Training, Offshoring and the Job Ladder

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Research question

- How does globalization affect labor market outcomes?
- Beyond employment and wage inequality
- Our focus:
  - Labor market dynamics across occupations: job-to-job transition, employment to non-employment transition
  - On-the job training
  - Life-cycle wage trajectories

Post 1980 trends in U.S. labor markets

- Skill premiums have grown (Acemoglu and Autor, 2011).
- Fraction of the population attending college has grown
- Jobs in the middle of the skill distribution have become relatively scarce (Acemoglu and Autor, 2011)
- Manufacturing work force has shifted toward services (Lee and Wolpin, 2006, 2010; Eberstein et al., 2014)
- Job turnover rates have fallen (Davis and Haltiwanger, 2014; Haltiwanger, et al., 2015)
- On-the-job training times have increased (Cairo, 2013)

This paper

- Develop an open-economy model with search and matching frictions in the labor market and human capital accumulation that generates predictions on all these variables
- Calibrate the model to labor market and trade data
- Show it is possible to generate noted trends, plus some less-known stylized facts, with a globalization shock
- Quantify relative importance of globalization and commercial policies (in progress)
- Put a structural underpinning behind large reduced-form literature by relating foreign competition to life cycle wage trajectories and unemployment spells

The basic mechanism

- Heterogeneous high school graduates decide whether to attend college
- After completing schooling, workers enter into the labor market
- Search randomly across occupations and eventually match with heterogeneous employers
- Once employed, workers
  - produce tasks
  - bargain over their wages
  - improve their ability through experience and job training
- Over their life cycles, workers' wage growth is driven by
  - improvements in ability
  - arrival of job offers from poaching employers ("job ladder")
  - unemployment spells

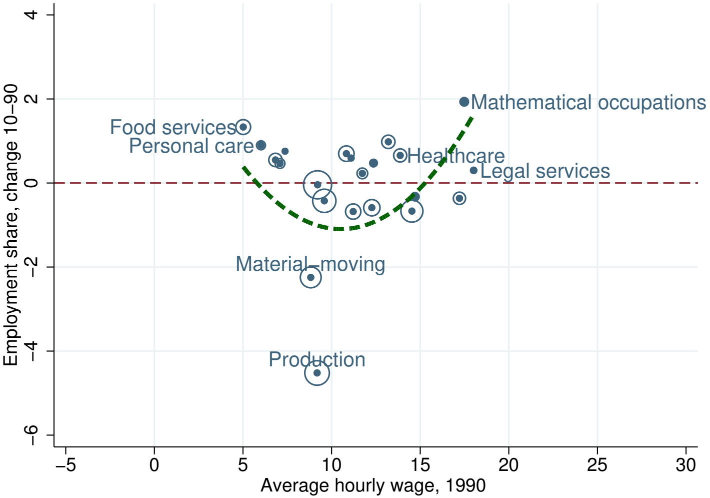
Key linkages

- Goods producers demand tasks and combine them with intermediates
- Reduction in trade costs allows goods producers to substitute tasks with foreign intermediates
  - Slows down turnover by limiting outside options of employees
  - Low arrival rate of attractive job offers slows movement up job ladder and wage growth
- Globalization changes the incentives to invest in college degrees
  - College allows one to leapfrog missing rungs in the job ladder
- Similarly, globalization affects training incentives
  - Those with college degrees see greater returns to job training
  - Those without degrees are discouraged by the missing rungs they see as they look upward
- Related literature

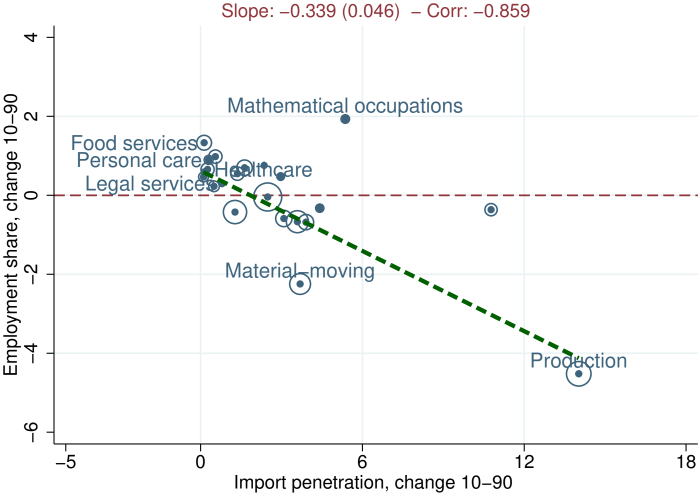
Some stylized facts

- Data sets:
  - **Survey of Income and Program Participation** (**SIPP**) nationally representative U.S. household-based survey; continuous series of national panels, each lasting approximately four years
  - **Occupational Information Network (O*NET)**: skill mix (brain, brawn) of 4-digit 2002 SOC occupations
  - **World I-O Table (WIOT)** imports, exports and output by sector
- Variables:
  - **Employment share:** average, by 2-digit occupation
  - **Job flows:** employment-weighted average monthly flows, by occupation
  - **Training indicator**: Have you received job training?
  - **Wage measures**: Hourly wage and monthly labor income, by age and/or occupation
  - **Skill indeces**: Brain, brawn content of occupations
  - **Tradability indices**: import penetration rates, by occupation

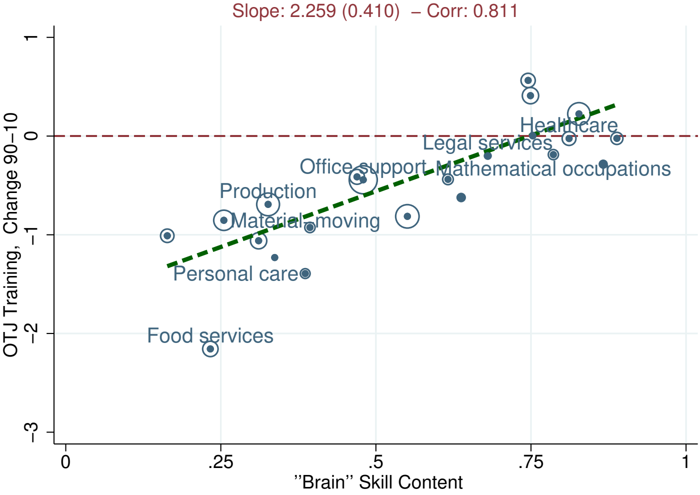
Change in emp-shares, 2010 vs. 1990



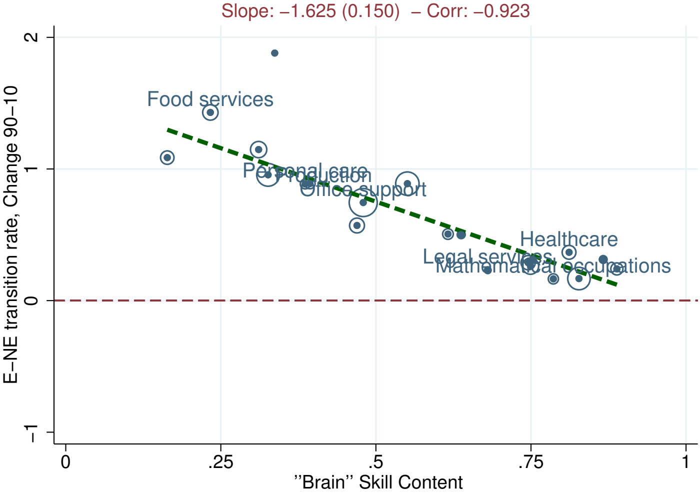
Change in emp-shares, 2010 vs. 1990



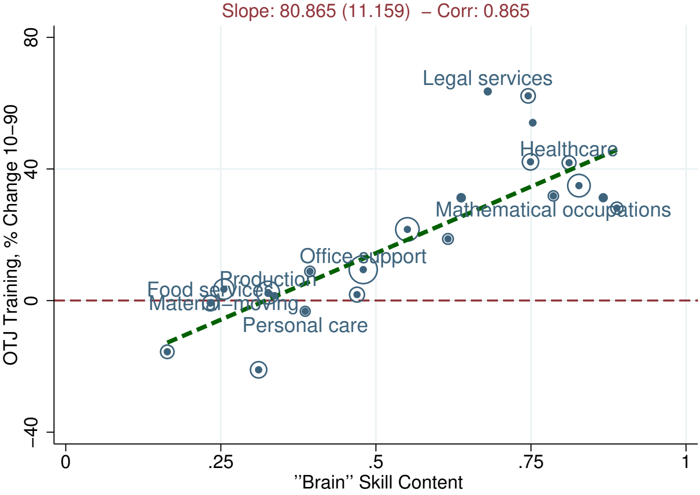
Change in J-to-J rates, 2010 vs. 1990



Change in E-to-NE rates, 2010 vs. 1990



Change in training rates, 2010 vs. 1990



Recap

- The share of employment in middle-paid and trade-exposed occupations have declined
- Job-to-job transitions have declined more within low-skill occupations
- Transition out of employment has increased more from low-skill occupations
- Provision of on-the-job training has declined in low-skill, but increased in high-skill occupations
- Further evidence on labor income

Model structure

Three main model building blocks:

- Life-cycle human capital accumulation and college education (Bagger et al. 2014, Lise et al. 2016, Flin et al. 2016)
- Search and matching frictions in the labor market (Mortensen and Pissarides 1999, Mortensen 2010)
- Ricardian production and trade with sectoral linkages (Caliendo and Parro 2014)

more

Worker-consumers

- Born with an initial ability level $a^* \in \{a_1, ..., a_I\}$ drawn from F_{a^*}
- Either invest in a college degree (become an H-type) or enter the labor market as low-skilled (L-type) worker.
- Those who go to college incur a utility cost of κ / a^*
- Search for jobs across tasks-producing firms and meet randomly with open vacancy
- Stochastically improve their ability level through on-the-job experience and job training
- Exogenous (δ_w) exit rate from labor market

Task-producing firms

- Specialize in a producing a particular "task", indexed by $j \in \{1, .., J\}$ (construction services, secretarial services, legal services, cleaning services, etc)
- Employ workers they match with in a frictional labor market (one worker or vacancy per firm)
- Face permanent productivity differences s_j and idiosyncratic productivity shocks z' drawn from $\Lambda(\cdot|z)$
- Task-producing technology:

$$y_E(j, z, i) = z s_j a_i^{\zeta_{jE}} - c^o \qquad E \in \{L, H\}$$

- Supply tasks $y_E(j, z, i)$ in competitive national market at price r_j
- Decide to invest in the training of their employees at a cost c^t/a
- Exogenous (δ_f) + endogenous job destruction rate

Matching and bargaining

- CRS matching function m between
  - seekers of jobs in occupation j (unemployed+employed)

$$X_j = \lambda_{0j} U + \lambda_{j'j} N_{j'}$$

  - different visibility of unemployed, λ_{0j} and employed workers $\lambda_{j'j}$ to occupation j
  - aggregate vacancies in occupation j, V_j

- Bargaining protocol based on Mortensen (2011)
  - Negotiation with unemployed workers more
  - Renegotiation after outside offers more
  - Renegotiation after productivity shocks more
  - Renegotiation after human capital updates more

Experience, training and education

- Hazard of a one-step improvement for a worker with education E and skill i at a type-j task-producing firm with productivity z:

$$\gamma_E(j,z,i) = \gamma^1_{j,E} + \gamma^2_{j,E}\mathbf{1}^t_E(j,z,i)$$

- Training provision determined cooperatively a lá Flinn et al. (2014)
  - joint match surplus maximization problem:

$$\mathbf{1}^t_E(j,z,i) = \begin{cases} 1 & \text{if} \quad S_E(j,z,i;\mathbf{1}^t_E(j,z,i)=1) \\ & \qquad \geq S_E(j,z,i;\mathbf{1}^t_E(j,z,i)=0) \\ 0 & \text{otherwise} \end{cases}$$

- College decision depends on initial ability, a^*:

$$E(a^*) = \begin{cases} H & \text{if} \quad \frac{k}{a^*} \leq J^u_H(a^*) - J^u_L(a^*) \\ L & \text{otherwise} \end{cases}$$

workers-value firm-value surplus-value

Good-producing firms

- Follow Caliendo and Parro (2015), except each producer uses bundles of labor services (tasks)
- N countries, K sectors
- Continuum of different varieties ω within each sectors
- For each country $n \in \{1, ...N\}$ and sector $k \in \{1, ...K\}$ there is a unique supplier of variety ω (domestic or foreign)
- Nested preferences over differentiated varieties utility

Production function

- Each producer of variety ω has a productivity $e_k^n(\omega)$ drawn from a Frechet distribution with location parameter T_k^n and dispersion θ_k
- Output is produced combining a bundle of tasks (y_k^n) and bundles of product varieties $(x_{k\widetilde{k}}^n)$

$$q_k^n(\omega) = e_k^n(\omega) \underbrace{\left(\frac{y_k^n}{\alpha_k^n}\right)^{\alpha_k^n}}_{\text{tasks}} \underbrace{\prod_{\widetilde{k}=1}^{K} \left(\frac{x_{k\widetilde{k}}^n}{(1-\alpha_k^n)\vartheta_{\widetilde{k}}^n}\right)^{(1-\alpha_k^n)\vartheta_{\widetilde{k}}^n}}_{\text{intermediates}}$$

- Task and intermediate bundles

$$y_k = \prod_{j=1}^{J} \left(\frac{y_{jk}^n}{\mu_{jk}^n}\right)^{\mu_{jk}^n}, \quad \mu_{jk}^n \geq 0, \sum_{j=1}^{J} \mu_{jk}^n = 1$$

$$x_{k\tilde{k}}^n = \left[\int_{\tilde{\omega} \in \Omega_{\tilde{k}}^n} x_{k\tilde{k}}^n(\tilde{\omega})^{\frac{\eta_k - 1}{\eta_k}} d\tilde{\omega}\right]^{\frac{\eta_k}{\eta_k - 1}}, \quad \eta_k > 1$$

Global sourcing

- Goods are sourced globally from their cheapest suppliers (Eaton and Kortum, 2002)

$$p_k^n(\omega) = \min_{\widetilde{n}} \frac{d_k^{n,\widetilde{n}} u_k^{\widetilde{n}}}{e_k^{\widetilde{n}}(\omega)},$$

  where $u_k^{\widetilde{n}}$ is marginal costs while $d_k^{n,\widetilde{n}} = \kappa_k^{n,\widetilde{n}}(1 + \tau_k^{n,\widetilde{n}}) \geq 1$ adjusts the f.o.b. prices of imported type-k goods for iceberg trade costs, $\kappa_k^{n,\widetilde{n}}$, and tariffs, $\tau_k^{n,\widetilde{n}}$

- Share of type-k goods that country n sources from country $\tilde{n}$

$$\pi_k^{n,\widetilde{n}} = \frac{T_k^{\tilde{n}} \left(u_k^{\tilde{n}} d_k^{n,\tilde{n}} \right)^{-\theta_k}}{\sum_{n'=1}^{N} T_k^{n'} \left(u_k^{n'} d_k^{n,n'} \right)^{-\theta_k}}$$

Calibration

Model set-up:

- Baseline period: 2005-2008
- Countries: 30 + ROW
- Industries: 30 ISIC Rev.3.1 (15 tradable)
- Occupations: 5 SOC 1-digit
- Model numeraire: monthly labor income per employee (USD 3700)

Assumptions:

- The economy is in steady state equilibrium
- Labor markets in non-US countries is frictionless and foreign labor is homogeneous
- Functional forms

Goods production calibrated directly from production data

External parameters

Parameter	Description	Value	Source
ρ	Discount factor	0.0033	4% yearly
δ_w	Retirement rate	0.0023	ages 25-60
δ_f	Firm exit rate	0.0045	BLS 2005
β	Bargaining power	0.50	Pissarides (2009)
χ	Matching function	0.45	Den Haan et al (2006)
(b_L, b_H)	Home production	(0.31, 0.52)	ACS 2005
c_v	Cost of vacancy	0.29	Abowd and Kramarz (2003)
c_t	Cost of training	0.16	Abowd and Kramarz (2003)
$(\alpha_{a^*}, \beta_{a^*})$	Distribution of a^*	(2.11, 2.45)	AFQT (NLSY) test distribution
(φ, Δ_z)	Productivity shock	(1.57, 0.24)	Lee and Mukoyama (2015)

Calibrated parameters

Parameter	Description	Value
κ	Cost of college education	181.02
c^o	Cost of operating	1.18
Δ_s	Productivity heterogeneity	0.64
λ_0	Visibility, unemployed	0.032
(λ_1, ξ)	Visibility, employed	(0.038, 0.02)
(ζ^L, ζ^H)	Return from human capital	(0.09, 0.24)
(γ_0^L, γ_0^H)	Experience, hazard rate	(0.03, 0.05)
(γ_1^L, γ_1^H)	Training, hazard rate	(0.06, 0.15)

Moments

Moments	**Data**	**Model**
Labor income		
College premium	0.557	0.491
St.Dev., non-college	0.605	0.375
St.Dev., college	0.735	0.641
45-25 y.o. premium, non-college	0.191	0.144
45-25 y.o. premium, college	0.382	0.376
Training premium	0.356	0.103
Occupation premium	0.337	0.199
Labor market flows		
NE-E rate	0.022	0.016
E-NE rate	0.023	0.025
J-J rate	0.019	0.022
Shares		
College share	0.281	0.310
Training share	0.392	0.304

Counterfactuals

Main experiment:

- change in tariffs (observed) from 1993 to 2005 (NAFTA + China shock)

Counterfactual outcomes

tasks j	1	2	3	4	5
1-digit SOC	45-49	51-53	31-39	41-43	11-29
Brain-content	0	0.056	0.134	0.236	1
Δr_j, %	+0.36	-0.41	-0.16	-0.24	+0.71
Employment share, Δ	+0.09	-0.15	-0.08	-0.07	+0.21
J-J rate , Δ	-0.22	-0.08	-0.07	-0.03	0.00
E-NE rate, Δ	+0.01	+0.02	+0.03	+0.02	-0.03
Training share, Δ	-0.10	-2.32	-1.91	-1.40	+2.54
Labor income, avg. Δ%	+0.06	-0.21	-0.12	-0.01	+0.30
Labor income growth, 45-25 y.o. Δ%	+0.00	-0.22	-0.19	-0.05	+0.22

Next steps

- Use full range of occupations and sectors and calibrate more seriously
- Little contribution of tariff reduction. Explore added contribution of:
    - reduction in physical trade costs
    - skill-biased technological change
- Consider counterfactual policy experiments with commercial policy, education subsidies, training subsidies
    - Trade Adjustment Assistance (TAA) program

Related labor literature

- **On-the-job search and bargaining with ex ante heterogeneous workers and firms**: Bagger et al. (2014), Lise et al. (2016), and Lise and Robin (2017).

- **Job and worker turnover decisions interdependent with training:** Cairo (2013), Cairo and Kajner (2016), Flinn, et al. (2017), Lentz and Roys (2015)

- **Stylized facts on job turnover, skill premium, relation to tradability of products**: Hyatt and Spletzer (2012), Decker et al. (2014), Davis and Haltiwanger (2014), Cairo et al. (2015), Haltiwanger et al. (2015), Autor and Dorn (2013), Jensen and Kletzer (2006), Kletzer (2007), Autor et. al (2013, 2014), etc..

back

Related trade literature

- **Output producers bundle specific tasks, some of which can be accomplished offshore and embodied in intermediate goods trade**: Grossman and Rossi-Hansberg (2008) and Eaton et al. (2017).

- **Product market shocks partly transmitted through global intermediate input markets**. Caliendo and Parro (2015).

- **Globalization affects the skill distribution by changing the worker-specific returns to human capital investment**: Cosar (2013), Davidson and Sly (2014), and Blanchard and Willmann (2016).

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Related trade literature, continued

- **Random search processes empirically link openness with job turnover and unemployment**: Cosar, et al., (2016), Helpman et al. (2017), and Fajgelbaum (2017), Carrere et al. (2017).

- **Quantify barriers to worker mobility across sectors and/or occupations:** Lee and Wolpin, 2006 and 2010; Cosar, 2013; Artuc et al., 2014 and 2016; Dix-Carneiro, 2014; Caliendo et al., 2016; Lee, 2016; and Traiberman, 2017.

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Measure of import exposure

The occupation-specific index of import exposure is a share-weighted import penetration rate:

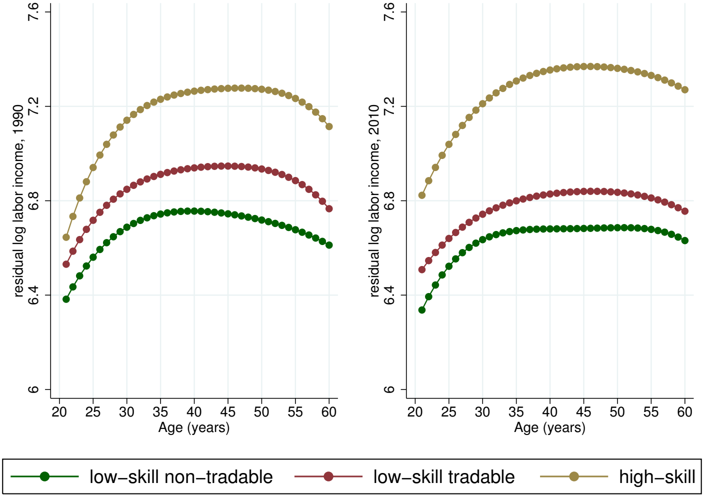
$$IMP_{j,t} = \sum_{k=1}^{K} \frac{L_{k,j,t}}{L_{j,t}} \frac{imports_{k,t}}{output_{k,t} + imports_{k,t} - exports_{k,t}},$$

where

- $k = 1, ..., K$ denotes sector
- $\frac{L_{k,j,t}}{L_{j,t}}$ is the employment share of sector k in occupation j at time t.

back

Age earnings profile, 2010 vs. 1990



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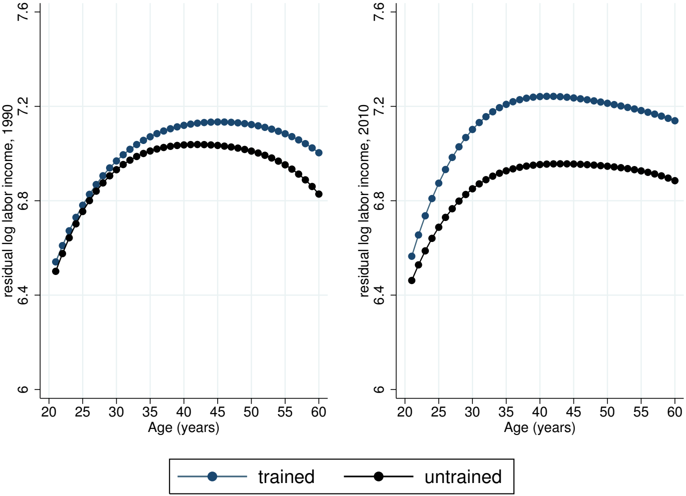
Age earnings profile, 2010 vs. 1990



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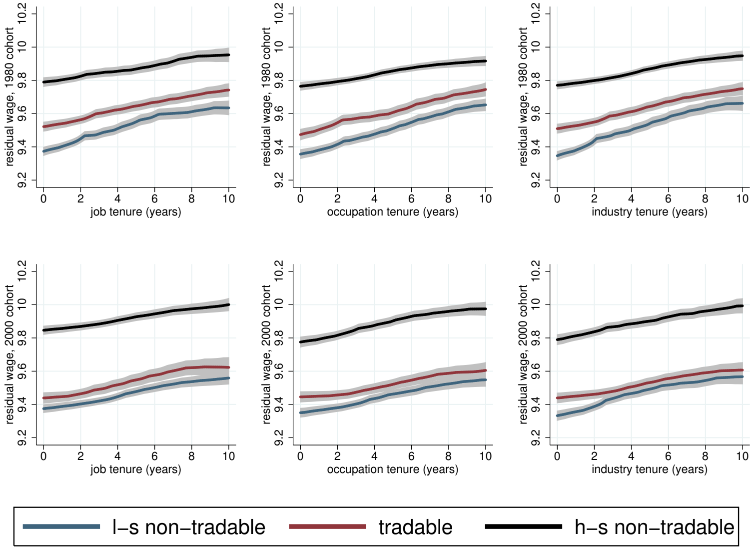
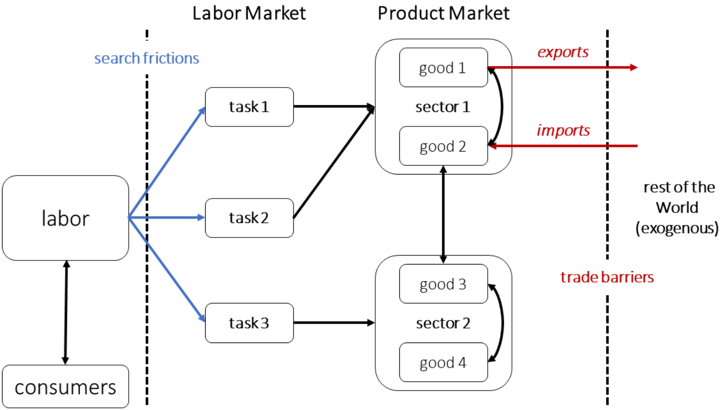
Tenure earning profile back



Model structure



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Preferences

Preferences over consumption goods, characterized by the nested flow utility function:

$$c(t) = \prod_{k=1}^{K} \left[\bar{c}_k(t)\right]^{\nu_k}, \quad \nu_k \in (0,1), \sum_{k=1}^{K} \nu_k = 1$$

$$\bar{c}(t)_k^n = \left(\int_{\omega \in \Omega_k} \left[c_{k\omega}^n(t)\right]^{\frac{\eta_k - 1}{\eta_k}} d\omega \right)^{\frac{\eta_k}{\eta_k - 1}}, \quad \eta_k > 1$$

Worker-consumers maximize the expected present value of their utility stream,

$$\mathcal{U} = \int_0^\infty c(t) \exp^{-(\rho+\delta_w)t} \, dt,$$

where $\rho > 0$ is a subjective discount rate of workers.

back

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back

Negotiation with unemployed workers

- Unemployed worker (E, i) gets in contact with firm (z, j). Wage w_u is negotiated using Nash bargaining protocol:

$$J_E^e(w_u, j, z, i) - J_E^u(i) = \beta S_E(j, z, i)$$

where $\beta \in (0, 1)$ is worker′s bargaining parameter

back

Renegotiation after outside offer

- Worker (E, i) employed in a firm (z, j) gets in contact with firm $(\tilde{z}, \tilde{j})$. Given current wage w, new wage w_o is updated using the following protocol:
  - (Case 1 – Worker moves)
    $\forall \tilde{z} \in \mathcal{A}_E(j, z, i|\tilde{j}) := \{\tilde{z} \in \mathcal{Z} : S_E(\tilde{j}, \tilde{z}, i) > S_E(j, z, i)\}$, w_o is set such that
    $$J_E^e(w_o, \tilde{j}, \tilde{z}, i) - J_E^u(i) = \beta S_E(\tilde{j}, \tilde{z}, i)$$
  - (Case 2 – Worker stays)
    $\forall \tilde{z} \notin \mathcal{A}_E(j, z|\tilde{j}, i)$, $w_o = w$

back

Renegotiation after productivity shock

- Worker (E, i) employed in a firm (z, j) facing a productivity jump from z to $\tilde{z}$. Given current wage w, new wage w_φ is updated as follow:

  - (Case 1 – Worker renegotiates)
    $\forall z \notin \mathcal{B}_E(j, i)$, w_φ is set such that

    $$J_E^e(w_\varphi, j, \tilde{z}, i) - J_E^u(i) = \beta S_E(j, \tilde{z}, i)$$

  - (Case 2 – Worker becomes unemployed)
    $\forall z \in \mathcal{B}_E(j, i) := \{z \in \mathcal{Z} : S_E(j, z, i) < 0\}$, $w_\varphi = b_E$

back

Renegotiation after human capital jump

- Worker (E, i) employed in a firm (z, j) which experience a human capital jump from a_i to a_{i+1}. Given current wage w, new wage w_γ is updated as follow:

  - (Case 1 – Worker renegotiates)
    $\forall z \notin \mathcal{C}_E(j, i)$, w_γ is set such that

    $$J_E^e(w_\gamma, j, z, i+1) - J_E^u(i+1) = \beta S_E(j, z, i+1)$$

  - (Case 2 – Worker becomes unemployed)
    $\forall z \in \mathcal{C}_E(j, i) := \{z \in \mathcal{Z} : S_E(j, z, i+1) < 0\}$, $w_\gamma = b_E$

back

Workers′ values

- Value of unemployment

$$[\rho + \delta_w] J_E^u(i) = \underbrace{b_E}_{\substack{\text{income}\\ \text{flow}}} + \sum_{j \in \mathcal{J}} \tilde{\phi}_{0j} \sum_{z \in \mathcal{Z}} \underbrace{\max\{J_E^u(w_u, j, z, i) - J_E^u(i), 0\}}_{\text{option value of employment}} v_j(z)$$

back

Workers′ values

- Value of employment

$$
\begin{aligned}
[\rho + \delta_w] J^e_E(w, j, z, i) = & \underbrace{w}_{\substack{\text{wage} \\ \text{flow}}} - \underbrace{c^t / a_i \mathbf{1}^t_E(j, z, i)}_{\text{training cost}} \\
& + \delta_f \underbrace{[J^u_E(i) - J^e_E(w, j, z, i)]}_{\text{option value of firm exit}} \\
& + \varphi \sum_{\tilde{z} \in \mathcal{Z}} \underbrace{\max\{J^e_E(w_\varphi, j, \tilde{z}, i) - J^e_E(w, j, z, i), J^u_E(i) - J^e_E(w, j, z, i)\}}_{\text{option value of productivity jump}} \Lambda(\tilde{z}|z) \\
& + \gamma_E(j, z, i) \underbrace{[J^e_E(w_\gamma, j, z, i+1) - J^e_E(w, j, z, i)]}_{\text{option value of human capital jump}} \\
& + \sum_{\tilde{j} \in \mathcal{J}} \tilde{\phi}_{j\tilde{j}} \sum_{\tilde{z} \in \mathcal{A}_E(j, z, i|\tilde{j})} \underbrace{[J^e_E(w_o, \tilde{j}, \tilde{z}, i) - J^e_E(w, j, z, i)]}_{\text{option value of j2j transition}} v_{\tilde{j}}(\tilde{z})
\end{aligned}
$$

back

Firms′ values

- Value of open vacancy

$$(\rho+\delta_f)\Pi^v(j,z) = \underbrace{-c^v}_{\substack{\text{flow cost of}\\\text{posting vacancy}}}$$

$$+\,\phi_{0j}\sum_{E\in\{L,H\}}\sum_{h_i\in\mathcal{H}}\underbrace{\max\{\Pi^e_E(w_u,j,z,i)-\Pi^v(j,z),0\}}_{\text{option value of hiring unemployed worker}}\,g_E(i)$$

$$+\sum_{E\in\{L,H\}}\sum_{h_i\in\mathcal{H}}\sum_{\tilde{j}\in\mathcal{J}}\phi_{\tilde{j}j}\sum_{\tilde{z}\in\mathcal{Z}}\underbrace{\max\{\Pi^e_E(w_o,j,z,i)-\Pi^v(j,z),0\}}_{\text{option value of poaching employed worker}}\,n_{E\tilde{j}}(\tilde{z},i)$$

back

Firms′ values

- Value of active vacancy

$$
\begin{aligned}
[\rho+\delta_f]\Pi^e_E(w,j,z,i) &= \underbrace{r_j y_E(j,z,i)-w}_{\text{profit flow}} \\
&+\delta_w \underbrace{[\Pi^v(j,z)-\Pi^e_E(w,j,z,i)]}_{\text{option value of worker retirement}} \\
&+\varphi\sum_{\tilde{z}\in\mathcal{Z}} \underbrace{\max\{\Pi^e_E(w_\varphi,j,\tilde{z},i)-\Pi^e_E(w,j,z,i),\Pi^v(j,\tilde{z})-\Pi^e_E(w,j,z,i)\}}_{\text{option value of productivity jump}}\Lambda(\tilde{z}|z) \\
&+\gamma_E(j,z,i)\underbrace{\max\{\Pi^e_E(w_\gamma,j,z,i+1)-\Pi^e_E(w,j,z,i),\Pi^v(j,z)-\Pi^e_E(w,j,z,i)\}}_{\text{option value of human capital jump}} \\
&+\sum_{\tilde{j}\in\mathcal{S}}\tilde{\phi}_{j\tilde{j}}\sum_{\tilde{z}\in\mathcal{A}_E(j,z,i|\tilde{j})}\underbrace{[\Pi^v(j,z)-\Pi^e_E(w,j,z,i)]}_{\text{option value of j2j transition}}v_{\tilde{j}}(\tilde{z})
\end{aligned}
$$

back

Surplus function

$$
\begin{aligned}
&[\rho + \delta_f + \delta_\ell + \varphi + \gamma_E(j,z,i) + \sum_{\tilde{j}\in\mathcal{S}} \tilde{\phi}_{j\tilde{j}} \sum_{\tilde{z}\in\mathcal{A}_E(j,z,i|\tilde{j})} v_{\tilde{j}}(\tilde{z})]S_E(j,z,i) = \\
&\underbrace{r_j y_E(j,z,i)}_{\text{revenue flow}} - \underbrace{c^t/a_i \mathbf{1}^t_E(j,z,i)}_{\text{training costs}} + \underbrace{\varphi \sum_{\tilde{z}\in\mathcal{Z}} \max\{S_E(j,\tilde{z},i),0\}\Lambda(\tilde{z}|z)}_{\text{surplus gain from productivity jump}} + \\
&\underbrace{\gamma_E(j,z,i)\max\{S_E(j,z,i+1),0\}}_{\text{surplus gain from human capital jump}} + \underbrace{\sum_{\tilde{j}\in\mathcal{J}} \tilde{\phi}_{j\tilde{j}} \sum_{\tilde{z}\in\mathcal{A}_E(j,z,i|\tilde{j})} S_E(\tilde{j},\tilde{z},i)v_{\tilde{j}}(\tilde{z})}_{\text{surplus gain from j2j transition}} \\
&+ \underbrace{\varphi\left[\sum_{\tilde{z}\in\mathcal{Z}}[\Pi^v(j,\tilde{z}) - \Pi^v(j,z)]\Lambda(\tilde{z}|z)\right]}_{\text{outside option gain from productivity jump}} + \underbrace{\gamma_E(j,z,i)\left[J^u_E(i+1) - J^u_E(i)\right]}_{\text{outside option gain from human capital jump}} \\
&- \underbrace{[\rho+\delta_\ell]J^u_E(i)}_{\text{worker's outside option}} - \underbrace{[\rho+\delta_f]\Pi^v(j,z)}_{\text{firm's outside option}}
\end{aligned}
$$

back

Equilibrium conditions (1)

- Clearing in product markets:

$$X_k^n = \sum_{\tilde{k}=1}^{K}(1-\alpha_{\tilde{k}}^n)\vartheta_{\tilde{k}k}^n \sum_{\tilde{n}=1}^{N} \frac{\pi_{\tilde{k}}^{\tilde{n},n} X_{\tilde{k}}^{\tilde{n}}}{1+\tau_{\tilde{k}}^{\tilde{n},n}} + \nu_k I_n$$

$$I^n = Y^n + T^n + D^n$$

$$T^n = \sum_{k=1}^{K}\sum_{\tilde{n}=1}^{N} \frac{\pi_k^{n,\tilde{n}}}{1+\tau_k^{n,\tilde{n}}}\tau_k^{n,\tilde{n}} X_k^n$$

$$D^n = \sum_{k=1}^{K}\sum_{\tilde{n}=1}^{N} \frac{\pi_k^{n,\tilde{n}}}{1+\tau_k^{n,\tilde{n}}} X_k^n - \sum_{k=1}^{K}\sum_{\tilde{n}=1}^{N} \frac{\pi_k^{n,\tilde{n}}}{1+\tau_k^{n,\tilde{n}}} X_k^{\tilde{n}}$$

- Clearing in task markets:

$$Y^n = \underbrace{\sum_{k=1}^{K} \mu_{jk}^n \frac{\bar{r}_k}{r_j}\frac{\alpha_k^n}{\bar{r}_k} X_k^n}_{\text{demand}} = \underbrace{N_j \sum_{E\in\{L,H\}}\sum_{i\in\mathcal{I}}\sum_{z\in\mathcal{Z}} y_E(j,z,i) f_E(j,z,i)}_{\text{supply}}$$

back

Equilibrium conditions (2)

- Free entry condition for task-producing firms

$$\sum_{z \in \mathcal{Z}} \Pi^v(j,z)\Lambda^e(z) \leq 0, \quad F_j \geq 0, \quad \forall j \in \mathcal{J}$$

- Flows of task-producing firms across states

$$\underbrace{F_{jz}\left[\delta_f + \varphi \sum_{\tilde{z} \in \mathcal{Z}/z} \Lambda(\tilde{z}|z)\right]}_{\text{outflows + exit}} = \underbrace{\varphi \sum_{\tilde{z} \in \mathcal{Z}} \Lambda(z|\tilde{z}) F_{j\tilde{z}}}_{\text{inflows}} + \underbrace{\Lambda^e(z) F^e_j}_{\text{new entrants}} \quad \forall z \in \mathcal{Z}, \forall j \in \mathcal{J}$$

back

Equilibrium conditions (3)

- Flows of task-producing firms-workers matches

$$\underbrace{\gamma_E(j,z,i-1)N_{Ej}f_E(j,z,i-1)}_{\text{inflows due to training updates}} + \underbrace{\varphi\sum_{\tilde{z}\in\mathcal{Z}}\Lambda(z|\tilde{z})N_{Ej}f_E(j,\tilde{z},i)}_{\text{inflows due to productivity change}}$$

$$\underbrace{+\left[\tilde{\phi}_{0j}U_E u_E(i)+\sum_{\tilde{j}\in\mathcal{S}}\tilde{\phi}_{\tilde{j}j}N_{E\tilde{j}}\sum_{\tilde{z}\in\mathcal{C}_1(\tilde{j},z,i|j)}n_E(\tilde{j},\tilde{z},i)\right]v_{Ej}(z)}_{\text{inflows due to new hirings}} =$$

$$\underbrace{\left[\delta_w+\delta_f+\varphi\sum_{\tilde{z}\in\mathcal{Z}/z}\Lambda(\tilde{z}|z)+\gamma_E(j,z,i)+\sum_{\tilde{j}\in\mathcal{S}}\tilde{\phi}_{j,\tilde{j}}\sum_{\tilde{z}\in\mathcal{C}_2(j,z,i|\tilde{j})}v_{E\tilde{j}}(\tilde{z})\right]N_{Ej}f_E(j,z,i)}_{\text{outflows}}$$

back

Equilibrium conditions (4)

- Flows of workers across states

$$\underbrace{U_{Ei}[\delta_w + \sum_{j \in \mathcal{J}} \tilde{\phi}_{0,j} \sum_{z \in \mathcal{Z}} \mathbf{1}_{\{S_E(j,z,i) \geq 0\}} v_{Ej}(z)]}_{\text{outflows from unemployment}}$$

$$= \underbrace{\delta_f \sum_{j \in \mathcal{J}} \sum_{z \in \mathcal{Z}} N_{Ejzi} + \varphi \sum_{j \in \mathcal{S}} \sum_{z \in \mathcal{Z}} N_{Ejzi} \sum_{\tilde{z} \in \mathcal{Z}} \mathbf{1}_{\{S_E(j,\tilde{z},i) < 0\}} \Lambda(\tilde{z}|z)}_{\text{inflows to unemployment}} + \underbrace{L^e_{Ei}}_{\text{new entrants}}$$

back

Countries in the model

- We treat the world economy as composed of 30 countries, plus a constructed rest of the world.
- The countries are Argentina, Australia, Austria, Brazil, Canada, Chile, China, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Turkey, UK, and USA.

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List of ISIC Rev.3.1. sectors

Code	ISIC Rev.3.1	Description	Import Penetration	Tradable
1	AtB	Agriculture, forestry and fishing	11.421	yes
2	C	Mining and Quarrying	51.757	yes
3	15t16	Food, Beverages and Tobacco	7.366	yes
4	17t19	Textiles, Textile Products, Leather and Footwear	138.992	yes
5	20	Wood and Product of Wood and Cork	18.645	yes
6	21t22	Pulp, Paper, Printing and Publishing	7.814	yes
7	23	Coke, Refined Petroleum and Nuclear Fuel	12.067	yes
8	24	Chemicals and Chemical Products	27.391	yes
9	25	Rubber and Plastics	17.987	yes
10	26	Other Non-Metallic Minerals	18.199	yes
11	27t28	Basic Metals and Fabricated Metals	22.139	yes
12	29	Machinery, Nec	44.211	yes
13	30t33	Electrical and Optical Equipment	81.201	yes
14	34t35	Transport Equipment	41.497	yes
15	36t37	Manufacturing, Nec; Recycling	59.991	yes
16	E	Electricity, Gas and Water Supply	0.942	no
17	F	Construction	0.102	no
18	50	Sale, Maintenance and Repair of Motor Vehicles	0.189	no
19	51	Wholesale Trade, Except of Motor Vehicles	1.092	no
20	52	Retail Trade, Except of Motor Vehicles	0.458	no
21	H	Hotels and Restaurants	0.182	no
22	60t63	Transportation	5.907	no
23	64	Post and Telecommunications	0.208	no
24	J	Financial Intermediation	1.501	no
25	70	Real Estate Activities	0.077	no
26	71t74	Renting and Other Business Activities	5.472	no
27	L	Public Admin and Defence; Compulsory Social Security	0.065	no
28	M	Education	0.601	no
29	N	Health and Social Work	0.048	no
30	OtP	Other Community, Social, Personal Services	0.907	no

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List of 1-digit SOC occupations

Code	1-digit SOC	Description	Brain-content
1	51-53	Production, Transportation, and Material Moving Occupations	0
2	45-49	Natural Resources, Construction, and Maintenance Occupations	0.056
3	31-39	Service Occupations	0.134
4	41-43	Sales and Office Occupations	0.236
5	11-29	Management, Business, Science, and Arts Occupations	1

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Calibration: goods production

Parameters	Description	Source
	Taken from the literature	
η	Elasticity of substitution between varieties ω	Broda and Weinstein (2006)
$\tau_k^{n\tilde{n}}$	Bilateral tariffs (countries n-$\tilde{n}$, sector k)	Caliendo and Parro (2015)
θ_k	Dispersion Frechet (sector k)	Caliendo and Parro (2015)
	Estimated	
ν_k^n	Consumption elasticity of product k (country n)	WIOD-IOT (2013) more
$\vartheta_{k\tilde{k}}^n$	Output elasticity of product $\tilde{k}$ (country n, sector k)	WIOD-IOT (2013) more
α_k^n	Output elasticity of labor tasks (country n, sector k)	KLEMS (2017) more
μ_{kj}^n	Labor tasks elasticity of task j (country n, industry k)	OES (2017) more

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Consumption elasticity of products

To identify the parameters $\{\nu_k^n\}_{\forall k=1..K}$ we construct the share of consumption expenditure in final goods k in each country n, i.e.

$$\frac{\bar{c}_k^n}{\bar{c}^n} = \frac{\nu_k I^n}{I^n} = \nu_k$$

back

Output elasticity of products

To identify the parameters $\{\vartheta^n_{k\tilde{k}}\}_{\forall k,\tilde{k}\in\{1,\ldots,K\}}$, we use the share of sector$-k$ expenditure in intermediate good $\tilde{k}$ out of total expenditure in materials in each country n, i.e.

$$\frac{(1-\alpha^n_k)\vartheta^n_{k\tilde{k}}\sum_{\tilde{n}=1}^{N}\frac{\pi^{\tilde{n}n}_k X^{\tilde{n}}_k}{1+\tau^{\tilde{n}n}_k}}{(1-\alpha^n_k)\sum_{\tilde{k}=1}^{K}\vartheta^n_{k\tilde{k}}\sum_{\tilde{n}=1}^{N}\frac{\pi^{\tilde{n}n}_k X^{\tilde{n}}_k}{1+\tau^{\tilde{n}n}_k}} = \frac{\vartheta^n_{k\tilde{k}}}{\sum_{\tilde{k}=1}^{K}\vartheta^n_{k\tilde{k}}} = \vartheta^n_{k\tilde{k}}$$

back

Output elasticity of labor tasks

To identify the parameters $\{\alpha_k^n\}_{\forall k \in \{1..K\}}$ we construct the ratio between domestic sector$-k$ expenditure in intermediate bundles and in task bundles in each country n, i.e.

$$
\begin{aligned}
\frac{\sum_{\tilde{k}=1}^{K} \bar{p}_{\tilde{k}}^{n} x_{\tilde{k}}^{n}}{\sum_{\tilde{k}=1}^{K} \bar{p} x_{\tilde{k}}^{k} + \bar{r}_k^n \bar{y}_k} &= \frac{(1-\alpha_k^n) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}}^{n} \sum_{\tilde{n}=1}^{N} \frac{\pi_k^{\tilde{n}n} X_k^{\tilde{n}}}{1+\tau_{\tilde{n}n}^{k}}}{\alpha_k^n \sum_{\tilde{n}=1}^{N} \frac{\pi_k^{\tilde{n}n} X_k^{\tilde{n}}}{1+\tau_k^{\tilde{n}n}} + (1-\alpha_k) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}} \sum_{\tilde{n}=1}^{N} \frac{\pi_k^{\tilde{n}n} X_k^{\tilde{n}}}{1+\tau_k^{\tilde{n}n}}} \\
&= \frac{(1-\alpha_k^n) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}}^{n}}{\alpha_k^n + (1-\alpha_k^n) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}}^{n}} = 1-\alpha_k^n
\end{aligned}
$$

back

Labor elasticity of tasks

To identify $\{\mu^n_{kj}\}_{\forall k=1..K, \forall j=1..J}$, we construct the share of tasks $j = 1..J$ demanded in sector $k = 1..K$ (measured by the employment share of occupation j for industry k) out of industry-k demand for task bundles in country n, i.e.

$$\frac{r^n_j y^n_{kj}}{\bar{r}^n_k \bar{y}^n_k} = \frac{\mu^n_{kj} \alpha^n_k \sum_{\tilde{n}=1}^{N} \frac{\pi^{\tilde{n}n}_k X^{\tilde{n}}_k}{1+\tau^{\tilde{n}n}_k}}{\alpha^n_k \sum_{\tilde{n}=1}^{N} \frac{\pi^{\tilde{n}n}_k X^{\tilde{n}}_k}{1+\tau^{\tilde{n}n}_k}} = \mu^n_{kj}$$

in conjuction with measures of r^n_j.

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Bilateral iceberg costs (symmetric)

To identify icerberg costs, $\kappa_k^{n\tilde{n}}$, we assume symmetry across trading countries ($\kappa_k^{n\tilde{n}} = \kappa_k^{\tilde{n}n}$), and we apply the Head and Reis (2001) formula:

$$\begin{aligned} \log \kappa_k^{n\tilde{n}} &= \frac{\left[\log \pi_k^{nn} + \log \pi_k^{\tilde{n}\tilde{n}}\right] - \left[\log \pi_k^{n\tilde{n}} + \log \pi_k^{\tilde{n}n}\right]}{2\theta_k} \\ &\quad -0.5[\log(1+\tau_k^{n\tilde{n}}) + \log(1+\tau_k^{\tilde{n}n})] \end{aligned}$$

in conjuction with data on trade shares, $\pi_k^{n\tilde{n}}$, and bilateral tariffs, $\tau_k^{\tilde{n}n}$.

back

Location Frechet

To estimate the location parameters T_k^n, we apply the Bolatto (2013) formula:

$$\log \frac{T_k^{\tilde{n}}}{T_k^n} = \log \frac{X_k^{\tilde{n},\tilde{n}}}{X_k^{\tilde{n}n}} - \theta_k \log d_k^{\tilde{n}n} + \theta_k \left[\alpha_k^{\tilde{n}} \log \bar{r}_k^{\tilde{n}} - \alpha_k^n \log \bar{r}_k^n\right]$$
$$+\theta_k \left[(1-\alpha_k^{\tilde{n}}) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}}^{\tilde{n}} \log p_{\tilde{k}}^{\tilde{n}} - (1-\alpha_k^n) \sum_{\tilde{k}=1}^{K} \vartheta_{k\tilde{k}}^{n} \log p_{\tilde{k}}^{n}\right]$$

in conjunction with pricing equations, data on trade flows, $X_k^{n\tilde{n}}$, data on task bundle prices, $\bar{r}_k^n$, bilateral tariffs, $\tau_k^{n\tilde{n}}$, and estimates of iceberg costs, $d_k^{n\tilde{n}}$.

back

Calibration: task production

- Initial distribution of human capital assumed to be Beta with shape parameters α_{a_0} and β_{a_0}
- Task-producing technology: $y_E(j, z, i) = z s_j a_i^{\zeta_{j,E}} - c^o$
- Permanent productivity assumed to be increasing in skill content:

$$s_j = (1 + \Delta_s)^{\text{brain}_j}, \quad \text{brain}_j \in (0, 1)$$

- Productivity shocks assumed following the Poisson jump process with hazard φ and realization equal to:

$$z' = \begin{cases} z + \Delta_z \\ z - \Delta_z \\ \text{other} \end{cases} \text{with probability} \begin{cases} \frac{1}{2}\left(1 - \frac{z}{n\Delta_z}\right) \\ \frac{1}{2}\left(1 + \frac{z}{n\Delta_z}\right) \\ 0 \end{cases}.$$

along the support $\mathcal{Z} \equiv \{-n\Delta_z, -(n-1)\Delta_z, ..., 0, ..., n\Delta_z\}$ and $n = 100$

back

Calibration: labor market

- Matching function b/w job seekers X_j, and vacancies, V_j

$$m(X_j, V_j) = \frac{X_j V_j}{(X_j^{\chi} + V_j^{\chi})^{\frac{1}{\chi}}} \quad \chi > 0$$

- Visibility parameters for unemployment workers: $\lambda_{0j} = \lambda_0 \quad \forall j \in \mathcal{J}$
- Visibility parameters for employment workers:

$$\lambda_{\tilde{j}j} = \frac{\lambda_1}{[1 + d(j, \tilde{j})]^{\xi}}$$

where $d(j, \tilde{j})$ is a measure of distance between occupations j and $\tilde{j}$, as in Traiberman (2017):

$$d(j, \tilde{j}) = \sqrt{(v^j - v^{\tilde{j}})' \Sigma^{-1} (v^j - v^{\tilde{j}})}$$
$$\Sigma = \text{var}(v)$$

and v_j is a vector of loadings on O*NET job characteristics, expressing the relative task content of occupation j.

back

Measure of distance

Distance matrix between 1-digit 2002 SOC occupations

	11-29	31-39	41-43	45-49	51-53
11-29	0	10.1895	8.25249	12.434	12.9067
31-39	10.1895	0	2.841	3.12521	3.26622
41-43	8.25249	2.841	0	5.84454	5.96841
45-49	12.434	3.12521	5.84454	0	0.756112
51-53	12.9067	3.26622	5.96841	0.756112	0

back

Proxies for task prices

- In the estimation algorithm and the current counterfactual, we treat the price of tasks, ${r_j}_1^J$, as exogenous parameters

- The model-implied prices of tasks account for
    - payment to employees: labor income received by workers
    - payments to employers: profit margin from an active job needed to cover the initial cost of posting the vacancy and the discounted sum of per-period operating costs

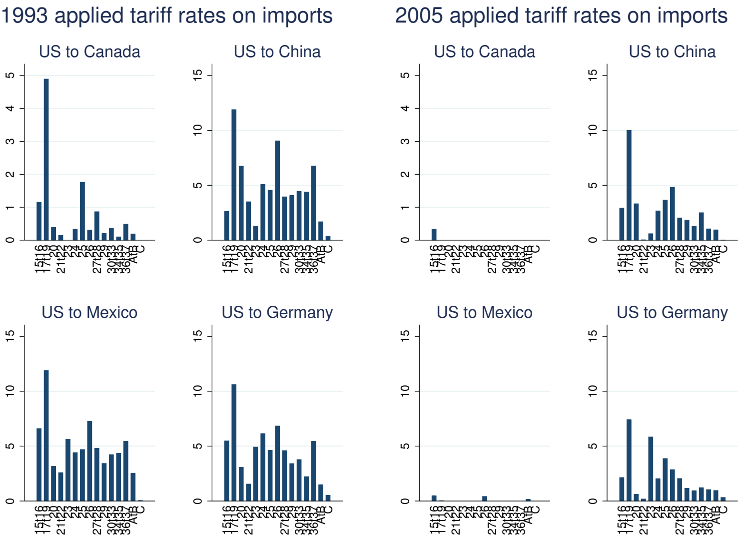
- They are constructed as the sum of two components,

$$r_j = w_j + \frac{\text{emp}_j}{\text{emp}} w_{\text{HR}}$$

where w_{HR} is the average labor income received by employees in human resource while $\frac{\text{emp}_j}{\text{emp}}$ is the share of employees in occupation j out of total employment

back

Tarifffs US-others back



Tarifffs others-US back