International Trade, Technology, and the Skill Premium

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What are the consequences of reductions in international trade costs for the relative wage of skilled to unskilled workers, the *skill premium*?

Two standard mechanisms linking $\Delta$trade to $\Delta s/w$

- Heckscher-Ohlin (H-O)

Skill intensity of country $i$, sector $j$ producer

$$\frac{h}{l} = \left( \frac{w_i}{s_i} \right)^\rho \frac{\alpha_j}{1 - \alpha_j}$$
Introduction

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  - Heckscher-Ohlin (H-O)
  - Skill-biased productivity

- Skill intensity of country $i$, sector $j$ producer with productivity $z$

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\frac{h}{l} = \left( \frac{w_i}{s_i} \right)^\rho \frac{\alpha_j}{1 - \alpha_j} z^{\phi(\rho-1)}
\]
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- Discipline *H-O*: sector-level data in US
- Discipline *skill-bias of productivity*: firm-level data Mexico, Brazil, US
  - Heterogeneous firm-model: BEJK-like
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- **Heckscher-Ohlin (H-O)**
- **Skill-biased productivity**

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- **Discipline H-O**: sector-level data in US
- **Discipline skill-bias of productivity**: firm-level data Mexico, Brazil, US
  - **Heterogeneous firm-model**: BEJK-like

$\phi(\rho - 1) \neq 0$: model does not yield analytic gravity at any level — alternative approach to match bilateral trade flows 60-countries
Counterfactuals: autarky-06, autarky-76, 10% reduction in trade costs

- while both real wages $\uparrow$ in all countries...
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- while both real wages ↑ in all countries...
- real wage of skilled ↑ more than unskilled
- \( s/w \) ↑ in almost all countries (mean 5%), *Goldberg & Pavcnik 07*
- \( \Delta \log s/w \) greater in smaller and more open countries, but not necessarily in skill-abundant countries like US
Preview of Quantitative Results

- Counterfactuals: autarky-06, autarky-76, 10% reduction in trade costs
  - while both real wages ↑ in all countries...
  - real wage of skilled ↑ more than unskilled
  - $s/w$ ↑ in almost all countries (mean 5%), *Goldberg & Pavcnik 07*
  - $\Delta \log s/w$ greater in smaller and more open countries, but not necessarily in skill-abundant countries like US

- Other counterfactuals: growth of China, global skill-biased technical change

- Revisit previous approaches to trade and $s/w$ that don’t specify GE model
  - factor content, between-sector factor reallocation, price changes
  - underestimate ↑ $s/w$ in countries with CA in skill-abundant sectors, predict counterfactual ↓ $s/w$ in other countries
Related literature

- **Trade and skill-biased productivity:** A many-country model, combined with H-O, and quantitative evaluation
  - **Theory:** e.g., Acemoglu (03), Yeape (05), Epifani and Gancia (06), Matsuyama (07)
  - **Empirics:** e.g., Bloom et. al. (11), Bustos (11), Verhoogen (08)

- **Quantitative models of trade and inequality:**
  - Burstein et. al. (11), Parro (11): We have different mechanism, firm-heterogeneity in skill intensity, discipline w/ cross-sectional firm-level data
  - Helpman et. al. (11): We have many countries & btw-group inequality

- **Generalized Heckscher-Ohlin:** We focus on skill premium
  - e.g., Trefler (93) and (95), Davis and Weinstein (01), Romalis (04), Costinot (05), Bernard et. al. (07), Chor (08), Morrow (08)

- **Factor content of trade (FCT) and other alternative approaches**
  - **Theory:** e.g., Deardorff and Staiger (88), Burstein and Vogel (11)
  - **Empirics:** e.g., Katz and Murphy (92), Berman et al. (94), Feenstra and Hanson (99)
Model
Final good

- $N$ countries indexed by $n$
- Aggregate consumption from merchandise and service sectors

\[ Q_n = (Q_n^M)^{\gamma_n} (Q_n^S)^{1-\gamma_n} \]

with

\[ Q_n^M = \left( \sum_{j=1}^{J_M} Q_n(j) \frac{\sigma-1}{\sigma} \right)^{\frac{\sigma}{\sigma-1}} \]

- Sector $j$ consumption a CES aggregate of a continuum of varieties

\[ Q_n(j) = \left( \int_0^1 q_n(\omega,j) \frac{\eta-1}{\eta} d\omega \right)^{\frac{\eta}{\eta-1}} \]

- Within each $(\omega,j)$: 2 potential producers x country, Bertrand pricing
International trade

- International trade of individual varieties:
  - Merchandise sectors:
    - iceberg transport cost $\tau_{in}(j) \geq 1$ of shipping from $i$ to $n$
    - $\tau_{nn}(j) = 1$ for all $n$
  - Service sectors:
    - no international trade
A country $n$ firm in $(\omega, j)$ with productivity $z$ produces

$$y = A_n(j)z \left[ \alpha_j \frac{1}{\rho} \left( z^{\frac{\phi}{2}} h \right)^{\frac{\rho-1}{\rho}} + (1 - \alpha_j) \frac{1}{\rho} \left( z^{-\frac{\phi}{2}} l \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\chi n \rho}{\rho-1}} m^{1-\chi n}$$

units of output, where

- $A_n(j)$ is Hicks-neutral sectoral TFP
- $\alpha_j$ determines the relative importance of skilled labor in sector $j$
- $\phi$ determines skill bias of productivity
- $z = u^{-\theta}$, where $u \sim \exp(1)$
  - $\theta > 0$ determines dispersion of productivities across firms
- With $\phi(\rho - 1) \neq 0$, no analytic gravity at any level of aggregation
Firms: Skill-biased productivity

\[ \frac{h}{l} = \left( \frac{w_i}{s_i} \right)^\rho \frac{\alpha_j}{1 - \alpha_j} z^{\phi(\rho-1)} \]

- if \( \phi(\rho - 1) = 0 \) we say productivity is Hicks neutral
- if \( \phi(\rho - 1) > 0 \) we say productivity is skill biased

Two ways reallocation affects demand for skill

1. Across firms between sectors
2. Across firms within sectors

Interaction btw sectoral skill-intensity heterogeneity and skill-biased productivity

- \( \phi > 0 \) and \( \rho \neq 1 \) \( \Rightarrow \) unit costs more sensitive to \( z \) in high \( \alpha_j \) sectors
- \( \downarrow \) trade costs reallocate factors towards skill-intensive sectors if \( \sigma > 1 \)
General equilibrium

- Goods-market clearing

\[ y_i (\omega, j) = \sum_n \tau_{in} q_n (\omega, j) \Pi_{in} (\omega, j) \]

- Factor-market clearing with inelastic supplies \( H_i \) and \( L_i \)

\[ L_i = \sum_j \int_0^1 l_i (\omega, j) \, d\omega \text{ and } H_i = \sum_j \int_0^1 h_i (\omega, j) \, d\omega \]

- Trade imbalances (where \( NX_i \) are net exports in \( i \))

\[ P_n Q_n = \left( (s_n H_n + w_n L_n) / \chi_n + \Pi_n \right) \left( 1 - \frac{NX_i}{Output_i} \right) \]

- We treat \( NX_i / Output_i \) as a parameter

- Also consider no labor mobility between merchandise & service sectors
Parameterization
Parameters to choose

- Factor endowments: $H_n/L_n$ and $H_n + L_n = 1$
- Merchandise share of absorption $\gamma_n$ and value added share $\chi_n$
- Elasticities
  - demand $\sigma, \eta$
  - between skilled and unskilled at firm level $\rho$
  - skill intensity to productivity $\phi (\rho - 1)$
- Variability of firm-level productivity $\theta$
- Sectoral skill intensities $\alpha_j$
- Net-exports relative to output $nx_n$
- Trade costs $\tau_{in} (j) \equiv t_{in} \times t_{in} (j)$
- Systematic productivities: set $A_n (j) \equiv a_n \times a_n (j)$
  - Services: $a_n (j) = 1$
  - Merchandise: divide sectors into 7 groups, $g$, and set $a_n(j) = \bar{a}_n(g)$ for $j$ in $g$
60 countries + rest of the world ROW (aggregate of 88 countries)
  60 countries account for approximately 93% of world GDP
Data averaged over 2005-2007 (if possible)
  Also consider alternative 1976 benchmark with fewer countries
Skilled worker: completed tertiary degree (i.e. in US, college degree)
76 merchandise sectors = goods producing industries
81 services industries including construction, excluding government
Parameterization basics

- Parameters assigned directly from data
  - $\gamma_n$ and $\chi_n$ from IO tables
  - $H_n / (H_n + L_n) = \%$ with tertiary degree from Barro Lee
  - $nx_n$ ratio of merchandise net exports to total output
  - $\alpha_j = \%$ w/ tertiary degree in US, American Community Survey
  - $t_{in}(j)$, bilateral import tariffs at 2 digit level for manufacturing sectors
  - $\sigma = \eta = 2.7$ median 5-digit SITC, Broda Weinstein

- Choose $a_n$ and $t_{in}$ to match relative GDP and bilateral trade
- Choose $\rho$, $\theta$, $\phi$, and $a_n(j)$ to target specific moments
Trade costs and productivities

- **Parameters**
  - \((N - 1)\) Relative productivities, \(a_n/a_1\)
  - \(N(N - 1)\) Trade costs, \(t_{in}\)

- **Moments**
  - \(N - 1\) relative outputs, \(Y_i\)
  - \(N^2\) export shares, \(Exports_{in}/(Output_i + Output_n)\)

- **Issue:** \(N - 1\) more parameters than moments

- Three alternative approaches yield very similar results
  - see paper for details
Elasticity of substitution between skilled and unskilled labor

- Aggregate elasticity of substitution btw $H_{US}$ and $L_{US}$ in US, $\hat{\rho} = 1.5$
  - Katz and Murphy 92 estimate elasticity = 1.4
  - Acemoglu and Autor 08 estimate elasticity btw 1.6 and 1.8
- In baseline parameterization, we $\uparrow H_{US}$ by 10% and calculate
  $$\hat{\rho} = \Delta \left[ \log \left( \frac{H_{US}}{L_{US}} \right) / \log \left( \frac{w_{US}}{s_{US}} \right) \right]$$
- If $\phi(\rho - 1) = 0$ and only one sector $\Rightarrow \hat{\rho} = \rho$
- With $\phi(\rho - 1) > 0$ and many sectors $\Rightarrow \rho = 1.43$
Elasticity of trade

- Elasticity of trade with respect to variable trade cost, $\hat{\varepsilon} = 5$
  - Head and Mayer 2013

- Run a gravity equation on data generated by our model
  \[
  \log \left( \frac{X_{in}X_{ni}}{X_{ii}X_{nn}} \right) = \text{constant} - \hat{\varepsilon} \log (\bar{\tau}_{in}\bar{\tau}_{ni})
  \]

- If $\phi (\rho - 1) = 0 \Rightarrow \theta = 1/\hat{\varepsilon}$

- With $\phi (\rho - 1) > 0 \Rightarrow \theta = 0.22$
  - The relationship remains close to log linear
Skill-bias of productivity

\[ \log \left[ \frac{h_i}{h_i + l_i} \right] = \beta_0 + \beta_1 \log sales_i + IndustryFE_i + \varepsilon_i \]

- In Mexico, \( \beta_1 = 0.136 \); unreported result from Verhoogen (2008)
  - 1998 *Encuesta Industrial Anual* (EIA) w/ large manufacturing plants

- In the model:
  - If \( \phi (\rho - 1) = 0 \Rightarrow \beta_1 = 0 \)
  - If \( \phi (\rho - 1) = 0.43 \Rightarrow \beta_1 = 0.136 \)
  - With \( \rho = 0.43, \phi = 1 \)
- Note: If \( \phi (\rho - 1) = 0 \) and \( \alpha \)s vary within sector, then elasticity in skill-scarce countries is negative
Target extent to which countries have revealed comparative advantage in sectors that are more or less skill intensive.

Define 7 groups of merchandise sectors, denoted by $g$

$$\nu_n (g) = \frac{Exports_n (g) - Imports_n (g)}{Exports_n (g) + Imports_n (g)}$$

Group manufacturing sectors by their skill intensity (in the US), form 6 groups.
Non-manufacturing merchandise (agro, mining, etc.)

Choose in each country $\tilde{a}_n (g)$ to match $\nu_n (g) - \tilde{\nu}_n$

If $\tilde{a}_n (g) = 1$, then $\nu_n (g)$ shaped only by $H/L$ - based comparative advantage.
Solution Algorithm: Overview of three steps

- See Appendix for details

- Outer loop: iterate over $\phi, \theta, \rho$
  - Aggregate elasticity of substitution between skilled and unskilled labor, aggregate elasticity of trade, elasticity of skill intensity with respect to size

- Middle loop: iterate over $t_{in}, a_n, \tilde{a}_n (g)$
  - Aggregate bilateral exports, relative outputs, relationship between sectoral trade balance and skill intensity

- Inner loop: iterate over $w_n, s_n, \pi_n$
  - Extends Alvarez and Lucas
    - no analytic gravity, 2 factors, $\Pi_n \neq 0$, & trade imbalances
    - no proof of uniqueness
    - numerical demonstration of existence
Model fit
Trade flows and output: Data versus model
Skill-biased productivity: Mexico

- Exporter skill-intensity premium, controlling for industry

\[ \ln \left( \frac{h_i}{h_i + l_i} \right) = \beta_0 + \beta_1 Exporter_i + IndustryFE_i + \varepsilon_i \]

- in model \( \beta_1 = 0.23 \) in merchandise
- in data \( \beta_1 = 0.21 \), 1998 EIA unreported from Verhoogen (2008)
Skill-biased productivity: Brazil

- Elasticity of skill intensity to firm $i$ size controlling for industry

$$\log \left[ \frac{h_i}{h_i + l_i} \right] = \beta_0 + \beta_1 \log sales_i + IndustryFE_i + \epsilon_i$$

  - in model $\beta_1 = 0.22$ in merchandise
  - in data $\beta_1 = 0.36$, 1995 *Pesquisa Industrial Anual* (PIA) sample (large manuf. firms) unreported from Menezes-Filho et. al. (2008)

- Elasticity of skill intensity to domestic sales controlling for industry

$$\log \left[ \frac{h_i}{h_i + l_i} \right] = \beta_0 + \beta_1 \log (domestic sales)_i + IndustryFE_i + \epsilon_i$$

  - in model $\beta_1 = 0.30$ in merchandise
  - in data $\beta_1 = 0.34$, unreported from Menezes-Filho et. al. (2008)
Skill-biased productivity: U.S.

- % of exporters = 0.54 too high, as in BEJK
- % of revenues by exporters, in model = 67% in merchandise, in data = 60%
- VA per worker exporter premium in US

\[
\ln (VA \text{ per worker}_i) = \beta_0 + \beta_1 \text{Exporter}_i + \text{IndustryFE}_i + \epsilon_i
\]

- in model \( \beta_1 = 0.14 \) in merchandise
- in data \( \beta_1 = 0.11 \), 2002 Census of Manuf., Bernard et al. (2007)

- Exporter skill-intensity premium, controlling for industry,

\[
\ln \left( \frac{h_i}{h_i + l_i} \right) = \beta_0 + \beta_1 \text{Exporter}_i + \text{IndustryFE}_i + \epsilon_i
\]

- in model \( \beta_1 = 0.08 \) in merchandise,
- in data \( \beta_1 = 0.11 \), 2002 Census of Manuf., Bernard et al. (2007)
  - non-production worker share in Census of Manuf.

- Consistent evidence (different measures) in Argentina and Colombia
Skill-intensities and trade shares

- Regress, for each country $i$, across merchandise sectors $j$

$$\log \frac{Exports_i(j) + Imports_i(j)}{Absorption_i(j)} = \psi_0 + \psi_1 \log \frac{H_{US}(j)}{H_{US}(j) + L_{US}(j)} + \varepsilon_i(j)$$

- data (2006):
  - $\psi_1 > 0$ for 45/46 countries w/ $\geq 30$ manufacturing sector observations
  - 14 (19) statistically significant at 5% (10%), e.g. US = 0.92

- model with skill-biased productivity:
  - $\psi_1 > 0$ for 56/60 countries, 52 significant at 5%, e.g. US = 0.32

- model with Hicks-neutral productivity:
  - $\psi_1 > 0$ and significant for 4/60 countries, 56 zero or negative
Skill-intensities and trade shares

- Regress, for each country \( i \), across merchandise sectors \( j \)

\[
\log \frac{\text{Exports}_i(j) + \text{Imports}_i(j)}{\text{Absorption}_i(j)} = \psi_{0i} + \psi_{1i} \log \frac{H_{US}(j)}{H_{US}(j) + L_{US}(j)} + \epsilon_i(j)
\]

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- \( \phi > 0 \) and \( \rho \neq 1 \) \( \Rightarrow \) unit costs more sensitive to \( z \) in high \( \alpha_j \) sectors
  - \( \Rightarrow \) lower trade elasticity in high \( \alpha_j \) sectors
  - \( \Rightarrow \) more trade in high \( \alpha_j \) sectors
Skill-intensities and trade elasticity

- Estimate across 2-digits manufacturing sectors, countries with available data

\[
\log \frac{X_{in}(j)}{X_{ni}(j)} = FE_i(j) - FE_n(j) - \psi_1 \left( 1 + \psi_2 \frac{H_{US}(j)}{H_{US}(j) + L_{US}(j)} \right) \log \frac{\tau_{in}(j)}{\tau_{ni}(j)} + \varepsilon_{in}(j)
\]

- Data: use tariffs as observable trade costs
- Model: use tariffs and trade costs as observable trade costs

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
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<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>$\psi_1$</td>
<td>3.7***</td>
<td>4.94***</td>
</tr>
<tr>
<td>$\psi_2$</td>
<td>-2.8</td>
<td>-9.7***</td>
</tr>
</tbody>
</table>

*** indicates statistically significantly different from zero at the 1% level; ** at the 5% level; * at the 10% level

- With Hicks-neutral productivity, $\psi_2$ weakly positive
Counterfactuals
Range of counterfactuals:

- autarky-2006 and autarky-1976
- 10% reduction in trade costs
- Growth in China
  - Last 2 counterfactuals, both with factor mobility and limited factor mobility (labor fixed in merchandise and services at baseline levels)
  - In 10% and China experiments, keep (Net Exports)/Output fixed
- Global skill-biased technical change

Revisit previous approaches using data generated by model and show why they would predict small effects of trade
From autarky to 2006 baseline

Change in real wages vs 2006 trade share

Real wage

Skilled
Unskilled

Trade share, 2006

0.05 0.1 0.15 0.2 0.25 0.3

Log change in real wage x 100

0
5
10
15
20
25
30
35

USA JPN MEX DEU CHN GBR FRA ITA CAN ESP BRA RUS KOR IND AUS NLD TUR SWE CHE IDN POL NOR AUT DNK GRC IRL ARG FIN MYS CHL ISR CZE PHL HUN NZL PER KAZ SVK VNM HRV ECU SVN BLR LVA LRT BLR CZE SVK SVN LVA LAT LVA UKR CZE SVK SVN HUN HUN LTU LVA LRT LVA UKR CZE SVK SVN HUN HUN LTU
From autarky to 2006 baseline

Change in skill premium vs 2006 trade share

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From autarky to 2006 baseline
Change in skill premium vs 2006 trade share

Regress log change in skill premium on (jointly):

- Log GDP, negative ***
- (Exports + Imports) / GDP, positive ***
- Normalized trade balance, skill intensive sectors - unskill intensive sectors, positive ***
- Log H/(H+L), insignificant
From autarky to 2006 baseline
Change in skill premium vs 2006 trade share

- Regress log change in skill premium on (jointly):
  - Log GDP, negative ***
  - \((\text{Exports} + \text{Imports}) / \text{GDP}\), positive ***
  - Normalized trade balance, skill intensive sectors - unskill intensive sectors, positive ***
  - Log \(H/(H+L)\), insignificant

- Regress log change in skill premium on (individually):
  - Log GDP, \(R^2 = 0.25\)
  - \((\text{Exports} + \text{Imports}) / \text{GDP}\), \(R^2 = 0.66\)
  - Normalized trade balance, skill intensive sectors - unskill intensive sectors, \(R^2 = 0.21\)
  - Log \(H/(H+L)\), \(R^2 = 0.07\)

Sensitivity
From autarky to 2006 baseline
Change in the skill premium, setting $\phi = 0$. Strength of the H-O mechanism

**H-O Proposition:** $\phi = 0$, $\sigma = \rho = 1$, 2x2, country 1 has CA in sector $x$. Rise (fall) in $s_1/w_1$ ($s_2/w_2$) caused by moving from autarky to fixed trade share decreasing in $\theta$ & increasing in $A_1 (x) A_2 (y) / [A_1 (y) A_2 (x)]$.
Autarky-to-2006 baseline vs. Autarky-to-1976 baseline

Difference in change in skill premium vs. change in trade share, 2006-1976

Change in skill premium: autarky-to-2006 minus autarky-to-1976

Trade share, 2006 - 1976

-0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16

$\Delta \log s/w \times 100, 2006 - 1976$
10% fall in trade costs from baseline parameterization

Skill premium with full and limited mobility between merchandise and services
↑ in China’s TFP: Share in world GDP ↑ from 8% to 20%

Skill premium change in China’s trading partners, with full and limited mobility between merchandise and services
Skill-biased technical change in all countries

s/w rises by 23% in median country

\[
\frac{h}{l} = \left( \frac{w_i}{s_i} \right) \rho \frac{A_h}{A_l} \frac{\alpha_j}{1 - \alpha_j} z^{\phi(\rho-1)}
\]

- Hicks-neutral productivity, \( \phi = 0 \)
  - Trade share for median country essentially unchanged

- Skill-biased productivity, \( \phi > 0 \)
  - Trade share for median country rises by 2%

- Aggregate implications of skill-biased technical similar to those of reductions in international trade costs
  - Both cause an increase in skill premium and in trade shares

- Intuition: \( \phi > 0 \Rightarrow \) elasticity of unit costs w.r.t. \( \uparrow \) if \( A_h/A_l \uparrow \)
  - same intuition for why more trade in high \( \alpha_j \) sectors
Alternative approaches
Alternative approaches

- Factor content of trade (FCT)
- Between-sector price changes
- Between-sector factor reallocation
Factor content of trade (FCT)

- Alternative approach: Measure changes in the “factor content of trade” (FCT) to infer impact of trade on $s/w$
  - e.g., Katz and Murphy (92), Berman et. al. (94), Krugman (95) and (08)
- Under strong assumptions
  1. Cobb Douglas production and utility
  2. All producers w/in sector share common factor intensity

$$\begin{align*}
\frac{s_n}{w_n} &= \frac{1 - FCT_n(L)/L_n}{1 - FCT_n(H)/H_n} \\
FCT_i(L) &= \sum_j \left( \text{Employment of } L \text{ in sector } j \right) \frac{\text{Net Exp}_i(j)}{\text{Revenue}_i(j)}
\end{align*}$$

- Strong assumptions violated in our model e.g. exporters are more skill intensive than non-exporters
Standard measure of FCT systematically understates in all countries the rise in $s/w$ caused by international trade
Changes in prices

- Price = unit cost * markup

Alternative approach:

1. project Δ trade on Δ producer prices
2. infer Δ wages from Δ prices assuming constant markups
3. If international trade ↑ relative price of skill intensive goods, it ↑ s/w
   - e.g. Lawrence and Slaughter 93, Sachs and Shatz 94, Feenstra and Hanson 99

In our model with Bertrand competition and φ > 0, markups fall more in more skill-intensive sectors
   - unit costs more dispersed & imports ↑ most in these sectors
   - can get ↑ in s/w and ↓ in relative price of skill intensive goods
Changes in domestic prices by sector

A: Perfect competition

B: Bertrand competition

- Model can generate ↑ in \( s/w \) and ↓ in relative price of skill intensive goods
Between sector factor reallocation

- H-O mechanism $\Rightarrow$ factors reallocate towards comparative advantage sectors

- Alternative approach: Measure extent of btw-sector reallocation to assess impact of trade on $s/w$
  - Berman et al. (1994), Attanasio et al. (2004)
  - Little systematic btw sector reallocation during selected trade liberalization
  - More within than btw reallocation, e.g. Haltiwanger et al. (2004)

- In our calibrated model (see e.g. Mexico, where $s/w \uparrow 4\%$)
  - Substantial heterogeneity in net employment changes by sector
  - Within $> \text{between factor reallocation}$
  - With skill-biased productivity, within sector reallocation larger in more skilled intensive sectors
Between sector factor reallocation

Model’s implication for Mexico: from autarky to 2006 baseline ($s/w$ rises 4%)

- Model can generate sizable impact of trade liberalization on $s/w$ accompanied by more pronounced within- than between-sector factor reallocation
Conclusion

- Embed into otherwise standard quantitative trade model 2 central mechanisms in theoretical and empirical trade literature through which trade shapes skill premium
  - Interaction between two mechanisms

- Skill premium rises in most countries in response to changes in trade costs

- Because model matches correlation between size and skill intensity within sectors, it does not yield analytic gravity. Requires computational approach.

- Multinational production (MP) is another major form of globalization
  - MP may strengthen H-O mechanism, high productivity firms can produce in countries with comparative advantage in their sector
  - MP may strengthen SBT mechanism, promotes international diffusion of best technologies
Sensitivity
Re-calibrate trade costs, aggregate productivities
- match trade shares and relative GDPs
From autarky to 2006 parameterization change in skill premium (%)

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<tr>
<th></th>
<th>Baseline</th>
<th>$A_i(j) = A_i$</th>
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<tbody>
<tr>
<td>mean</td>
<td>+5.1</td>
<td>+6.6</td>
</tr>
<tr>
<td>max</td>
<td>+12.1</td>
<td>+16.0</td>
</tr>
<tr>
<td>min</td>
<td>-0.4</td>
<td>+1.0</td>
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</table>
Re-calibrate trade costs, aggregate productivities, and sectoral productivities
- match trade shares and relative GDPs
- match sectoral measure or normalized trade

From autarky to 2006 parameterization, change in skill premium (%)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>$\chi_n = 1$</th>
<th>$\chi_n = 1$</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>re-calibrate $\rho, \theta, \phi$</td>
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<tr>
<td>mean</td>
<td>+5.1</td>
<td>+5.7</td>
<td>+7.3</td>
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<tr>
<td>max</td>
<td>+12.1</td>
<td>+12.6</td>
<td>+16.6</td>
</tr>
<tr>
<td>min</td>
<td>-0.4</td>
<td>+0.5</td>
<td>+1.1</td>
</tr>
</tbody>
</table>
Varying $\theta$

- Re-calibrate trade costs, aggregate productivities, and sectoral productivities
  - match trade shares and relative GDPs
  - match sectoral measure or normalized trade

- From autarky to 2006 parameterization, change in skill premium (%)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
</tr>
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<tbody>
<tr>
<td>$\theta = 0.22$</td>
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</tr>
<tr>
<td>$\theta = 0.12$</td>
<td>+2.2</td>
</tr>
<tr>
<td>$\theta = 0.17$</td>
<td>+3.7</td>
</tr>
<tr>
<td>$\theta = 0.27$</td>
<td>+6.5</td>
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<tr>
<td>mean</td>
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</tr>
<tr>
<td>max</td>
<td>+8.0</td>
</tr>
<tr>
<td>min</td>
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<tr>
<td>min</td>
<td>-2.2</td>
</tr>
<tr>
<td>min</td>
<td>-1.2</td>
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<tr>
<td>min</td>
<td>+0.5</td>
</tr>
<tr>
<td>trade elasticity</td>
<td>5.03</td>
</tr>
<tr>
<td></td>
<td>9.3</td>
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<td></td>
<td>6.5</td>
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<td></td>
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</tbody>
</table>
Varying $\phi$

- Re-calibrate trade costs, aggregate productivities, and sectoral productivities
  - match trade shares and relative GDPs
  - match sectoral measure or normalized trade

- From autarky to 2006 parameterization, change in skill premium (%)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>$\phi = 1$</td>
<td>$\phi = 0.6$</td>
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<tr>
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<td>+5.1</td>
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<tr>
<td>max</td>
<td>+12.1</td>
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<tr>
<td>min</td>
<td>-0.4</td>
</tr>
<tr>
<td>skill-intensity elasticity</td>
<td>0.136</td>
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</table>
Varying $\sigma$

- Re-calibrate trade costs, aggregate productivities, and sectoral productivities
  - match trade shares and relative GDPs
  - match sectoral measure or normalized trade
- From autarky to 2006 parameterization, change in skill premium (%)

<table>
<thead>
<tr>
<th>Baseline</th>
<th>$\sigma = 2.7$</th>
<th>$\sigma = 1.01$</th>
<th>$\sigma = 2$</th>
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<tbody>
<tr>
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<td>+4.8</td>
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<tr>
<td>max</td>
<td>+12.1</td>
<td>+12.4</td>
<td>+12.1</td>
</tr>
<tr>
<td>min</td>
<td>-0.4</td>
<td>-2.9</td>
<td>-0.9</td>
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</tbody>
</table>
Varying elasticity of CES aggregator of merch., services

- Re-calibrate trade costs, aggregate productivities, and sectoral productivities
  - match trade shares and relative GDPs
  - match sectoral measure or normalized trade
- From autarky to 2006 parameterization, change in skill premium (%)

<table>
<thead>
<tr>
<th></th>
<th>Baseline elasticity = 1</th>
<th>Baseline elasticity = 0.4</th>
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</thead>
<tbody>
<tr>
<td>mean</td>
<td>+5.1</td>
<td>+5.5</td>
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<tr>
<td>max</td>
<td>+12.1</td>
<td>+12.6</td>
</tr>
<tr>
<td>min</td>
<td>-0.4</td>
<td>-0.1</td>
</tr>
</tbody>
</table>
Perfect competition

- Assume all markets are perfectly competitive
- Fix $\phi$ and calibrate the remaining parameters following our baseline procedure

- This alternative market structure has a very small impact on results
  - Maximum and mean absolute differences btw the change in the skill premium in percentage points in our baseline and here are 0.6% and 0.1%, respectively
Heterogeneity of $\alpha$ within sectors

- $\alpha_j(\omega) = \min \{\alpha_j \exp(\varepsilon), 1\}$
- $\varepsilon \sim \ln N(0, \sigma_{\alpha})$

Re-calibrate trade costs, aggregate productivities, sectoral productivities, $\phi$
- match trade shares and relative GDPs
- match sectoral measure or normalized trade
- match elasticity of skill intensity to size

Let $\iota =$ standard deviation of log share of skilled workers across firms for the median merchandise sector relative to across merchandise sectors for the U.S.

<table>
<thead>
<tr>
<th>Baseline</th>
<th>$\sigma_{\alpha} = 0$</th>
<th>$\sigma_{\alpha} = 0.06$</th>
<th>$\sigma_{\alpha} = 0.1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>+5.1</td>
<td>+6.1</td>
<td>+7.6</td>
</tr>
<tr>
<td>max</td>
<td>+12.1</td>
<td>+14.4</td>
<td>+18.5</td>
</tr>
<tr>
<td>min</td>
<td>-0.4</td>
<td>+0.3</td>
<td>+1.1</td>
</tr>
<tr>
<td>$\iota$</td>
<td>0.21</td>
<td>0.71</td>
<td>1.63</td>
</tr>
</tbody>
</table>
Skill premium decomposition

- Can write skill premium in country $i$ as
  \[
  \frac{s_i}{w_i} = \frac{L_i}{H_i} \times \frac{\Phi_i(H)}{\Phi_i(L)} \times \frac{1 - FCT_i(L)/L_i}{1 - FCT_n(H)/H_i}
  \]

- Define:
  - $L_{k,i} =$ employment of factor $k$ in country $i$
  - $L_{k,in}(j) =$ employment of $k$ in country $i$ sector $j$ used in goods bound for country $n$
  - $w_{k,i} =$ avg wage paid to factor $k$ in country $i$
  - $FCT_i(k) = \sum_j \sum_n \left[ L_{k,in}(j) - L_{k,ii}(j) \Lambda_{ni}(j) \frac{w_{k,ii}(j)}{w_{k,i}} \right]$
    - $w_{k,ii}(j) =$ wage to factor $k$ employed in sector $j$ used to supply domestic mkt
    - $\Lambda_{ni}(j) =$ share of $i$'s expenditure in sector $j$ from country $n$
  - $\Phi_i(k) = \sum_j \left[ w_{k,ii}(j) L_{k,ii}(j) \right] / \Lambda_{ii}(j)$
  - Accounting identity $L_{k,i} = \sum_j \sum_n L_{k,in}(j)$ implies
    \[ w_{k,i} L_{k,i} = w_{k,i} FCT_i(k) + \Phi_i(k) \]
Skill premium decomposition

- Can express $\Phi_i(k)$ and $FCT_i(k)$ as

  \[ \Phi_i(k) = \sum_j \lambda_{ii}(j) \alpha_{k,ii}(j) E_i(j) \]

  \[ w_{k,i} FCT_i(k) = \sum_{j,n} [\alpha_{k,in}(j) \lambda_{in}(j) \Lambda_{in}(j) E_n(j) - \alpha_{k,ii}(j) \lambda_{ii}(j) \Lambda_{ni}(j) E_i(j)] \]

  - $\alpha_{k,in}(j) =$ share of factor payments paid to $k$, in $j$ prodn bound for $n$
  - $\lambda_{in}(j) =$ share of $i$ sales in country $n$ in sector $j$ paid to all factors
  - $E_n(j) = n$’s expenditure in $j$

- If $\alpha_{k,in}(j)$ and $\lambda_{in}(j)$ fixed across destinations
  \[ \Rightarrow FCT_i(k) = \sum_j L_{k,i}(j) \omega_i(j) \]

  - $\omega_i(j) = (\text{Net Exp}_i(j))/(\text{Rev}_i(j))$

  \[ \Rightarrow \text{Component 1 easily measured using sector-level data} \]

- If $\lambda_{ii}(j)$ and $\alpha_{k,ii}(j)$ fixed and $E_i(j)/E_i(j')$ fixed \[ \Rightarrow \Rightarrow \text{Component 2 constant across equilibria} \]
Costs and prices

Let $c_{ink}(\omega, j)$ denote $\tau_{in} \times$ the unit cost of production of the $k$'th most productive $(\omega, j)$ firm in country $i$

$$c_{in}(\omega, j) = \bar{\chi}_i \frac{\tau_{in}(j)}{A_i(j) z_i} P_i^{1-\chi_i} \times \left( \alpha_j \left( z^{\frac{-\phi}{2}} s_i \right)^{1-\rho} + (1 - \alpha_j) \left( z^{\frac{\phi}{2}} w_i \right)^{1-\rho} \right)^{\frac{\chi_i}{1-\rho}}$$

where $z$ is the productivity of this firm

Denote $1^{st}$- and $2^{nd}$-lowest costs of supplying $(\omega, j)$ to $n$ by $C_n(\omega, j)$, $C'_n(\omega, j)$

Price of $(\omega, j)$ in country $n$ is

$$p_n(\omega, j) = \min \left\{ C_{2n}(\omega, j), \frac{\eta}{\eta - 1} C_{1n}(\omega, j) \right\}$$
The strength of the mechanisms
What determines strength of H-O mechanism?

- If $\phi = 0$, then only H-O mechanism is active
- Assume marginal cost pricing; $i = 1, 2; j = x, y; \& \sigma = \rho = 1$
  - Let $i = 1$ have comparative advantage in skill-intensive sector $x$
The strength of the mechanisms
What determines strength of H-O mechanism?

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- Assume marginal cost pricing; $i = 1, 2; j = x, y$; & $\sigma = \rho = 1$
  - Let $i = 1$ have comparative advantage in skill-intensive sector $x$
- Proposition: Rise (fall) in $s_1/w_1$ ($s_2/w_2$) caused by moving from autarky to fixed trade share decreasing in $\theta$ & increasing in $A_1(x)A_2(y)/[A_1(y)A_2(x)]$
- Intuition 1: Higher $\theta \Rightarrow$ firm productivities more dispersed $\Rightarrow$ in relative firm costs, $z$ more important vs. $A_i(j)$ and wages $\Rightarrow$ comparative advantage mitigated $\Rightarrow$ less btw sector reallocation $\Rightarrow$ smaller wage changes
The strength of the mechanisms
What determines strength of H-O mechanism?

- If $\phi = 0$, then only H-O mechanism is active
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- **Intuition 1**: Higher $\theta \Rightarrow$ firm productivities more dispersed $\Rightarrow$ in relative firm costs, $z$ more important vs. $A_i(j)$ and wages $\Rightarrow$ comparative advantage mitigated $\Rightarrow$ less btw sector reallocation $\Rightarrow$ smaller wage changes
- **Intuition 2**: Higher $A_1(x) A_2(y) / [A_1(y) A_2(x)]$ strengthens 1’s comparative advantage in $x \Rightarrow$ more btw sector reallocation $\Rightarrow$ bigger wage changes
The strength of the mechanisms
Skill-biased productivity mechanism and trade

If $\phi > 0$ then skill-biased productivity and trade interact

$$\frac{h}{l} = \left( \frac{w_i}{s_i} \right)^{\rho} \frac{\alpha_j}{1 - \alpha_j} z^{\phi(\rho - 1)}$$

What shapes the strength of this mechanism?

- $\frac{h(z')}{l(z')} / \frac{h(z)}{l(z)}$ is increasing in $\phi$ for all $z' > z$
- avg difference btw expanding $z'$ & contracting $z$ increasing in $\theta$

Shown quantitatively: strength of mechanism $\uparrow$ in $\theta$ and $\phi$
The strength of the mechanisms

The between-sector SBP mechanism

- If $\rho > 1$ and $\phi > 0$ then skill-biased productivity and trade interact

  - Elasticity of unit cost with respect to firm productivity higher in more skill-intensive sectors
    \[
    \left| \frac{d}{d\alpha_j} \left| \frac{d \log c_{ni}(\omega, j)}{d \log z(\omega, j)} \right| \right| > 0
    \]

  - Elasticity of unit cost to productivity and sectoral skill intensity is more pronounced the higher is the share of value added in gross output
    \[
    \left| \frac{d^2}{d\alpha_j d\chi_n} \left| \frac{d \log c_{ni}(\omega, j)}{d \log z(\omega, j)} \right| \right| > 0
    \]

  - Trade reduces sector-level prices in more skill-intensive sectors

  - If $\sigma > 1$, this increase expenditure in skill-intensive sectors in all countries.
Skill Intensities

Five most and least skill-intensive merchandise sectors

<table>
<thead>
<tr>
<th>Most skill intensive</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharma. &amp; medicine manuf.</td>
<td>.611</td>
</tr>
<tr>
<td>Aerospace product and parts manuf.</td>
<td>.561</td>
</tr>
<tr>
<td>Computer and peripheral equip. manuf.</td>
<td>.553</td>
</tr>
<tr>
<td>Commun., audio, &amp; video equip. manuf.</td>
<td>.465</td>
</tr>
<tr>
<td>Forestry except logging</td>
<td>.455</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Least skill intensive</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging</td>
<td>.040</td>
</tr>
<tr>
<td>Animal slaughtering, processing</td>
<td>.073</td>
</tr>
<tr>
<td>Fiber, yarn, and thread mills</td>
<td>.075</td>
</tr>
<tr>
<td>Carpets and rug mills</td>
<td>.085</td>
</tr>
<tr>
<td>Turned product, screw, nut, bolt manuf.</td>
<td>.086</td>
</tr>
</tbody>
</table>