International Trade, Technology, and the Skill Premium

Ariel Burstein Jonathan Vogel

UCLA
Columbia University

April 2016

Introduction

- 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 Δtrade 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

- 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 Δtrade to $\Delta s/w$
  - Heckscher-Ohlin (**H-O**)
  - Skill-biased productivity
- Skill intensity of country i, sector j producer with productivity z

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

Introduction

- 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 Δtrade to $\Delta s/w$
  - Heckscher-Ohlin (**H-O**)
  - Skill-biased productivity
- Skill intensity of country i, sector j producer with productivity z

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

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

Introduction

- 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 Δtrade to $\Delta s/w$
  - Heckscher-Ohlin (**H-O**)
  - Skill-biased productivity
- Skill intensity of country i, sector j producer with productivity z

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

- 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

Preview of Quantitative Results

- Counterfactuals: autarky-06, autarky-76, 10% reduction in trade costs
  - while both real wages $\uparrow$ in all countries...

Preview of Quantitative Results

- Counterfactuals: autarky-06, autarky-76, 10% reduction in trade costs
  - while both real wages $\uparrow$ in all countries...
  - real wage of skilled $\uparrow$ more than unskilled
  - $s/w \uparrow$ 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 $\uparrow$ in all countries...
  - real wage of skilled $\uparrow$ more than unskilled
  - $s/w \uparrow$ 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, betweeen-sector factor reallocation, price changes
  - underestimate $\uparrow s/w$ in countries with CA in skill-abundant sectors, predict counterfactual $\downarrow s/w$ 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), Yeaple (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

$$Q_n = \left(Q_n^M\right)^{\gamma_n} \left(Q_n^S\right)^{1-\gamma_n}$$

with

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

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

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

- Within each (ω, 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

Firms: Production function

- A country n firm in (ω, 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
  - α_j determines the relative importance of skilled labor in sector j
  - ϕ 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 α_j sectors
  - $\downarrow$ trade costs reallocate factors towards skill-intensive sectors if $\sigma > 1$

▸ Details and Analytics

General equilibrium

- Goods-market clearing

$$y_i(\omega, j) = \sum_n \tau_{in} q_n(\omega, j) \mathbb{I}_{in}(\omega, j)$$

- 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)

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

  - 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 γ_n and value added share χ_n
- Elasticities
  - demand σ, η
  - between skilled and unskilled at firm level ρ
  - skill intensity to productivity $\phi(\rho - 1)$
- Variability of firm-level productivity θ
- Sectoral skill intensities α_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

Connecting model and data

- 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
  - γ_n and χ_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 ▸ Skill Intensities
  - $t_{in}(j)$, 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 ρ, θ, ϕ, 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, $\widehat{\rho} = 1.5$
  - 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

$$\widehat{\rho} = \Delta \left[\log \left(\frac{H_{US}}{L_{US}} \right) \Big/ \log \left(\frac{w_{US}}{s_{US}} \right) \right]$$

- If $\phi(\rho - 1) = 0$ and only one sector $\Rightarrow \widehat{\rho} = \rho$
- With $\phi(\rho - 1) > 0$ and many sectors $\Rightarrow \rho = 1.43$

Elasticity of trade

- Elasticity of trade with respect to variable trade cost, $\widehat{\varepsilon} = 5$
  - Head and Mayer 2013
- Run a gravity equation on data generated by our model

$$\log\left[\left(X_{in}X_{ni}\right)/\left(X_{ii}X_{nn}\right)\right] = constant - \widehat{\varepsilon}\log\left(\bar{\tau}_{in}\bar{\tau}_{ni}\right)$$

- If $\phi\left(\rho-1\right)=0 \Rightarrow \theta = 1/\widehat{\varepsilon}$
- With $\phi\left(\rho-1\right)>0 \Rightarrow \theta = 0.22$
  - 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 αs vary within sector, then elasticity in skill-scarce countries is negative

Sectoral trade-balance and skill-intensity

- 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

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

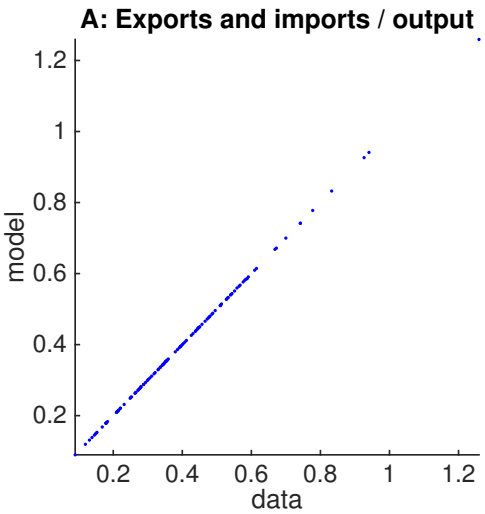
  - Group manufacturing sectors by their skill intensity (in the US), form 6 groups
  - Non-manufacturing merchandise (agro,mining, etc.)
- Choose in each country $\bar{a}_n(g)$ to match $\nu_n(g) - \bar{\nu}_n$
- If $\bar{a}_n(g) = 1$, then $\nu_n(g)$ shaped only by H/L - based comparative advantage

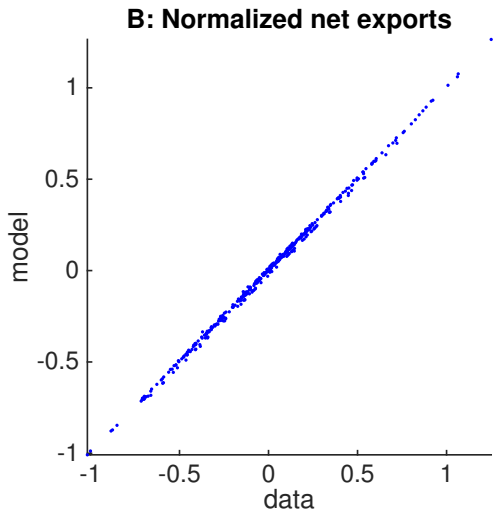
Solution Algorithm: Overview of three steps

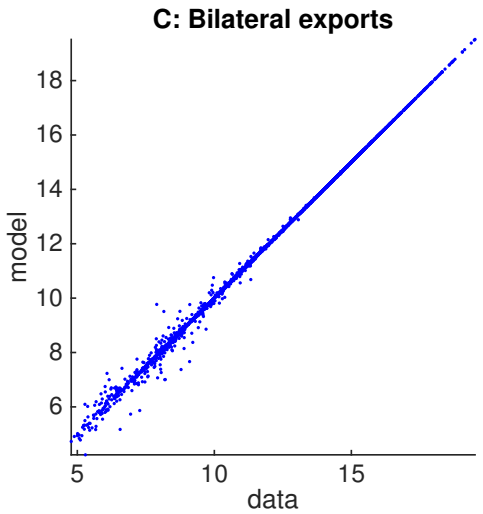
- See Appendix for details
- Outer loop: iterate over ϕ, θ, ρ
  - Aggregate elasticity of substitution between skilled and unskilled labor, aggregate elasticity of trade, elasticity of skill intensity with respect to size
- Middle loop: iterate over $t_{in}, a_n, \bar{a}_n(g)$
  - Aggregate bilateral exports, relative outputs, relationship between sectoral trade balance and skill intensity
- Inner loop: iterate over w_n, s_n, π_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

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

  - 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

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

  - 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

$$\ln(VA \text{ per worker}_i) = \beta_0 + \beta_1 Exporter_i + IndustryFE_i + \varepsilon_i$$

  - 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,

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

  - 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

$$\log \frac{Exports_i(j) + Imports_i(j)}{Absorption_i(j)} = \psi_{0i} + \psi_{1i} \log \frac{H_{US}(j)}{H_{US}(j) + L_{US}(j)} + \varepsilon_i(j)$$

- data (2006):
  - $\psi_{1i} > 0$ for 45/46 countries w/ ≥ 30 manufacturing sector observations
  - 14 (19) statistically significant at 5% (10%), e.g. US $= 0.92$
- model with skill-biased productivity:
  - $\psi_{1i} > 0$ for 56/60 countries, 52 significant at 5%, e.g. US $= 0.32$
- model with Hicks-neutral productivity:
  - $\psi_{1i} > 0$ and significant for 4/60 countries, 56 zero or negative

Skill-intensities and trade shares

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

$$\log \frac{Exports_i(j) + Imports_i(j)}{Absorption_i(j)} = \psi_{0i} + \psi_{1i} \log \frac{H_{US}(j)}{H_{US}(j) + L_{US}(j)} + \varepsilon_i(j)$$

- data (2006):
  - $\psi_{1i} > 0$ for 45/46 countries w/ ≥ 30 manufacturing sector observations
  - 14 (19) statistically significant at 5% (10%), e.g. US $= 0.92$
- model with skill-biased productivity:
  - $\psi_{1i} > 0$ for 56/60 countries, 52 significant at 5%, e.g. US $= 0.32$
- model with Hicks-neutral productivity:
  - $\psi_{1i} > 0$ and significant for 4/60 countries, 56 zero or negative
- $\phi > 0$ and $\rho \neq 1 \Rightarrow$ unit costs more sensitive to z in high α_j sectors
  - $\Rightarrow$ lower trade elasticity in high α_j sectors
  - $\Rightarrow$ more trade in high α_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

	Data			Model
	2005	2006	2007	
ψ_1	3.7***	4.94***	4.6***	5.04***
ψ_2	-2.8	-9.7***	-6.2*	-1.99***

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

- With Hicks-neutral productivity, ψ_2 weakly positive

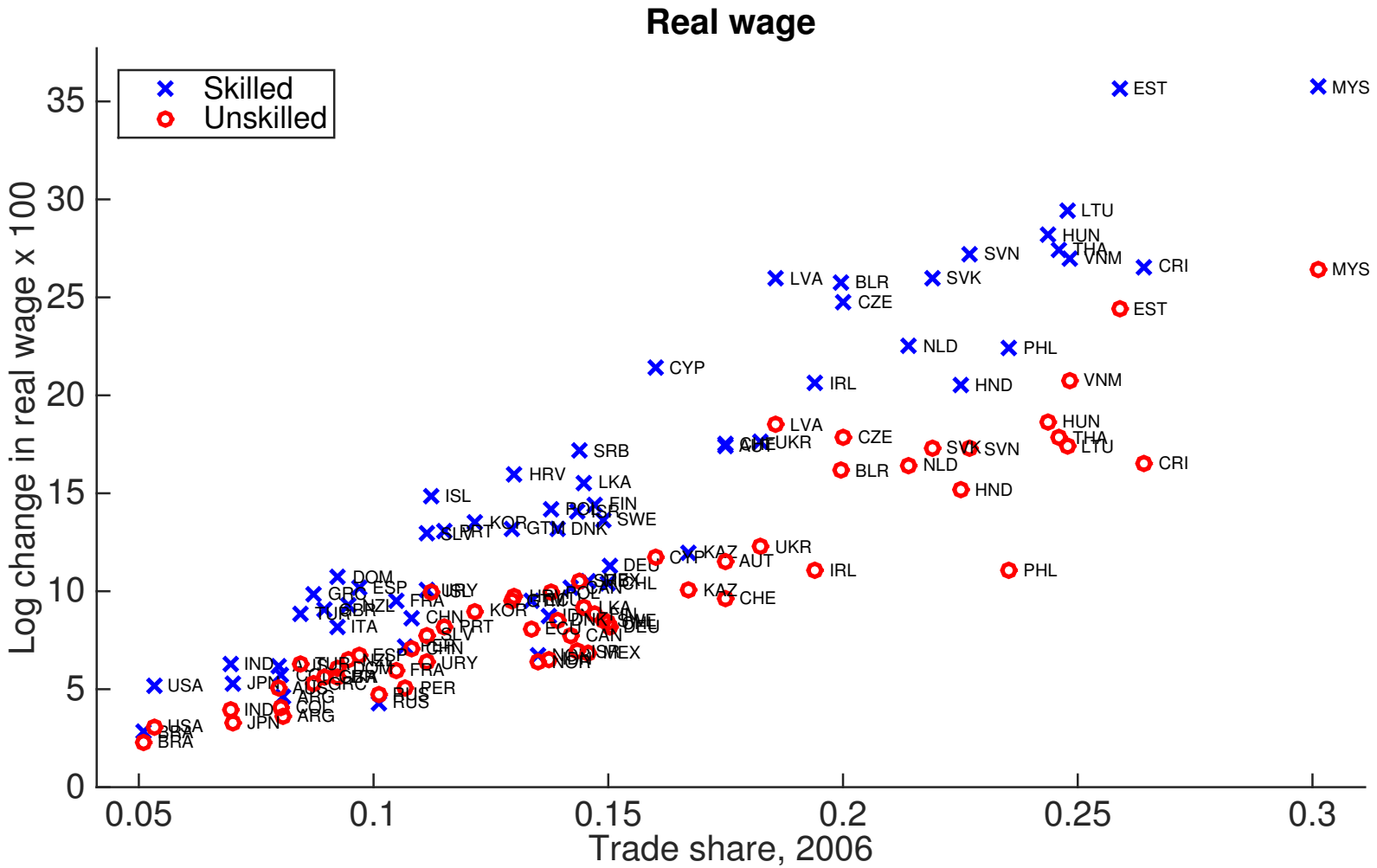
Counterfactuals

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 $(\text{Net Exports})_i / Output_i$ fixed
  - Global skill-biased technical change
- Revisit previous approaches using data generated by model and show why they would predict small effects of trade

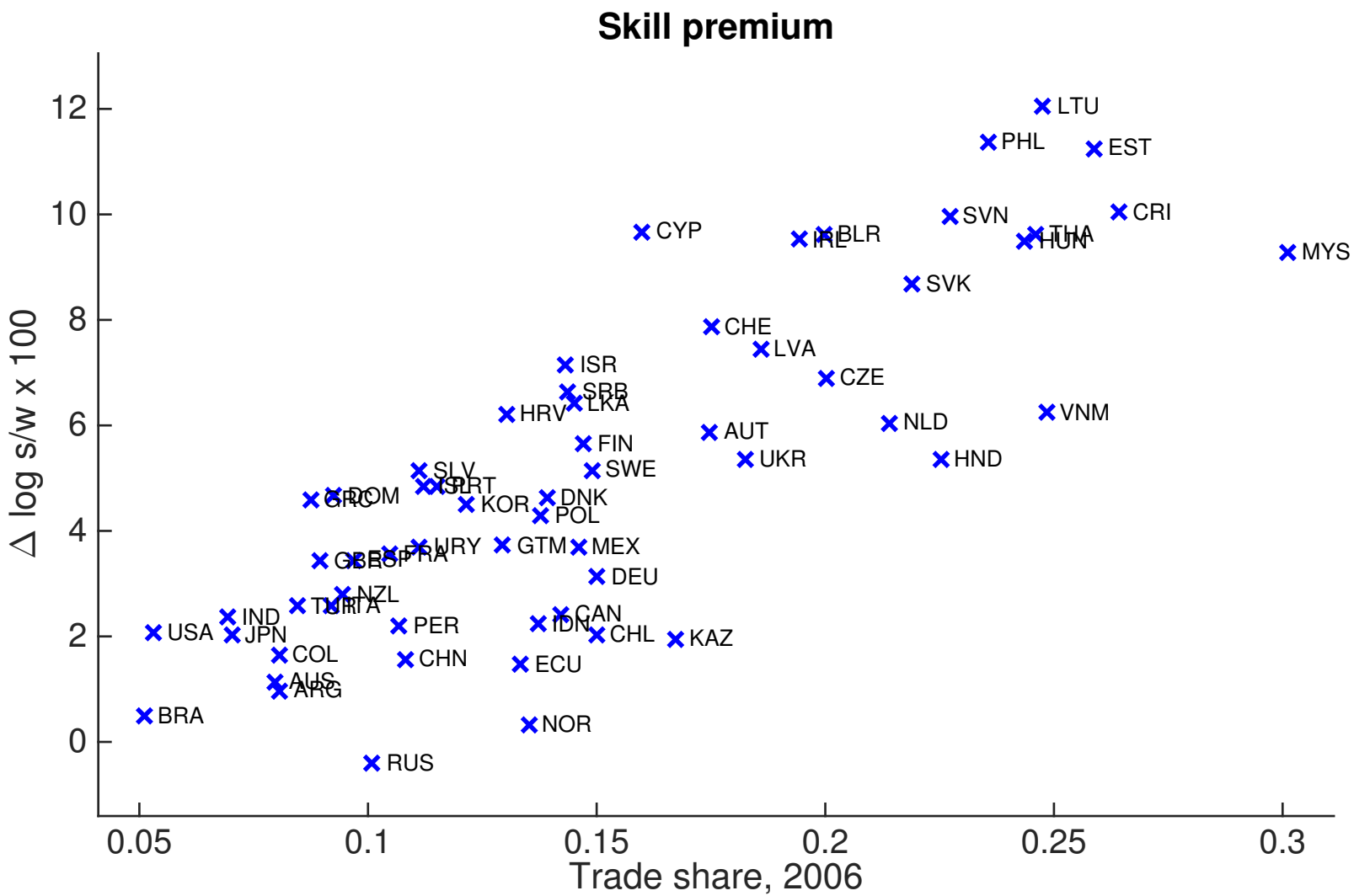
From autarky to 2006 baseline

Change in real wages vs 2006 trade share



From autarky to 2006 baseline

Change in skill premium vs 2006 trade share



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

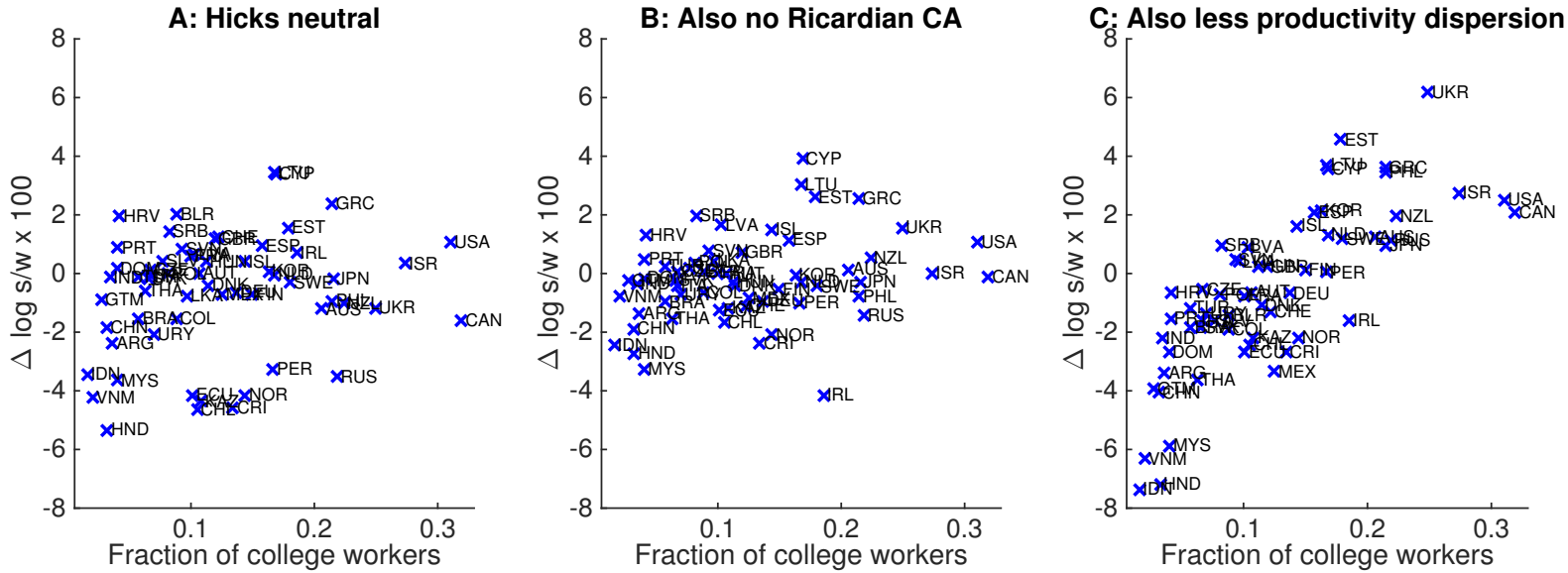
Change in skill premium vs 2006 trade share

- Regress log change in skill premium on (jointly):
  - Log GDP, negative ***
  - (Exports + Imports) / 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, $R^2 = 0.25$
  - (Exports + Imports) / 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

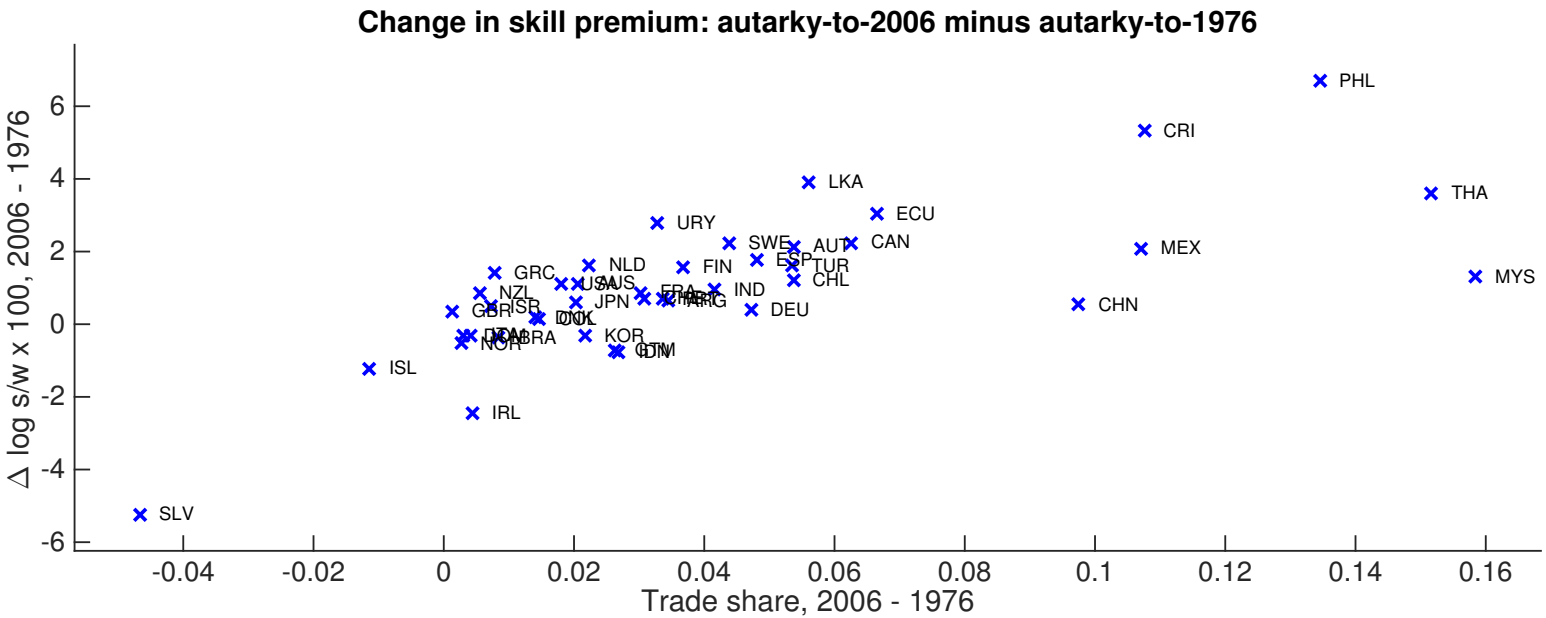
Change in the skill premium, setting $\phi = 0$. Strength of the H-O mechanism



- **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 θ & increasing in $A_1(x) A_2(y) / [A_1(y) A_2(x)]$

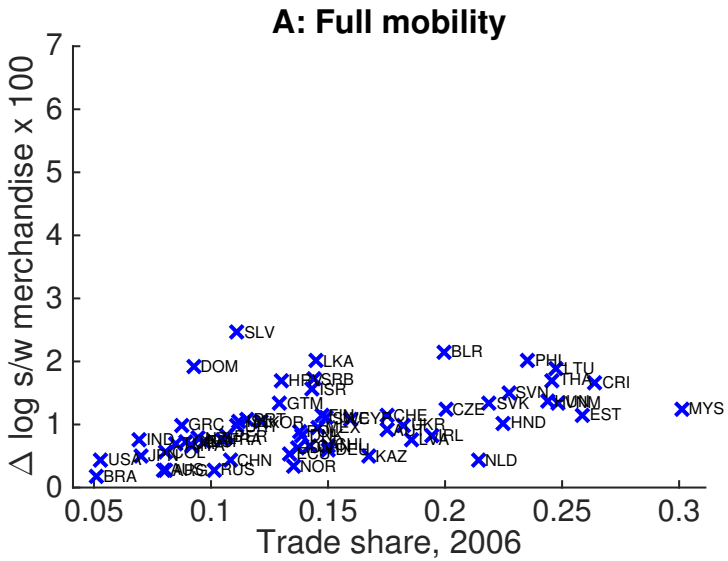
Autarky-to-2006 baseline vs. Autarky-to-1976 baseline

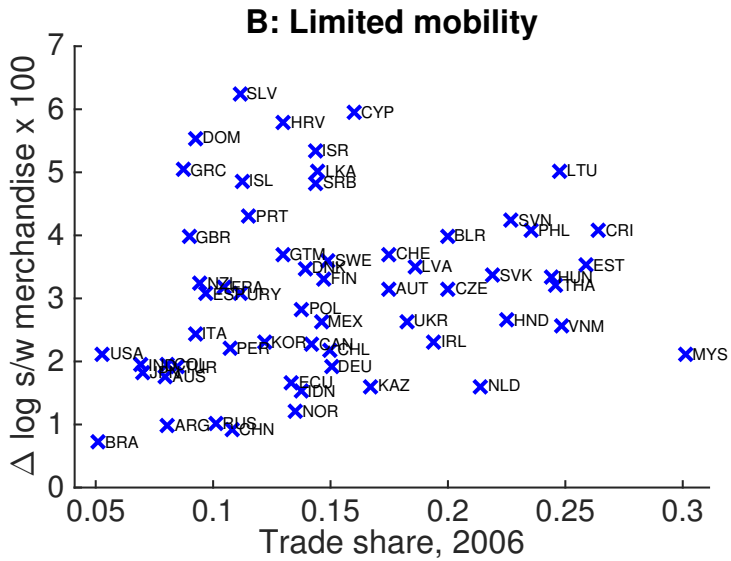
Difference in change in skill premium vs. change in trade share, 2006-1976



10% fall in trade costs from baseline parameterization

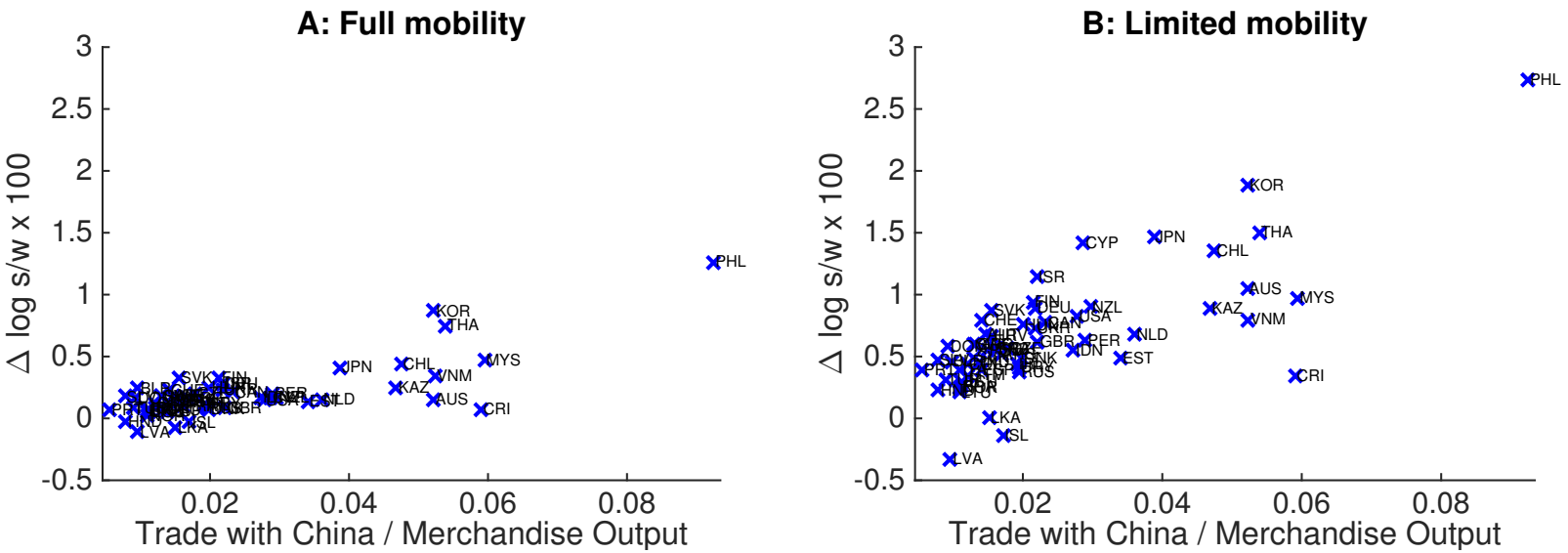
Skill premium with full and limited mobility between merchandise and services





↑ 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 α_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 details
  - 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

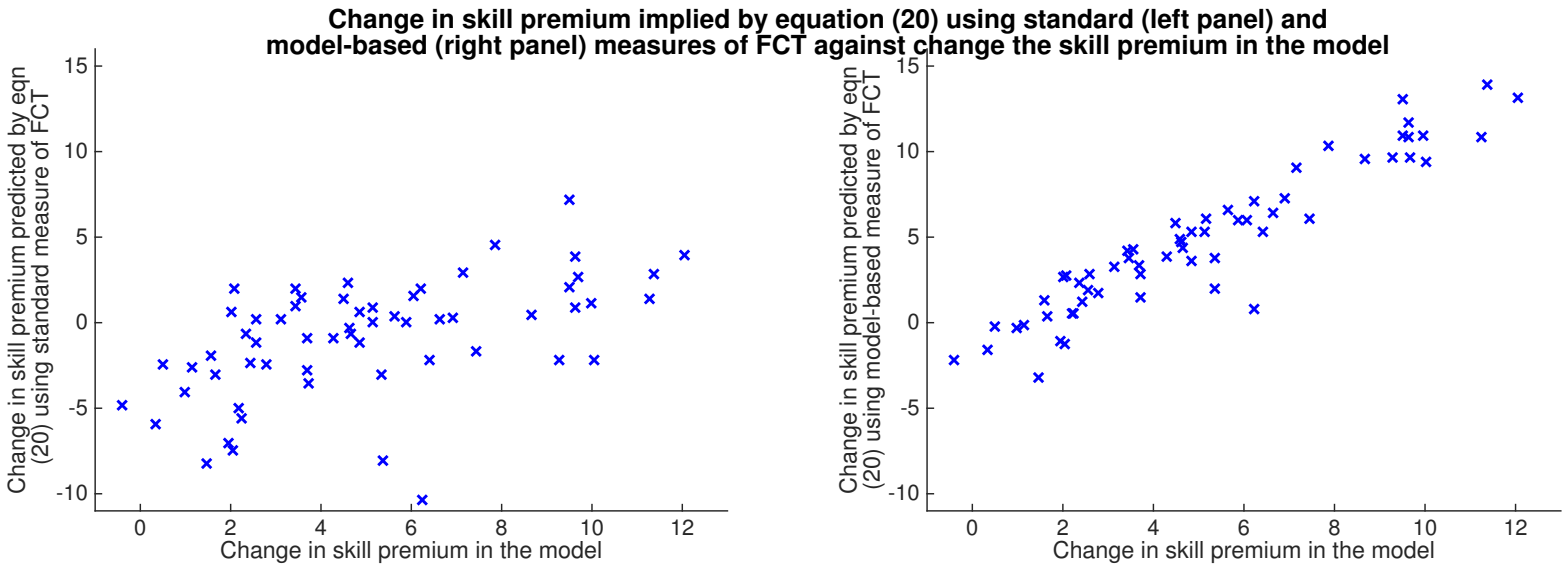
$$\frac{s_n}{w_n} = \frac{1 - FCT_n(L)/L_n}{1 - FCT_n(H)/H_n}$$

$$FCT_i(L) = \sum_j (\text{Employment of } L \text{ in sector } j) \frac{\text{Net Exp}_i(j)}{\text{Revenue}_i(j)}$$

- Strong assumptions violated in our model e.g. exporters are more skill intensive than non-exporters

Factor content of trade (FCT)

Model based vs. standard measures of FCT compared to change in skill premium

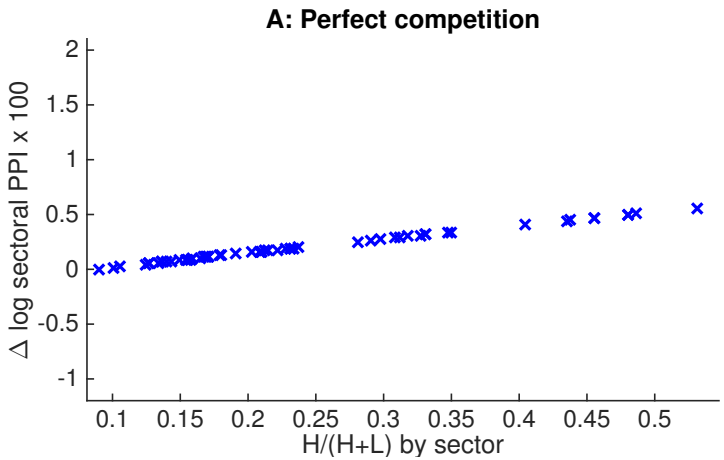


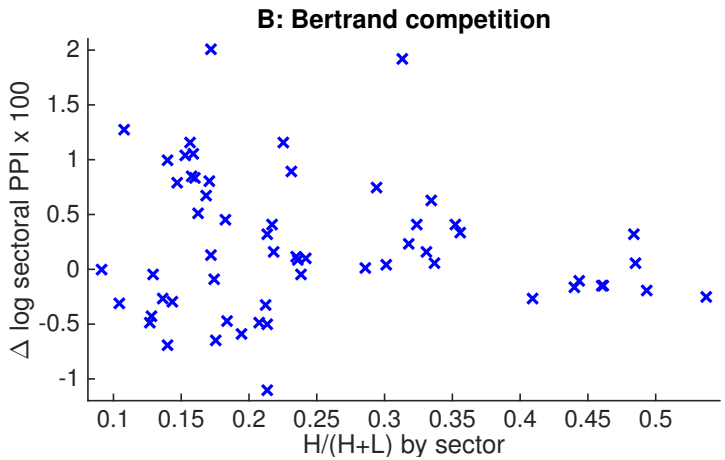
- Standard measure of FCT systematically understates in all countries the rise in s/w caused by international trade

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 $\uparrow$ relative price of skill intensive goods, it $\uparrow s/w$
     - e.g. Lawrence and Slaughter 93, Sachs and Shatz 94, Feenstra and Hanson 99
- In our model with Bertrand competition and $\phi > 0$, markups fall more in more skill-intensive sectors
  - unit costs more dispersed & imports $\uparrow$ most in these sectors
  - can get $\uparrow$ in s/w and $\downarrow$ in relative price of skill intensive goods

Changes in domestic prices by sector





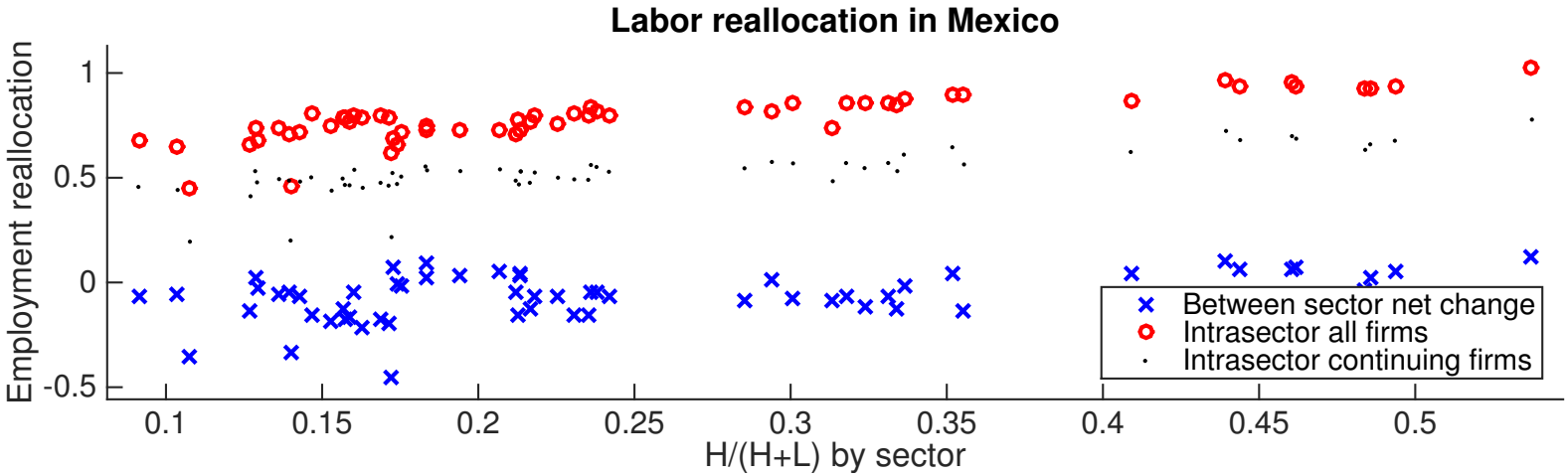
- Model can generate $\uparrow$ in s/w and $\downarrow$ in relative price of skill intensive goods

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 $>$ 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

Sectoral comparative advantage

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

	Baseline	$A_i(j) = A_i$
mean	+5.1	+6.6
max	+12.1	+16.0
min	-0.4	+1.0

No intermediate inputs

- 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 (%)

	Baseline	$\chi_n = 1$	$\chi_n = 1$ re-calibrate ρ, θ, ϕ
mean	+5.1	+5.7	+7.3
max	+12.1	+12.6	+16.6
min	-0.4	+0.5	+1.1

Varying θ

- 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 (%)

	Baseline			
	$\theta = 0.22$	$\theta = 0.12$	$\theta = 0.17$	$\theta = 0.27$
mean	+5.1	+2.2	+3.7	+6.5
max	+12.1	+8.0	+10.0	+14.2
min	-0.4	-2.2	-1.2	+0.5
trade elasticity	5.03	9.3	6.5	4.1

Varying ϕ

- 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 (%)

	Baseline		
	$\phi = 1$	$\phi = 0.6$	$\phi = 1.4$
mean	+5.1	+2.5	+7.8
max	+12.1	+8.3	+16.9
min	-0.4	-1.7	+1.1
skill-intensity elasticity	0.136	0.083	0.189

Varying σ

- 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 (%)

	Baseline		
	$\sigma = 2.7$	$\sigma = 1.01$	$\sigma = 2$
mean	+5.1	+4.4	+4.8
max	+12.1	+12.4	+12.1
min	-0.4	-2.9	-0.9

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 (%)

	Baseline	
	elasticity $= 1$	elasticity $= 0.4$
mean	+5.1	+5.5
max	+12.1	+12.6
min	-0.4	-0.1

Perfect competition

- Assume all markets are perfectly competitive
- Fix ϕ 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 α within sectors

- $\alpha_j(\omega) = \min\{\overline{\alpha}_j \exp(\varepsilon), 1\}$
- $\varepsilon \sim \ln \mathcal{N}(0, \sigma_\alpha)$
- Re-calibrate trade costs, aggregate productivities, sectoral productivities, ϕ
  - match trade shares and relative GDPs
  - match sectoral measure or normalized trade
  - match elasticity of skill intensity to size
- Let ι = standard deviation of log share of skilled workers across firms for the median merchandise sector relative to across merchandise sectors for the U.S.

	Baseline		
	$\sigma_\alpha = 0$	$\sigma_\alpha = 0.06$	$\sigma_\alpha = 0.1$
mean	+5.1	+6.1	+7.6
max	+12.1	+14.4	+18.5
min	-0.4	+0.3	+1.1
ι	0.21	0.71	1.63

Back to baseline

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
  - $FCT_i(k) = \sum_j \sum_n \left[L_{k,in}(j) - L_{k,ii}(j) \frac{\Lambda_{ni}(j)}{\Lambda_{ii}(j)} \frac{w_{k,ii}(j)}{w_{k,i}} \right]$
    - $w_{k,ii}(j)$ = 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

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

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

  - $\alpha_{k,in}(j)$ = 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
  $\Rightarrow FCT_i(k) = \sum_j L_{k,i}(j)\,\omega_i(j)$
  - $\omega_i(j) = (\text{Net Exp}_i(j))/(\text{Rev}_i(j))$
  - $\Rightarrow$ 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 $\Rightarrow \Rightarrow$ Component 2 constant across equilibria back to FCT

Costs and prices

- Let $c_{ink}(\omega, j)$ denote $\tau_{in} \times$ the unit cost of production of the k'th most productive (ω, 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 (ω, j) to n by $C_n(\omega, j)$, $C'_n(\omega, j)$

- Price of (ω, j) in country n is

$$p_n(\omega, j) = \min \left\{ C_{2n}(\omega, j), \frac{\eta}{\eta - 1} C_{1n}(\omega, j) \right\}$$

back to Trade

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?

- 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
- **Proposition**: Rise (fall) in s_1/w_1 (s_2/w_2) caused by moving from autarky to fixed trade share decreasing in θ & 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
- 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 θ & 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
- **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?
  - $\frac{h(z')}{l(z')} \Big/ \frac{h(z)}{l(z)}$ is increasing in ϕ for all $z' > z$
  - avg difference btw expanding z' & contracting z increasing in θ
- Shown quantitatively: strength of mechanism $\uparrow$ in $\theta$and ϕ

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

$$\frac{d}{d\alpha_j}\left|\frac{d\log c_{ni}(\omega,j)}{d\log z(\omega,j)}\right| > 0$$

  - Elasticity of unit cost to productivity and sectoral skill intensity is more pronounced the higher is the share of value added in gross output

$$\frac{d^2}{d\alpha_j d\chi_n}\left|\frac{d\log c_{ni}(\omega,j)}{d\log z(\omega,j)}\right| > 0$$

  - Trade reduces sector-level prices in more skill-intensive sectors
  - If $\sigma > 1$, this increase expenditure in skill-intensive sectors in all countries.

Back to h/l

Skill Intensities

- Five most and least skill-intensive merchandise sectors

Most skill intensive	Intensity
Pharma. & medicine manuf.	.611
Aerospace product and parts manuf.	.561
Computer and peripheral equip. manuf.	.553
Commun., audio, & video equip. manuf.	.465
Forestry except logging	.455

Least skill intensive	Intensity
Logging	.040
Animal slaughtering, processing	.073
Fiber, yarn, and thread mills	.075
Carpets and rug mills	.085
Turned product, screw, nut, bolt manuf.	.086

Back to Parameterization Basics