Motivation

Observations

- Capital equipment (e.g. computers and industrial machinery):
  - embodies skill-biased technology
  - At firm, sector, plant level, surveyed in Katz & Autor ’99
  - is highly traded and world production is highly concentrated
    Eaton and Kortum ’01

Implication

- Countries import skill-biased technology with equipment

This paper

- To what extent does trade in equipment raise demand for skilled labor and increase skill premia in many countries?
Framework

- Introduce capital-skill complementarity into a multi-country, multi-sector Ricardian model of trade

- Capital-skill complementarity:
  - ↑ in capital ↑ demand for skilled relative to unskilled labor

- With trade, capital stock depends on
  - domestic productivities and factor supplies,
  - foreign productivities and factor supplies,
  - and trade costs
Preview of analytic results

- *All* changes in
  - trade costs
  - foreign technologies
  - foreign factor supplies

  affect domestic skill premium *only* through changes in
  - domestic sectoral expenditure shares, $\pi_{ii}(j)$

- Analytic 1\textsuperscript{st}-order approx for SS change in skill premium
  - highlights intuition
  - facilitates sensitivity analysis
Preview of quantitative results

Two counterfactuals taking changes in trade shares as given:
Preview of quantitative results

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- **Counterfactual 1: Move to autarky**
  - Effect varies widely across countries in our sample
  - Large in countries with comparative disadvantage in equipment
  - Skill Premium falls:
    - e.g., 16% in median country, 5% in US, 20% in Chile
Preview of quantitative results

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- **Counterfactual 2: Feed observed changes in trade shares**
  - Moving from 2000 to 1963 trade shares, skill premium falls:
    - e.g., 13% in UK, 19% in Canada
  - Numbers significant relative to observed changes in skill premia
Related literature

- Evidence on trade and technology change:
  - Pavcnik ('02), De Loecker ('10), Lileeva & Trefler ('10), Bustos ('11a)

- Evidence on trade and skill intensity:
  - Verhoogen ('08), Bloom et. al. ('11), Bustos ('11b), Koren & Csillag ('11)

- Trade and SBTC:
  - Acemoglu (2003), Yeaple ('05), Thoenig and Verdier (2003)

- Capital skill complementarity and skill premium
  - Krusell et. al. ('00), Polgreen & Silos ('08)

- Quantitative trade models and inequality:
  - Parro ('10), Burstein & Vogel ('10)
Model
Model: Overview

- $I$ countries, 3 sectors (Manufacturing, Equipment and Services)
  - $M$ used for consumption and intermediate inputs
  - $S$ used for consumption, intermediate inputs and structures
  - $E$ used for capital equipment

- Production uses
  - skilled and unskilled labor, $H_i$ and $L_i$
  - capital structures and equipment, $K_i(S)$ and $K_i(E)$
  - intermediate inputs, $X_i(S)$ and $X_i(M)$

- Countries endowed with labor, capital is accumulated

- Factors and goods markets are perfectly competitive

- Iceberg trade costs
Model: Preferences and final output

- Preferences:

\[
\sum_{t=0}^{\infty} \beta^t u \left[ C_{i,t} (M)^\phi C_{i,t} (S)^{1-\phi} \right]
\]

- Sectorial output is an aggregate of intermediates:

\[
Y_i (j) = \left[ \int_0^1 q_i (\omega, j)^{(\eta-1)/\eta} d\omega \right]^\eta/(\eta-1)
\]

- Market clearing in final goods:

\[
\begin{align*}
Y_i (M) &= C_i (M) + X_i (M) \\
Y_i (S) &= C_i (S) + X_i (S) + I_i (S) \\
Y_i (E) &= I_i (E)
\end{align*}
\]
Production of intermediate goods

- KORV production function—nested CES using $H_i$, $L_i$, $K_i(S)$, $K_i(E)$—w/ intermediate inputs & heterogeneous productivity
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$$y_i(\omega, j) = A_i(j) z_i(\omega, j) \times [\text{Int. Inputs}]^{1-\zeta} \times [\text{VA}]^\zeta$$

- Productivity: $A_i(j)$ sectoral, $z_i(\omega, j)$ idiosyncratic:

$$z_i(\omega, j) = u^{-\theta}, u \sim \exp(1)$$
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- $\text{VA} = k_S^\alpha x_2^{1-\alpha}$
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- $\text{VA} = k_S^{\alpha} x_2^{\alpha-\alpha}$

- $\chi_2 = \left[ \mu \frac{1}{\sigma} I^{\sigma-1} \sigma + (1 - \mu) \frac{1}{\sigma} \chi_1^{\sigma-1} \sigma \right] \rightarrow \epsilon (l, Y_1) = \sigma$

- $\chi_1 = \left[ \lambda \frac{1}{\rho} k_E^{\rho-1} \rho + (1 - \lambda) \frac{1}{\rho} h^{\rho-1} \rho \right] \rightarrow \epsilon (k_E, h) = \rho$

Capital skill complementarity if $\sigma > \rho$
Equilibrium

- **Unit cost of producer** $(\omega, j)$:

  \[
  c_{in} (\omega, j) = \frac{c_i \tau_{in} (j)}{A_i (j) z_i (\omega, j)}
  \]

- **Prices**:

  \[
  p_n (\omega, j) = \min_i \{ c_{in} (\omega, j) \},
  \]

- **Price indexes**:

  \[
  P_n (j) = \left[ \int_0^1 p_n (\omega, j)^{1-\eta} d\omega \right]^{1/(1-\eta)}.
  \]

- **Trade share**:

  \[
  \pi_{in} (j) = \frac{\int_0^1 p_n (\omega, j)^{1-\eta} \mathbb{1}_{in} (\omega, j) d\omega}{P_n (j)^{1-\eta}}
  \]
Analytic Results
Skill Premium

Following KORV:

$$\frac{s_i}{w_i} = \kappa \left[ \lambda^\frac{1}{\rho} \left( \frac{K_i(E)}{H_i} \right)^\frac{\rho - 1}{\rho} + (1 - \lambda)^\frac{1}{\rho} \right] \left( \frac{L_i}{H_i} \right)^{\frac{\sigma - \rho}{(\rho - 1)\sigma}}$$

- $\frac{s_i}{w_i}$ increasing in $\frac{L_i}{H_i}$ if $\sigma > 0$
- $\frac{s_i}{w_i}$ increasing in $\frac{K_i(E)}{H_i}$ if $\sigma > \rho$
Skill Premium

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- \( \frac{s_i}{w_i} \) increasing in \( \frac{L_i}{H_i} \) if \( \sigma > 0 \)
- \( \frac{s_i}{w_i} \) increasing in \( \frac{K_i (E)}{H_i} \) if \( \sigma > \rho \)
  - \( K_i (E) \) determined in equilibrium
Proposition

Given parameters, country i’s steady state skill premium can be calculated using only

1. Domestic expenditure shares, $\pi_{ij}(j)$’s
2. Domestic technologies, $A_i(j)$’s
3. Domestic endowments, $H_i$ and $L_i$

Implication: $\pi_{ij}(j)$’s are sufficient statistics for all international forces

- Only need data on the domestic country for each counterfactual
In trade models with gravity, change in stock of consumption resulting from foreign shocks is a function of $\pi_{ii}$

- Arkolakis, Costinot, Rodriguez-Clare (2011)
- e.g., in EK (2002), $Q_i \propto A_i \pi_{ii}^{-\theta}$

Here, changes in skill premium depend on changes in $K_i(E)$
- And $K_i(E)$ depends on $A_i(j)$ and $\pi_{ii}(j)$ in a related manner...
First-order approximation for the change in SP

- Log linearizing, the change in $s_i/w_i$ is given by

$$\hat{s}_i - \hat{w}_i = \sum_j \beta_{1,i}(j) \left[ \hat{A}_i(j) - \theta \hat{\pi}_{ii}(j) \right] - \beta_{2,i} \left( \hat{H}_i - \hat{L}_i \right)$$

$\beta_{1,i}(j)$, $\beta_{2,i}$ are functions of factor shares and parameters

- Two ways to increase stock of equipment:
  - produce more ($\hat{A}_i(E) > 0$)
  - import more ($\hat{\pi}_{ii}(E) < 0$)
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$$\left[ \hat{A}_i(j) - \theta \hat{\pi}_{ii}(j) \right] \uparrow \text{ for } j \neq E \Rightarrow \text{stock of equipment } \uparrow$$

  - Production of equipment uses intermediates from $j \neq E$
Approximation

First-order approximation for the change in SP

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- Parameters and factor shares $\Rightarrow$ elasticities
Quantitative results
Counterfactuals:

- Two counterfactuals taking changes in trade shares as given
- How would the skill premium change in each country if
  - it were moved to autarky?
  - trade shares return to base-year levels?
- From analytic results:
  - We conduct each counterfactual without solving for full multi-country general equilibrium
  - Only need data for domestic country
  - Value of elasticities $\rho$ and $\sigma$ key for results
Data

- Compute $\pi_{ii}(j)$ as $1 - \frac{\text{Imports}}{\text{Output}+\text{Imports}-\text{Exports}}$

- Trade data: Feenstra et.al. (2004)

- Gross Output Data: UNIDO Industrial Statistics Database

- Follow Eaton-Kortum (2001) to group goods into $E$ and $M$
  - The major investment sectors in Germany, US, & Japan:
    - non-electrical equipment
    - electrical equipment
    - instruments

- 54 countries, 1963 (or 1st available year) - 2000
  - period varies across countries b/c of data coverage
Data Summary

<table>
<thead>
<tr>
<th>Data Summary</th>
<th>Median Level (2000)</th>
<th>Median Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_{ii}(E)$</td>
<td>0.25</td>
<td>-30%</td>
</tr>
<tr>
<td>$\pi_{ii}(M)$</td>
<td>0.67</td>
<td>-15%</td>
</tr>
</tbody>
</table>

- Countries import a large share of their capital equipment
- Large increases in import shares over the period
- Import share is higher ($\pi_{ii}$ lower) and change is larger in $E$
Baseline Parameterization

- Factor shares from NIPA and IO tables
- Calibrate:

\[
\rho^{-1} = 1 + \frac{\zeta^H}{K(E)/H} \quad \text{and} \quad \sigma = \frac{(\rho - 1)(H/L) + \rho \left(1 + 1/\zeta^H\right)}{(1 - \rho)(s/w) + \left(1 + 1/\zeta^H\right)}
\]

where \(\zeta^H = s_iH_i/(r_iK_i(E))\) & changes from 1963 to 2000
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where $$\zeta^H = \frac{s_i H_i}{(r_i K_i(E))}$$ & changes from 1963 to 2000

- US 63-00: $$\rho = 0.63$$, $$\sigma = 1.56$$
- Implied elasticities:

$$\frac{d \log \left[ \frac{s}{w} \right]}{d \log \left[ \pi_{ii}(E) \right]} = -0.10$$, $$\frac{d \log \left[ \frac{s}{w} \right]}{d \log \left[ \pi_{ii}(M) \right]} = -0.04$$
Alternative Parameterizations

1. Estimate $\rho$ and $\sigma$ via non-linear least squares using annual rather than cumulative changes
   - $\rho = 0.66$, $\sigma = 1.47$ (precisely estimated)

2. Allow exogenous SBT change similar to Katz & Murphy ’92
   - If SBT annual growth is $\leq 5.2\%$, then $\sigma \geq \rho$

3. Estimate $\sigma$ and $\rho$ using Chilean data 74-00
   - $\rho = 0.53$, $\sigma = 1.54$

Recall baseline parameterization in US: $\rho = 0.63$, $\sigma = 1.56$
Counterfactual 1: Moving to Autarky
Counterfactual 1: Moving to Autarky

The graph illustrates the log change in SP (y-axis) against the log change in domestic share of equipment (x-axis) for various countries. Each country's data point represents its position on the graph, indicating how changes in equipment share correlate with changes in domestic share.

The two lines on the graph represent different scenarios:
- Changing equipment and manufacturing trade shares
- Changing equipment trade shares only

Countries represented on the graph include Japan, India, Iran, Brazil, USA, Italy, Korea, Finland, China, Germany, France, Russia, Argentina, Pakistan, Turkey, Slovenia, Israel, Egypt, UK, Bulgaria, Slovakia, Latvia, Cameroon, and Czech Rep.
Counterfactual 1: Moving to Autarky

- Skill premium declines 16% in median country

- Wide variation across countries depending on comparative advantage rather than stage of development, e.g.
  - 2% decline in Japan,
  - 5% decline in US,
  - 11% decline in Argentina,
  - 25% decline in Canada,
  - 39% decline in Czech Republic

- Trade in manufactures important for some countries
Counterfactual 2: Observed changes in trade shares

![Graph showing the relationship between log change in SP and log change in domestic share of equipment.](image-url)
Counterfactual 2: Observed changes in trade shares

- Median decline of 6%
- Wide variation depending on changing trade patterns
  - Significant in some developing countries (e.g. Argentina, Chile, Brazil, Greece, Uruguay)
  - Large in some developed countries, e.g. UK and Canada
  - Small in Japan and the US
  - Increase in the SP in some countries
- Most is coming from trade in equipment
- Get very similar results using the approximation
Conclusions

- Presented a theory of international trade and capital skill complementarity:
  - By importing equipment (and intermediates), countries import rise in skill premium

- Simple analytical expression summarizes all effects of trade
  - For quantitative work, only need data on domestic country

- Channel quantitatively important for various developing and developed countries