Teacher Labor Market and the Dynamics of Inequality

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Motivation

- Teachers account for less than 5% of the labor force but play a disproportionate role in the production of human capital
- Reward structure in teacher labor market affects:
  - → Selection of teachers
  - → Achievements of students (e.g., test scores, earnings)
- This paper studies the dynamic spillover effects of teacher labor market on income inequalities in the aggregate labor market
- Putting the teacher labor market in a dynamic GE context

This paper

- An OLG model of occupation choice & child investments:
  1. Teacher quality affected by (1) the relative returns to human capital across occupations and (2) the endogenous human capital distribution
  2. Teacher quality has differential impacts across the income distribution
- New mechanism: endogenous human capital formation amplifies the occupation selection channel
- Key parameter: substitutability b/w private and public inputs in education
- Analytical solutions + empirical evidence from duty-to-bargain laws $\Longrightarrow$ closed-form identification
- Counterfactual + model-based decompositions

Preview of Findings

1. Performance-based compensation in the teacher labor market:
   - $\rightarrow$ Increases inequality among teachers
   - $\rightarrow$ Reduces inequalities elsewhere
   - $\rightarrow$ Raise intergenerational mobility
2. With skill-biased technical change (SBTC) in non-teaching occupations:
   - $\rightarrow$ Teacher labor market greatly propagates the effects on inequalities
   - $\rightarrow$ To offset the direct effects of SBTC, the returns to human capital among teachers need to rise relatively more than the SBTC itself

$\Longrightarrow$ existing one-generation estimates understate long-run effects on teacher quality, child outcomes, and inequalities

Literature

- Education and inequality: Benabou (2002), Durlauf & Seshadri (2018), Caucutt & Lochner (2020), Fogli & Guerrieri (2019)
  Contribution: role of the teacher labor market (supply side)

- Teacher market: Hoxby (1996), Bacolod (2007), Lovenheim & Willèn (2019), Tincani (2021), Biasi & Sarsons (2022), Cohodes et al. (2023)
  Contribution: dynamic spillover effects in GE

- Aggregate impacts of occupational reward structure: Murphy, Shleifer, & Vishny (1991), King and Levine (1993), Acemoglu (1995)
  Contribution: new quantification strategy applied to teachers

Roadmap

- Model
- Solution, Dynamics, and Mechanism
- Identification and Calibration
- Counterfactual Results

Model Overview

- Two-period OLG: children and adults
- Two occupations: teachers and non-teachers (workers)
- Human capital production w/ parental investments & teacher quality
- In each period: occupation selection, then make child investments

Occupation Choice

- In period t, heterogeneous human capital $h \sim F_t(h)$
- Individuals make occupation choice after observing idiosyncratic preference shock ν (Gumbel w/ parameter θ):

$$\max_{j \in \{1,2\}} \mathbb{1}_{j=1} (\underbrace{\log(w_t \cdot h^{\psi_1} \cdot \kappa) + \nu}_{\text{teachers}}) + \mathbb{1}_{j=2} \underbrace{\log(h^{\psi_2})}_{\text{workers}}$$

- w_t is the relative wage across occupations
- ψ_j is the occupation-specific returns to human capital
- κ is the non-pecuniary benefits for being teachers

Child Investments

- Workers have children and solve

$$\max_{c,e\geq 0} \ \log(c) + \beta \log(\mathbb{E}_\epsilon h')$$

$$c + e = y = h^{\psi_2}$$

- Human capital production function $H(h, e, \xi, \epsilon)$:

$$\log(h') = A + \underbrace{\log(\epsilon)}_{\text{normal dist.}} + \underbrace{\delta_0 \xi_t + \delta_1 \log(e) + \delta_2 \cdot \xi_t \cdot \log(e)}_{\text{translog}} + \underbrace{\rho \log(h)}_{\text{residual persistence}}$$

- ξ_t is the z-score of average teacher human capital in the population

$$\xi_t = \frac{\overline{\log(h_1)} - \mu_t}{\sigma_t}$$

Discussions of Assumptions

- A reduced-form approach w/o micro-founding the assignment problem between children and teachers (Sattinger 1975, Seshadri 2003)
  - $\rightarrow$ $\delta_1 \log(e)$ captures both purchasing more books and getting matched with more effective teachers
  - $\rightarrow$ $\delta_2 < 0 \implies$ higher ξ_t reduces the role of parental investments
- ξ_t being z-score of teacher human capital in the population
  - $\rightarrow$ "Relative" learning: parallel shifts in μ_t does not affect ξ_t
  - $\rightarrow$ Results will be stronger if the level of human capital matters
- One-dimensional human capital h
  - $\rightarrow$ A Roy model generates the same intuition, but requires estimating multi-dimensional human capital production function more
- Homogeneous preferences regarding occupations robustness

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Teacher Labor Market

- Assume $F_h(h) \sim$ lognormal(μ_t, σ_t^2) - verified in equilibrium
- Share of teachers by h is

$$l(h) = \frac{(w_t \kappa h^{\psi_1 - \psi_2})^\theta}{1 + (w_t \kappa h^{\psi_1 - \psi_2})^\theta} \approx (w_t \kappa h^{\psi_1 - \psi_2})^\theta$$

- Aggregate share of teacher π_t is

$$\pi_t = \int l(h)\, dF_t(h) = (w_t \kappa)^\theta \cdot \exp\left(\mu_t(\psi_1 - \psi_2)\theta + \frac{((\psi_1 - \psi_2)\sigma_t \theta)^2}{2}\right)$$

- If π_t is fixed in real life, $\{w_t, \kappa, \psi_1\}$ need to adjust to clear the market

Teacher Quality

- Teacher quality depends on both relative skill bias and σ_t

$$\xi_t = \frac{\overline{\log(h_1)} - \mu_t}{\sigma_t} = (\psi_1 - \psi_2) \cdot \sigma_t \cdot \theta$$

- Change in teacher quality can be decomposed as

$$\underbrace{d\log(\xi)}_{\text{change in teacher quality}} = \underbrace{d\log(\psi_1 - \psi_2)}_{\text{change in selection}} + \underbrace{d\log(\sigma)}_{\text{change in h.c. dispersion}}$$

- Endogeneity of σ_t is the key to dynamic effects

Optimal Investment

- Optimal private education investment (interior solution)

$$\frac{e}{y} = \frac{\beta(\delta_1 + \delta_2 \xi_t)}{1 + \beta(\delta_1 + \delta_2 \xi_t)} \approx \beta(\delta_1 + \delta_2 \xi_t)$$

- Substitute back to the human capital production function

$$\log(h') = A + \log(\epsilon) + f(\xi_t; \vec{\delta}) + (\rho + \psi_2(\delta_1 + \delta_2 \xi_t)) \log(h)$$

where $\vec{\delta} = \{\delta_0, \delta_1, \delta_2\}$ and

$$f(\xi_t; \vec{\delta}) = \delta_0 \xi_t + (\delta_1 + \delta_2 \xi_t) \cdot \log(\beta(\delta_1 + \delta_2 \xi_t))$$

Human Capital Dynamics

- H.c. dist. follows an AR(1) process that preserves lognormality:

$$\log(h') = A + \log(\epsilon) + f(\xi_t; \vec{\delta}) + (\rho + \psi_2(\delta_1 + \delta_2 \xi_t)) \log(h)$$

- The transition path is analytically characterized (c.f. Benabou 2002)

$$\begin{cases} \mu_{t+1} = f(\xi_t; \vec{\delta}) + (\rho + \psi_2(\delta_1 + \delta_2 \xi_t)) \cdot \mu_t - \sigma_\epsilon^2 / 2 \\ (\sigma_{t+1})^2 = (\rho + \psi_2(\delta_1 + \delta_2 \xi_t))^2 \cdot \sigma_t^2 + \sigma_\epsilon^2 \\ \xi_t = (\psi_1 - \psi_2) \cdot \sigma_t \theta \end{cases}$$

Mechanism

- Suppose $\psi_1 < \psi_2$ so that $\xi_t < 0$, a reduction in ψ_1 evidence
  - $\rightarrow$ Reduces teacher quality ξ_t
  - $\rightarrow$ If $\delta_2 < 0$, raises $\text{IGE}_t = \rho + \psi_2(\delta_1 + \delta_2 \xi_t)$
  - $\rightarrow$ Raises σ_{t+1} because $\sigma^2_{t+1} = \text{IGE}^2_t \cdot \sigma^2_t + \sigma^2_\epsilon$
  - $\rightarrow$ Reduces teacher quality ξ_{t+1} even further as $\xi_{t+1} = (\psi_1 - \psi_2) \cdot \sigma_{t+1}\theta$
  - $\rightarrow$ $\ldots$
- Spillover to non-teacher markets as $F_{t+1}(h)$ changes
- Effects depend on other parameters because parental investment e endogenously respond to teacher quality ξ

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The Model Summarized

- 15 unknowns: $\underbrace{\delta_0, \delta_1, \delta_2, A, \rho, \sigma_\epsilon^2,}_{\text{h.c. technologies}}$ $\underbrace{\kappa, \theta, \beta}_{\text{preferences}}$, $\underbrace{\psi_1, \psi_2}_{\text{labor market}}$, $\underbrace{\xi, w, \mu, \sigma^2}_{\text{equilibrium objects}}$

Steady-state relationships in the model:

$$\frac{\mathbb{E}(y_1)}{\mathbb{E}(y_2)} = w \cdot \exp\left(\mu(\psi_1 - \psi_2) + \frac{\sigma^2}{2}(\psi_1 - \psi_2)(\psi_1 + \psi_2 + 2\psi_1\theta)\right) \tag{1}$$

$$\text{CV}(y_1) = \sigma\psi_1 \tag{2}$$

$$\text{CV}(y_2) = \sigma\psi_2 \tag{3}$$

$$\pi = (w\kappa)^\theta \cdot \exp\left(\frac{\mu\xi}{\sigma} + \frac{\xi^2}{2}\right) \tag{4}$$

$$\xi = (\psi_1 - \psi_2) \cdot \theta\sigma \tag{5}$$

$$\text{IGE} = \rho + \psi_2(\delta_1 + \delta_2 \xi) \tag{6}$$

$$\sigma^2 = \frac{\sigma_\epsilon^2}{1 - \text{IGE}^2} \tag{7}$$

$$\mu = \frac{A + \delta_0 \xi + (\delta_1 + \delta_2 \xi) \cdot \log\left(\frac{e}{y}\right) - \sigma_\epsilon^2/2}{1 - \text{IGE}} \tag{8}$$

$$\frac{e}{y} = \beta(\delta_1 + \delta_2 \xi) \tag{9}$$

- 15 unknowns with 9 equations
- Can make one normalization to pin down the scale of h.c. (set $\psi_2 = 1$)
- Still need additional information/moments

Effects of Changes in Teacher Pay Rigidities - ψ_1

$$\frac{\partial \overline{\log(y')}}{\partial \psi_1} = \psi_2 \cdot \underbrace{\sigma\theta}_{\frac{\partial \xi}{\partial \psi_1}} \left[\underbrace{\delta_0 + \delta_2 \log\left(e/y\right) + \psi_2 \delta_2 \mu}_{\text{direct effect through } \xi} + \underbrace{\beta\delta_2 \cdot \frac{\delta_1 + \delta_2 \xi}{e/y}}_{\text{indirect through } e} \right] \tag{10}$$

$$\frac{\partial^2 \log y'}{\partial \psi_1 \partial \log y} = \sigma\theta \cdot \psi_2 \cdot \delta_2 \tag{11}$$

$$\frac{\partial \mathbb{E}(y_1)}{\partial \psi_1} = \mathbb{E}(y_1) \cdot \left(\mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2))\right) \tag{12}$$

$$\frac{\partial \pi}{\partial \psi_1} = \pi \cdot (\theta\mu + \sigma\theta\xi) \tag{13}$$

Identification

Proposition: The model is identified up to the calibration of ρ if we observe $\mathbb{E}(y_1)/\mathbb{E}(y_2)$, CV$(y_1)$, CV$(y_2)$, π, IGE, e/y and measure the left-hand-sides of Equations (10)-(13).

Proof: Given that $\psi_2 = 1$, Equation (3) identifies σ; then Equation (2) identifies ψ_1; Equation (7) identifies σ_ϵ. Combining Equations (12) and (13) by substituting out μ identifies θ. Then, Equation (5) identifies ξ; Equation (13) identifies μ; Equation (1) identifies w; Equation (4) identifies κ; Equation (11) identifies δ_2; Equation (6) identifies δ_1 given that I calibrated ρ; Equation (9) identifies β; and lastly Equation (8) identifies A.

- Choose conservative value $\rho = 0.6 \cdot$ IGE following Lefgren et al. (2012)

Empirical Setting

- Passage of duty-to-bargain (DTB) laws across states
- Mandated that districts have to negotiate in good faith with a union that has been elected for the purposes of collective bargaining
- NBER collective bargaining law dataset (1960-1996)
- In recent years some states discontinued collective bargaining requirements $\Rightarrow$ variations from expiration of preexisting collective bargaining agreements (Biasi 2021)

Effects on Next Generation

- Lovenheim & Willèn (2019) on long-run outcomes (ACS)

$$Y_i = \beta \cdot \text{DTB exposure}_i + \zeta X_i + \epsilon$$

- 10-year exposure reduces next gen's earnings by 2.36% on average
- Effects are 4.74 pp smaller for White and Asian households (who have 40% higher income than Black and Hispanic parents) $\Longrightarrow \delta_2 < 0$

Effects on Teacher Labor Market

- Effects on teachers' employment and earnings (CPS-ASEC)

$$Y_{\text{state,year}} = \beta \cdot \text{DTB}_{\text{state,year}} + \text{State FE} + \text{Year FE} + \epsilon$$

	(1)	(2)	(3)
	Teacher share	CV(teacher)	Average teacher earnings
DTB	-0.351**	-0.0292*	-591.3
	(0.110)	(0.0138)	(425.4)
# Observations	1378	1364	1378

Notes: This table displays the results of regression (21). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Average teacher earnings is measured in year 2000 dollars.

- Results are qualitatively consistent with Biasi (2021)

Link Back to Model Predictions

- Interpreting DTB laws as reductions in ψ_1, measured using robustness

$$\Delta\psi_1 = \psi_1 \cdot \frac{\Delta \mathrm{CV}(y_1)}{\mathrm{CV}(y_1)}$$

- Revisit Equations (10)-(13) and rewrite them as:

$$\Delta\overline{\log(y')} = \mathrm{CV}(y_2) \cdot \theta \left[\delta_0 + \delta_2 \log\left(e/y\right) + \psi_2\delta_2\mu + \beta\delta_2 \cdot \frac{\delta_1 + \delta_2\xi}{e/y}\right] \cdot \Delta\psi_1 \qquad (10')$$

$$\frac{\Delta^2 \log y'}{\Delta \log y} = \theta\delta_2 \cdot \mathrm{CV}(y_2) \cdot \Delta\psi_1 \qquad (11')$$

$$\Delta \log(y_1) = \left[\mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2))\right] \cdot \Delta\psi_1 \qquad (12')$$

$$\frac{\Delta\pi}{\pi} = (\theta\mu + \sigma\theta\xi) \cdot \Delta\psi_1 \qquad (13')$$

Calibration Result

Human capital formation parameters		Value
δ_0	teacher effect (level)	-0.48
δ_1	investment effect	-0.42
δ_2	teacher effect (gradient)	-0.88
A	TFP of h.c. production	1.12
ρ	residual persistence	0.22
σ_ϵ	ability shock dispersion	0.72

Labor market parameters		Value
ψ_1	skill bias (teachers)	0.73
ψ_2	skill bias (non-teachers)	1

Preference parameters		Value
κ	teacher cost	0.21
θ	taste shock dispersion	3.07
β	weight on children's h.c.	0.35

Equilibrium objects		Value
ξ	teacher quality	-0.64
w	relative wage	2.18
μ	average h.c.	1.15
σ	h.c. dispersion	0.77

Non-Targeted Moments

- One standard deviation change of ξ raises human capital by 1.6 percent
  - $\rightarrow$ Chetty et al. (2014): 1.3 percent
- Using Kmenta (1967) approximation, the implied elasticity of substitution between e and ξ is around 2
  - $\rightarrow$ Blankenau (2015): 1.92
  - $\rightarrow$ Kotera and Seshadri (2017): 2.43

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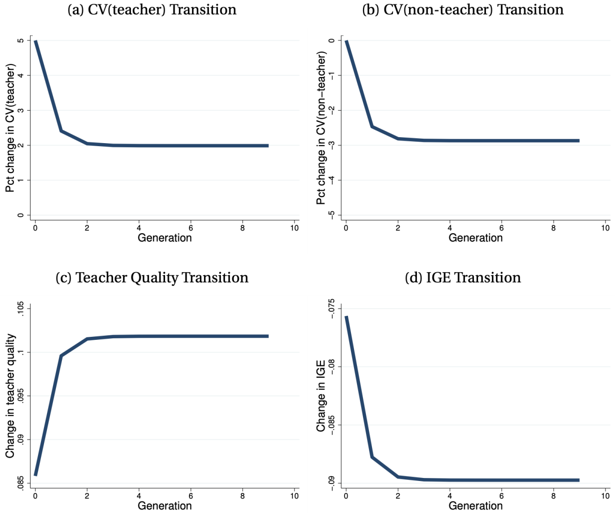
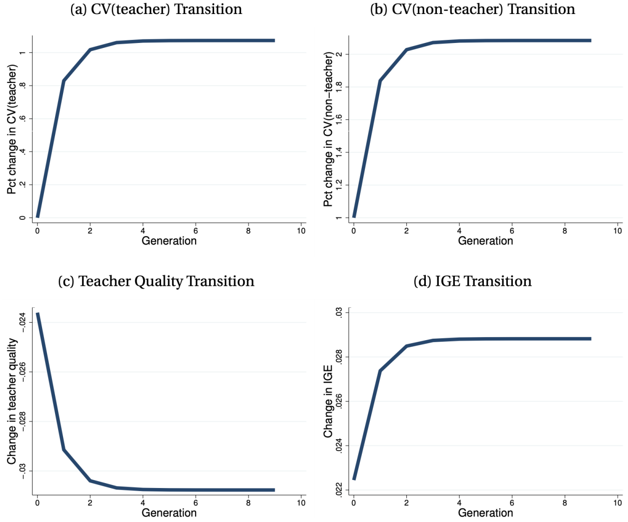
Counterfactual 1: Performance-Based Compensation

- Increase ψ_1 by 5% (similar magnitude as DTB)



Counterfactual 2: SBTC

- Increase ψ_2 rises by 1% - “convexification” (Autor, Goldin & Katz 2020)



Decompose the Source of Changing Inequality

- First, because $\text{CV}(y_2) \equiv \sigma\psi_2$, I decompose $\text{CV}(y_2)$:

$$\underbrace{\text{CV}(y_2)' - \text{CV}(y_2)}_{\text{changes in inequality}} = \underbrace{\sigma'(\psi_2' - \psi_2)}_{\text{direct effect}=48\%} + \underbrace{(\sigma' - \sigma)\psi_2}_{\text{indirect h.c. dist.}=52\%}$$

- To understand what drives changes in σ, I conduct a decomposition of IGE because in the steady-state σ is proportional to $\sqrt{1 - \text{IGE}^2}$

$$\underbrace{\psi_2'(\delta_1 + \delta_2\xi') - \psi_2(\delta_1 + \delta_2\xi)}_{\text{changes in IGE}} = \underbrace{\psi_2\delta_2(\xi' - \xi)}_{\text{teacher quality}=94\%} + \underbrace{(\delta_1 + \delta_2\xi')(\psi_2' - \psi_2)}_{\text{parental income}=6\%}$$

- ψ_1 needs to rise relatively more than ψ_2 to neutralize the effects of the SBTC on inequalities in non-teaching markets

Conclusion

- Dynamic spillover effects of teacher labor market on aggregate inequality
- Identify and calibrate the model using empirical evidence from DTB laws
- Key takeaways:
  1. Performance-based compensation trades off income inequality among teachers versus non-teachers
  2. Teacher market greatly amplifies the effects of SBTC
- Same mechanism applies to other occupations such as doctors and elected officials – avenue for future research

Skill Requirement by Occupation

Table 1: Skill Importance by Occupation

	Teacher	Non-Teachers	
	Value	Mean	Standard Deviation
Complex Problem Solving Skills	3.53	3.19	0.50
Resource Management Skills	2.40	2.39	0.66
Social Skills	3.27	2.89	0.52
System Skills	3.17	2.85	0.60
Technical Skills	1.45	1.93	0.79

Notes: This table displays the importance of each cross-functional skills by teachers and non-teachers in the O*NET dataset.

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Declining Teacher Quality Over Time

TABLE 3.—DECLINE IN TEACHER QUALITY AS EVIDENCED BY TEST SCORES: FRACTION SCORING LOWER OR UPPER 20% ON IQ, AFQT AMONG FEMALE TEACHERS

Birth Cohort	*Above 80th Percentile*	*Below 20th Percentile*
1941–45	0.41	0.08
1946–49	0.40	0.05
1951–53	0.34	0.06
1957–59	0.44	0.06
1960–62	0.20	0.12
1963–64	0.19	0.19

Source: NLS-YW,YM,Y79. Sample for this table includes black and white female respondents with at least two years of college who ever taught when they were aged 21 to 30. Sample selection is further described in the text and appendix A.

Source: Bacolod (2007)

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Interpretation of DTB Laws

What if DTB laws not only affect ψ_1, but also κ and w?

$$\begin{cases} \Delta \log(y_1) = \Delta\psi_1[\mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2))] + \Delta w \\ \frac{\Delta\pi}{\pi} = \Delta\psi_1 \cdot (\theta\mu + \sigma\theta\xi) + \theta(\Delta w + \Delta\kappa) \end{cases} \tag{14}$$

They threat the identification of θ and μ

- Insight: alternative values of θ does not affect counterfactual results
- Results remain unchanged as long as either Δw or $\Delta\kappa$ equals to zero because we can choose θ exogenously
- If both Δw and $\Delta\kappa$ are non-zero, then need additional moment (e.g., teacher value-added) $\Rightarrow$ model performs well in that dimension

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Heterogeneous Assumptions

- Suppose instead there is a systematic relationship between taste and human capital, consider

$$\nu = \psi_3 \log(h) + \tilde{\nu}$$

- Individual's choice problem becomes

$$\max_{j \in \{1,2\}} \mathbb{1}_{j=1} (\log(w h^{\psi_1} \cdot \kappa \cdot h^{\psi_3}) + \tilde{\nu}) + \mathbb{1}_{j=2} \log(h^{\psi_2})$$

- Model is largely unchanged, but need another moment to identify ψ_3
- Can use teacher value-added

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