tau_{gj}$ captures variation in import barriers and preferences

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- CA pattern is given by ranking of exporter fixed effects: $\gamma_i$
Country ranking in terms of routineness ($\gamma_i$) for 2005

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

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

(Slight convergence or weakening of routineness-based comparative advantage)
Within EU ranking by routineness ($\gamma_i$)

(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:

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

$\leftrightarrow$ Recall that $\hat{\gamma}_i$ increases in routine-intensity of exports: expect $\delta_1 < 0$
Country characteristics that explain $\gamma_i$ in full sample

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

- Coefficients are standardized $\beta$ 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

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

- Coefficients are standardized $\beta$ 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 $\sigma$ to the magnitude of adjustment costs.

- Current approach is reduced form: countries differ in $K-L$ substitutability, but this is a feature of the production function.
- Microfoundation of $\sigma$: worker- or employer-side friction that reduces the sensitivity of $K/L$ ratio to changes in $w/r$.
- If this changes the incentives for automation or $K$ accumulation, the mechanism would be re-enforcing.
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